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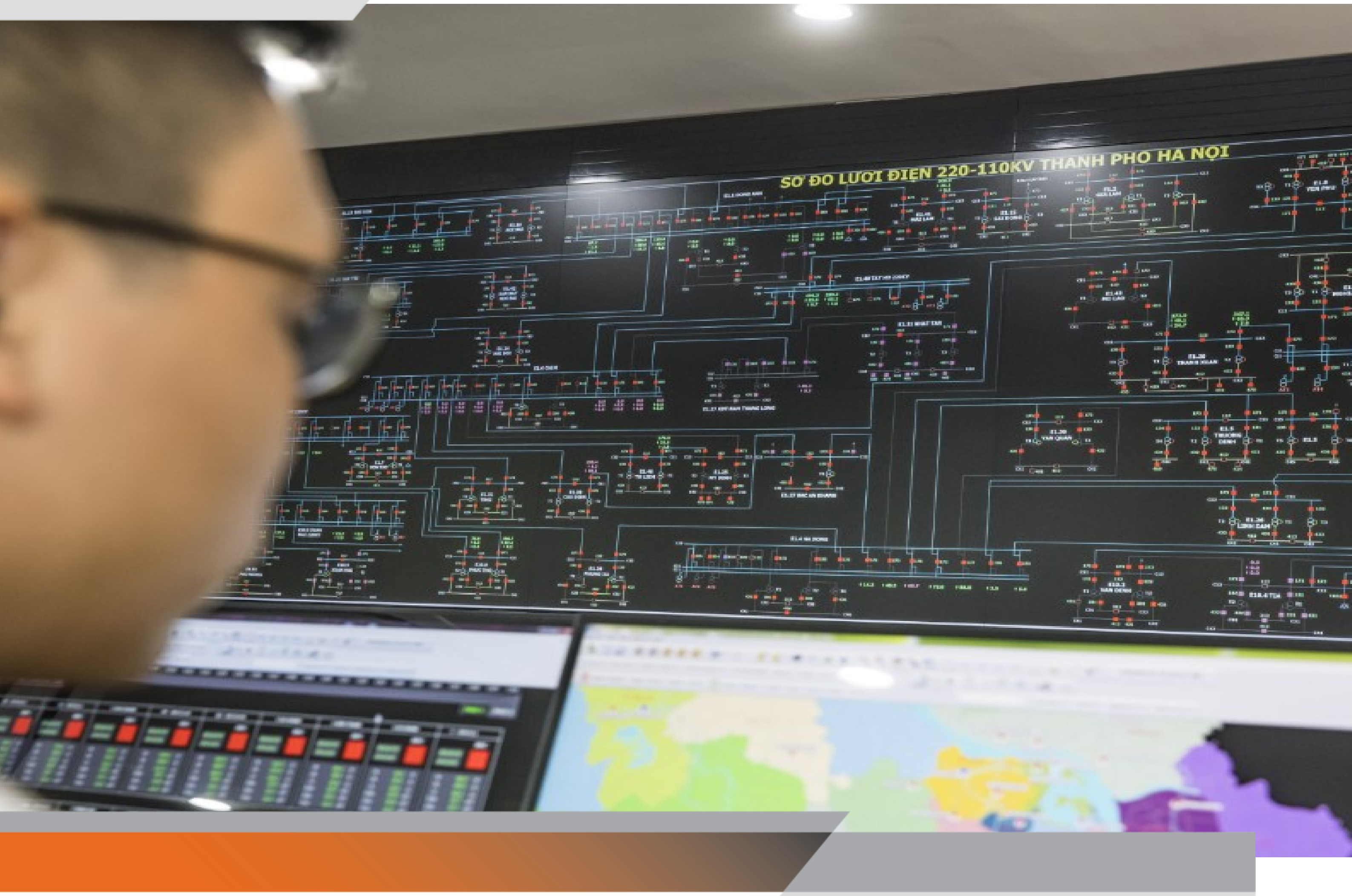

Grid Management Solutions to Support the Optimal Operation of Renewable Energy Sources in Power System

Action Area I: Legal and Regulatory Framework

Funded by

Smart Grids for Renewable Energy and Energy Efficiency

FINAL REPORT (Task 1, Task 2.1 and Task 2.2)

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Review

Duong Manh Cuong, Senior project officer GIZ SGREEE

On behalf of the
German Federal Ministry for Economic Cooperation and Development (BMZ)

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Abbreviations

AMI:	Advanced Metering Infrastructure
BESS:	Battery Energy Storage Systems
CA:	Contracting Authority
CBA:	Cost Benefit Analysis
GM:	Grid Management
GMM:	Grid Management Measure
CF:	Consultant Firm
CLP:	Curtailable Load Program
DSM:	Demand Side Management
DTLR:	Dynamic Thermal Line Rating
DR:	Demand Response
EDRP:	Emergency Demand Response Program
ERAV:	Electricity Regulatory Authority of Viet Nam
EMS:	Energy Management System
EVN:	Electricity of Vietnam (state-owned corporation)
EPTC:	Electricity Power Trading Company
EVNNPT:	National Power Transmission Corporation
EVNCPC:	Central Power Corporation (Utility)
FACTS:	Flexible Alternating Current Transmission System
FIT:	Feed in tariff
GIZ:	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
HVDC:	High Voltage Direct Current
ICF:	International Consultant Firm
ICT:	Information and Communication Technology
LCF:	Local Consultant Firm
MOF:	Ministry of Finance
NLDC:	National Load Dispatch Center (A0)
OBMC:	Optional Binding Mandatory Curtailment Plan
OLTC:	On-Load Tap Changer
PDP:	Power Development Plan
PST:	Phase-shifting transformer
PV:	Photovoltaics
PM:	Prime Minister
RE:	Renewable Energy
RES:	Renewable Energy System
SCADA:	Supervisory Control and Data Acquisition
SGREEE:	Smart Grids for Renewable and Energy Efficiency project
SGRM:	Smart Grid Road Map (Decision No. 1670/QD-TTg)
TOR:	Terms of Reference
VRE:	Variable Renewable Energy

Acknowledgement and disclaimer

Fichtner would like to express its gratitude and appreciation for the very valuable and close co-operation to RCEE Niras engineers and GIZ support, who took part in this stage of the project.

They contributed to the local system investigations and data collection in a very constructive way and the discussions have been held in a very trustful and professional level.

Chapter

01

Executive summary

1 Executive summary

The project “Smart Grids for Renewable Energy Efficiency” (SGREEE) is a joint cooperation project between ERAV (Electric Regulatory Authority of Vietnam) and GIZ (Deutsche Gesellschaft für internationale Zusammenarbeit GmbH). GIZ aims to develop “grid management solutions” in order to reduce Renewable Energy (RE) curtailment. Fichtner's approach to solve this task is split into 2 main tasks.

In the first part of Task 1, the vietnamese electricity grid and economy are analysed. The main focus is on the electricity sector in Vietnam, the regulatory framework, the status of the electricity grid and the current market environment. The findings of this analysis are summarized in a table to show the challenging areas regarding grid management and to provide initial suggestions for solutions. In summary, the following foure challenge areas

- 500kV transmission line between the two load centres Hanoi in the north of the country and Ho Chi Minh City in the south
- the VRE-Hotspots Ninh Thuan, Binh Thuan in the south
- the two load centres Hanoi and Ho Chi Minh in the north and south of the country
- Expansion of VRE limited to a few provinces in the south of Vietnam

show that the high proportion of variable renewable energies (VREs[1]) leads to congestion at the transmission as well as at the distribution grid level in Vietnam.

In order to find suitable, internationally proven grid management solutions, a two step selection process is carried out to identify suitable countries. The selected countries then form a master group, which makes it possible to identify the most relevant grid management measures for Vietnam by combining the characteristics of the individual countries.

In the final part of Task 1, all countries from the Master Group and Vietnam are assessed in an Assessment Matrix on the basis of possible grid management measure (GMM) groups. An advantage that the creation of the Master Group brings with it is that by comparing the countries in the Master Group with Vietnam, gaps or GMMs that are not developed on a further level in Vietnam are identified. From the assessment of Vietnamese grid management, the following grid management measures could be identified which offer further potential for strengthening grid management in Vietnam:

- *Regulatory framework*
    - *Load-depending feed-in tariffs (FIT):* The load-dependent feed-in tariff is an internationally proven method, e.g. in California in the USA that provides incentives for grid-serving behaviour for investors and RE system (RES) operators.
    - *Structuring of market zones:* Structuring Vietnam into smaller bidding zones could counteract the structural congestion on the north-south link in Vietnam and at the same time strengthen the cooperation of the wholesale market and grid management.

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[1] Variable renewable energies are renewable energies, such as solar energy or wind energy, whose electricity generation fluctuates, i.e. is subject to fluctuations.

- *Digitalisation/Automation:*
    - *Strengthening the digital components in Vietnam's distribution system:* For many of the already recommended GMMs, such as DSM, a high degree of digitisation of the distribution grid level is necessary. It is therefore recommended that the development of a solid digitised infrastructure be extended to the distribution grid level.

- *Grid expansion:*
  According to initial assessments, Vietnam is already very active in the area of grid expansion. It is recommended to now look at the other areas of grid management in order to use the existing grid capacities as efficiently as possible.

- *Grid-related measures:*
    - *HVDC connection between north and south Vietnam (long term):* High-voltage direct current transmission (HVDC) can serve as the backbone of Vietnam's electricity supply system due to its grid-stabilising properties such as reactive power compensation.
    - *PST solutions to avoid congestions at Nort-South link:* Phase-shifting transformers (PST) are a technology that could make more efficient use of existing transmission capacity through its power flow adjustment characteristics, especially on the 500 kV north-south link line in Vietnam.
    - *DTLR solution to increase the current transmission capacities:* The DTLR makes it possible to increase the transmission capacities of the existing power lines. This is made possible by benefiting from changes in the meterological conditions on the overhead lines. This technology is also mainly a solution for the transmission grid level.

- *Market-related measures:*
    - *Spread and expand energy storage options:* Energy storage options can compensate for fluctuations in VRE feed-in and create flexibility in operation.
    - *Demand side management (DSM):* Demand side management is an innovative GMM that can have a great input by flexibly adjusting the loads, especially in the load centres of a country.

- *Priorization of RE feed-in:*
  Currently, in Vietnam, RE is used for curtailment in order to relieve a congestion when the potential of conventional power plants has been exhausted.

The identification of gaps in Vietnam's grid management is used in Task 2.1 to present international best practices for grid management. For this purpose, at least one international best practice from a Master Group country is used for each gap.

- *Regulatory framework*
    - *Load-dependent FIT:* California in the USA has a project that shows how a variable feed-in tariff for RESs can look like and how more costs for maintaining grid security and availability can be avoided. The FIT is structured in such a way that the highest tariff is paid at times when the load on the grid is highest and the lowest tariff is paid at times when the load is lowest.

    - *Structuring of market zones*
        - *Bidding zone:* Bidding zone subdivisions can be found in Norway. By dividing the country into price zones, Norway has been able to relieve congestion and stabilise the national grid.
        - *Nodal pricing:* The most extreme form of market structuring is nodal pricing, in which the transmission capacities of the grid nodes are included in the electricity trade. Regional differences in the electricity price are the result. This variant is already being used in the United States.

- *Digitalisation / Automation*
  In the area of digitalisation and automation of the electricity grid, two examples from Norway are identified.. The first project in Norway is laying the foundation for the application of demand response programs, namely the expansion of intelligent metering systems. The second project provides a more detailed insight into which digital components are at the forefront of a substation and illustrates the importance of grid control technology with fibre optics.

- *Grid-related measures*
    - *HVDC:* The two Master Group countries Japan and Germany show which grid-serving properties an HVDC line can take on at the transmission grid level. The main focus here is on the hurdles of off-load generation from VEE in connection with long transmission distances.
    - *PST:* PST enables better utilisation of existing grid capacities as power flow control elements in coordinated deployment. In this area, Germany already has initial projects that are being used both to prevent loop flows at borders with neighbouring countries and to ensure the efficient use of domestic transmission lines.
    - *DTLR:* The DTLR makes it possible to increase the transmission capacities of the existing transmission lines. However, international experience from Germany shows that a large amount of meteorological data needs to be collected for the application of this technology.

- Market-related measures
    - *Energy Storage Options:* Battery energy storage solutions (BESSs) are used in America to mitigate the increasing load ramp in the evening with a higher share of solar PV feed-in. Furthermore, a demonstration project by the Public Service Company of New Mexico (PNM) illustrates that at the distribution grid level, a smoothing effect of solar PV systems provides additional grid stability.
    - *DSM:* South Korea relies on demand side flexibility through a demand response programme. Consumers can adjust their electricity demand in such a way that they benefit financially and can thus better accommodate the interests of the transmission system operator.

- *RE feed-in:*
  With regard to RE feed-in, an approach from Germany shows how decentralised RESs can be included in the mobilisation and curtailment of power plants. In this context, the new version of Germany´s Redispatch, Redispatch 2.0, aims to reduce

the overall costs of GMMs against the backdrop of an ever increasing share of RES generators.

In the final task, Task 2.2, the recommended GMMs are prioritised under consideration of the following evaluation criteria:

- technical applicability in Vietnam
- implementation duration
- investment costs
- operating costs
- the overall effectiveness for the respective challenge area and beyond

For each criterion of this prioritisation, a weighting is determined, which is adjusted on the basis of the requirements of Vietnam that emerge from the analysis. The weighting is chosen so that the effectiveness of the individual measures is weighted highest. Technical availability and implementation time were chosen as two important characteristics, as against the backdrop of a fast growing economy, solutions are needed quickly in Vietnam in order to be able to continue to guarantee a safe and secure energy supply. By evaluating the individual measures in the respective criteria, a prioritisation order results that best addresses Vietnam's requirements.

The following order of measures is the most beneficial in terms of Vietnam's current requirements:

1. Load dependent FIT
2. Large scale BESS at transmission level
3. BESS at distribution level
4. DTLR
5. HVDC and PST
6. Market structuring in bidding zones
7. Inclusion of small RE power plants in Redispatch
8. Market structuring with nodal pricing
9. DSM

These measures best address the challenges and requirements of the Vietnamese electricity system for integrating a high proportion of VRE within the scope of the present investigation.

Chapter

02

Contact details and communication channels

2 Contact details and communication channels

2.1 Contact details

In the following table the contact details of the involved persons as well as their responsibility within the assignment are given.

Table 1: Contact details

Name	Company	Position
Dr. Nguyen Hoai Nam	RCEE-NIRAS	Senior Expert
Dr. Nguyen Duc Tuyen	RCEE-NIRAS	Senior Expert
Mr. Nguyen Thanh Ha	RCEE-NIRAS	Senior Expert
Ms. Phan Minh Thao	RCEE-NIRAS	Administrator
Dr. Hermann EGGER	FICHTNER	Project Manager
Dr. Albrecht REUTER	FICHTNER	Project Expert
Dr. Roland NEIFER	FICHTNER	Project Expert
Moritz GRIESBECK	FICHTNER	Project Analyst
Tran Tue Quang	ERAV	Deputy Director General of ERAV
Nguyen The Huu	ERAV	Director of Power system department of ERAV
Nguyen Quang Minh	ERAV	Deputy Director of Power system department of ERAV ERAV
Tu Van Hung	ERAV	Expert of Power system department of ERAV
Nguyen Hoai Nam	ERAV	Expert of Power system department of ERAV
Do Hong Thanh	ERAV	Expert ERAV
Nguyen Hong Minh	ERAV	Expert of Power system department of ERAV
Ho Duc Linh	ERAV	Expert of Power system department of ERAV
Tobias Cossen	GIZ	Project Director of SGREEE
Duong Manh Cuong	GIZ	Senior Project Officer of SGREEE
Tran Tien Hoa	GIZ	Project Officer of SGREEE

2.2 Data exchange

In the following table an overview of data exchange is given.

Table 2: Data exchange overview

Topic	FROM	TO	Description	Date
Supporting documents	GIZ	RCEE NIRAS, FICHTNER	General, Solar + Wind incentive Mechanisms + PPAs, Power Market regulations + PPAs of other Power Plants, Electricity tariff regulations, Dispatching regulations, Planning regulations + upcoming RE projects, RE-related hurdles, Previous Studies	27th May 2020
Update Supporting documents	GIZ	RCEE NIRAS, FICHTNER	Ancillary Service contract regulations, Grid Codes & Distribution Codes	25th June 2020
Update Supporting documents	GIZ	RCEE NIRAS, FICHTNER	GIZ´s recent studies	27th June 2020
Additional background documents	GIZ	RCEE NIRAS, FICHTNER	EVNNLDC, ERAV	19thAugust 2020
Additional background documents	GIZ	RCEE NIRAS, FICHTNER	EVN/PECC2	21stAugust 2020
Task 1	FICHTNER	RCEE NIRAS, GIZ	Submission Draft Task 1 Report	25th November 2020
Task 1	FICHTNER	RCEE NIRAS, GIZ	Submission Draft Task 1 Power Point Presentation	11th December 2020
Task 2.1	FICHTNER	RCEE NIRAS, GIZ	Submission Draft Task 2.1 Report	13th April 2021
Workshop Task 1 & 2.1	FICHTNER	RCEE NIRAS, GIZ	Submission Draft Workshop Power Point Presentation	13th April 2021
Task 2.2/ Final Report	FICHTNER	RCEE NIRAS, GIZ	Submission Draft Task 2.2 /Final Report	28th May 2021
Task 2.2/ Final Report Revison	FICHTNER	RCEE NIRAS, GIZ	Submission Draft Task 2.2 /Final Report Revision	15th July 2021

Final Workshop presentation	FICHTNER	RCEE NIRAS, GIZ	Submission Final Workshop Power Point Presentation	06th August 2021

Chapter

03

Activities performed

3 Activities performed

To perform a Study for Grid management Solutions for Reducing Renewable Energy Curtailment in Vietnam, the activities listed in Table 3 have been conducted since the signing of the contract.

Table 3: History of activities

Date	Activity	Note
26th May 2020	Greeting and Kick-off call: Grid management solutions	The minutes of the call are added as annex 11.1
27th May 2020	Providing documents by the client	The list of updated documents is given in the bibliography in Annex 11.2
03rd June 2020	Consultation Call COV19 Restrictions	-
08th June 2020	Preparation and submission of draft inception report and questionnaire 1 related to data collection to GIZ	The questionnaire 1 is attached as Annex 11.3
24th June 2020	Inception video call on “Grid management Solutions”	The minutes of the call are added as Annex 11.1
17th July 2020	Preparation and submission of the revised draft inception report related to COV19 restrictions and outcomes of the inception video call	The minutes of the call are added as Annex 11.1
12th August 2020	Virtual Kick-off-meeting (Authority Level); Participants: ERAV, EREA, IE	The minutes of the call are added as Annex 11.1
13th August 2020	Virtual Kick-off-meeting (National Level); Participants: EVN, NLDC A0, ERAV	The minutes of the call are added as Annex 11.1
17th August 2020	Virtual Kick-off-meeting (Regional. Level); Participants: NPT, SPC, CPC, CRLDC A3, SRLDC A2	The minutes of the call are added as Annex 11.1
21st December 2020	Virtual Presentation of Draft Task 1 (Power Point)	The minutes of the call are added as Annex 11.1
20th April 2021	Intermediate Consultation Workshop: Grid management	The minutes of the call are added as Annex 11.1
26th August 2021	Final Workshop on Grid Management	

Chapter

04

Data collection process

4 Data collection process

Several activities have been carried out during the data collection process up to now. Initiated by a questionnaire provided by Fichtner (Questionnaire 1 top-level questions, see Annex 11.3) the client provided the documents as mentioned in the ToR to this project as well as other supporting documents. The list of updated documents is given in the bibliography in Annex 11.2.

The provision of the documents by the client listed in the following has to be updated if necessary (pending since July 17th, 2020):

Only available in Vietnamese:

- Overview on methods of determining gerneration cost
- Circular 45/2018/TT-BCT dated 15th November 2018 promulgating operation of Viet Nam wholesale electricity market (VWEM) and amendment and supplements some articles to Circular 56/2014/TT-BCT provision on methods of determining generation prices and order to check electricity purchase contract
- Decision 6463/QD-TTg dated July 22, 2014 on Conceptual design of the VWEM
- Circular 31/2019/TT-BCT dated 18th Nov 2019 supplement some Articles to Circular 40/2014/TT-BCT dated 5th Nov 2014
- Document 3299/BCT-DL dated 8th May 2020 request PM for supplementing the planning on wind power project (second time)
- Congestion Articles
- Documents 1791/DDQG-TTD dated 28th May 2019 on dispatching principle of RE sources
- Documents 5378/BCT-DTDL dated 29th July 2019 on dispatching principle of RE sources
- No.39_Grid Study - NLDC Tai lieu luoi truyen tai lien quan Tay Nguyen
- AGC - Curtailment principle (A0, NLDC)
- Bao cao tong ket LDTM 2019- final

Not shared yet:

- Reports of Grid Status at some hot-spots regions (EVN, ERAV, EREA, MOIT)
- Presentation of current Viet Nam Power system with major challenges
- EVN NLDC, "Updates on solar and wind power development in Vietnam," 2019
- EVN NPT, "Grid analysis for injection of renewable energy in central and southern region of Vietnam," Hanoi, 2018
- Other studies and technical assistance programs exisiting to improve grid management with respect to RE development in Vietnam

Chapter

05

Fichtner´s project methodology

5 Fichtner´s project methodology

Within this section Fichtner provides the methodology for execution of the project considering the proposal and the results from the discussions so far.

To solve the tasks described in the terms of reference – Grid management Solutions for Reducing Renewable Energy Curtailment of ERAV (Electric Regulatory Authority of Vietnam) – Fichtner will apply a praxis tested approach. The methodology consists of 2 main tracks. In the 1st track, the overall steering variables will be evaluated and fixed. As a basic precondition, possible scenarios for the expected feed in of Renewable Energy, system area and boundaries as well as the time horizon must be taken into consideration.

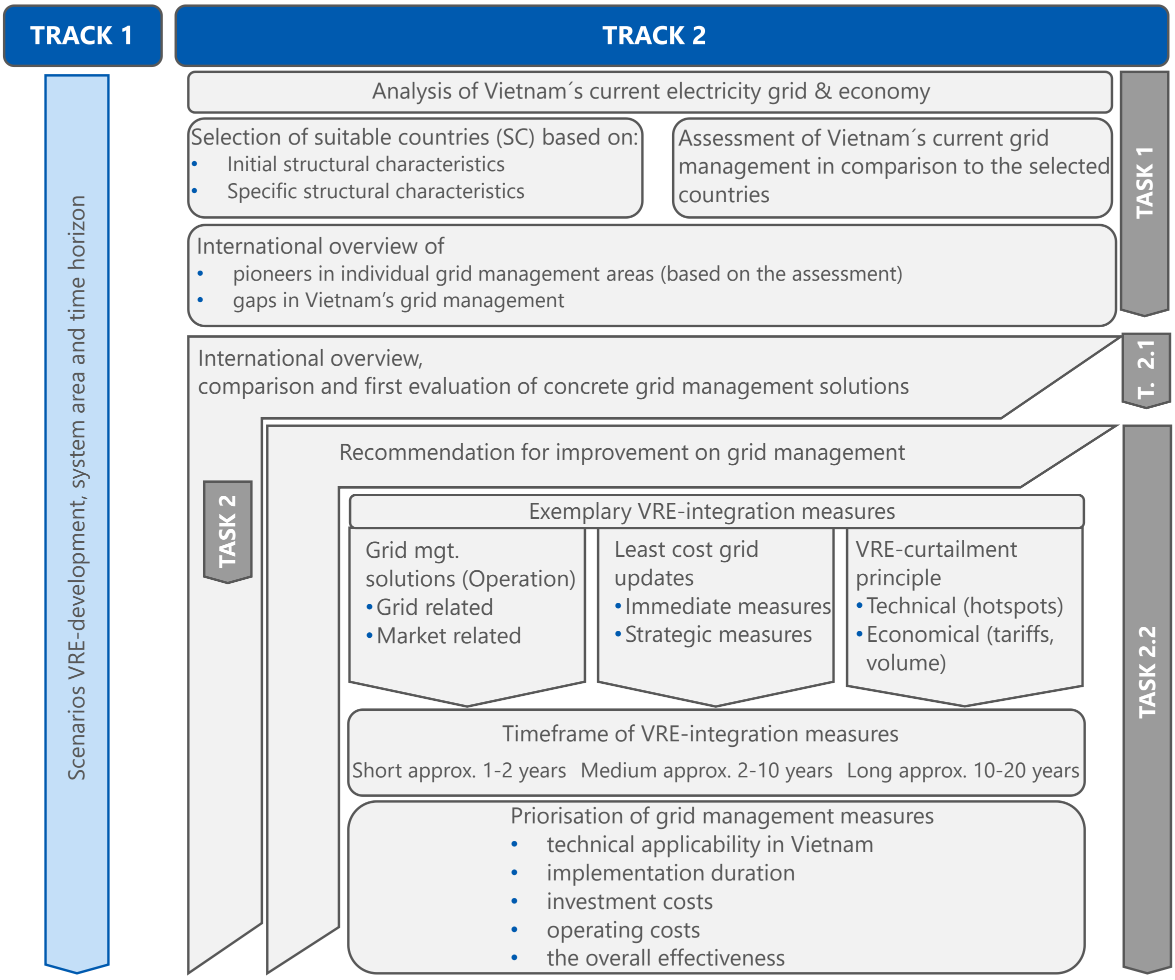


Figure 1: Structure and break down of the tasks

In the 2nd track - under agreed preconditions (the results of track 1), the main tasks of ERAV are structured and broken down as shown in Figure 1. Due to an efficient process in the project, it must be evaluated if a partly parallelization of task 1 and task 2 in track 2 is possible.

For the internal structure of task 2, a mainly sequential approach is chosen. To achieve the overall goal of the project – regulatory and economic prioritised grid management measures for better VRE-integration including a possible time horizon – many subtasks and boundary conditions, as for example from Track 1, must be taken into consideration. In this case, a sequential working process in the project with simple interfaces between subtasks is more effective for structured project work, reporting and communication. In the following chapters, the methodology and deliverables for the tasks and subtasks are described in detail.

5.1 Assessment of Vietnam's current power grid status and review of existing RE-related legal framework (Task 1)

As shown in Figure 1, suggested track 1 is necessary to set clearly define the scope of work. Before task 1 in track 2 is started, the evaluation and determination of the following basic boundary conditions for the project are carried out:

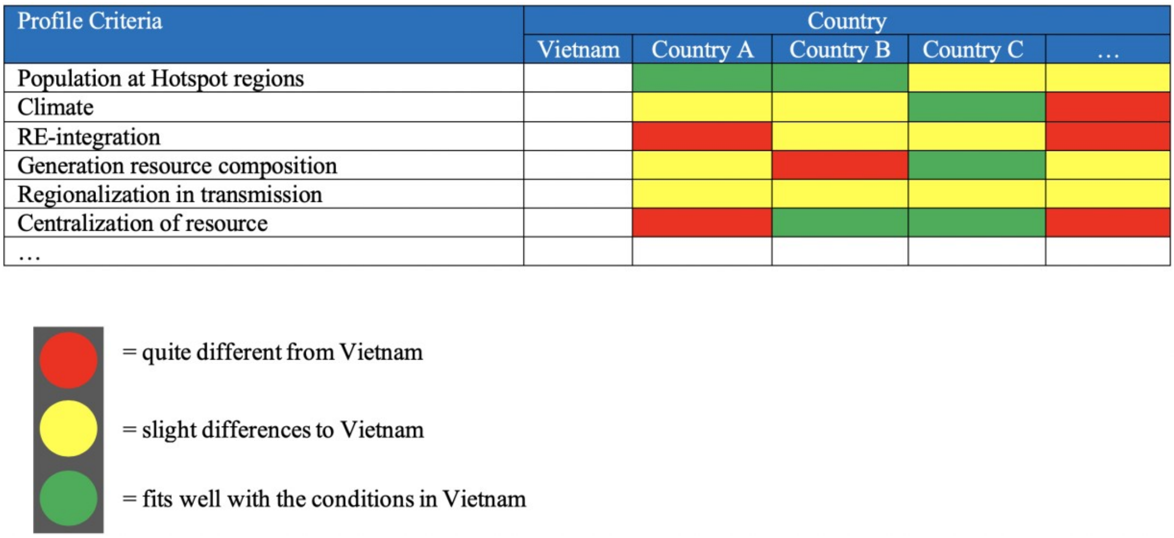
- Considered time horizon in the project
- Climate (dry & rain season)
- Technical boundary conditions
    - Voltage level(s)
    - Grid area
    - Generation resources composition
    - Grid management measures for VRE-integration planned or in operation
- Possible scenarios for future VRE-generation in Vietnam

Based on the fixed boundary conditions, the assessment of Vietnams current electricity grid status and review of the existing RE-related legal framework is started. This includes exemplarily documents regarding the topics listed below. In case of additional documents, they will also be taken into consideration.

- Technical grid assessment studies
- Grid dispatching procedures including power plant redispatch
- Energy storages
- RE-related legislation
- Distribution grid management
- Market simulations and grid calculations
- Regulation
    - Integration strategy of renewables
    - Tariffs (e.g. RE-feed in, redispatch)
    - RE-curtailment
    - Market design

In order to assess the current Vietnamese grid management at a top level, a country selection is first made. For this country selection, a comparison matrix similar to the one shown in Figure 2, is used to find countries similar to Vietnam as well as international experts in the field of VRE integration.

Based on the documents mentioned above, in a next step an assessment matrix will be specified and implemented. The goal is to provide a top-level estimation of the current development status of Vietnams power grid and regulation compared to other countries. An exemplarily assessment matrix is shown in Figure 3, which will be further developed and specified within the work in task 1.



Profile Criteria	Country				
	Vietnam	Country A	Country B	Country C	…
Population at Hotspot regions		🟩	🟩	🟨	🟨
Climate		🟨	🟨	🟩	🟥
RE-integration		🟥	🟨	🟨	🟥
Generation resource composition		🟨	🟥	🟩	🟨
Regionalization in transmission		🟨	🟨	🟨	🟨
Centralization of resource		🟥	🟩	🟩	🟥
…					

🔴 = quite different from Vietnam

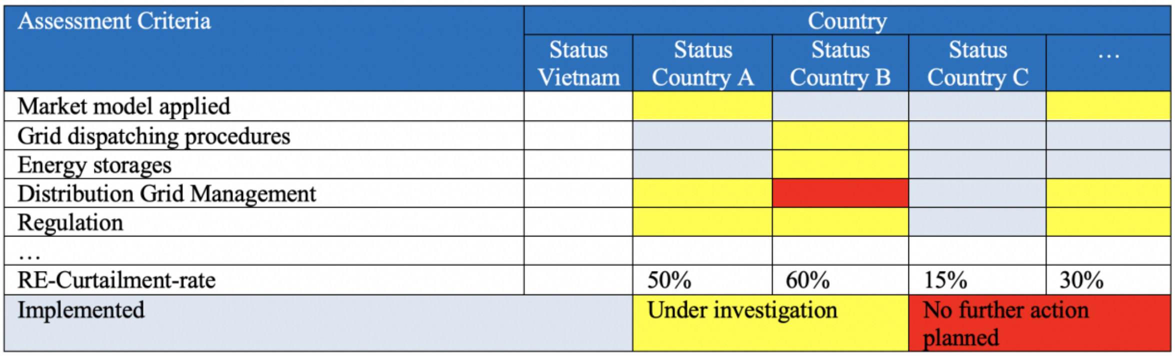
🟡 = slight differences to Vietnam

🟢 = fits well with the conditions in Vietnam

Figure 2: Exemplarily comparison of countries with Vietnamese characteristics

Comparing different countries with Vietnamese characteristics makes it more clear which country shows a likely scenario. In this process FICHTNER takes in consideration the criteria out of the comments from the Draft Inception Report (09.06.2020) as well as minutes from the Inception Call (24.06.2020).

Different characteristics have different effects on VRE-generation and VRE-integration (like Climate). So it is also very important to use the characteristics of Vietnam to assess the different countries.



Assessment Criteria	Country				
	Status Vietnam	Status Country A	Status Country B	Status Country C	…
Market model applied		🟨	▨	▨	🟨
Grid dispatching procedures		▨	🟨	▨	▨
Energy storages		▨	🟨	▨	▨
Distribution Grid Management		🟨	🟥	▨	🟨
Regulation		🟨	🟨	▨	🟨
…					
RE-Curtailment-rate		50%	60%	15%	30%
Implemented		Under investigation		No further action planned	

Figure 3: Exemplarily assessment matrix

The assessment matrix provides an insight into Vietnam´s current power grid and takes the analysis of possible scenarios to the next level. Throughout this process, the individual GMMs of the different countries, which were compared to Vietnam in the first step, are assessed. The various GMMs shown in the exemplarily assessment matrix (Figure 3) are grouped into different topics. These different topics were filtered out of the TORs and also added by FICHTNER. In the further course the different method topics are divided and structured.

The assessment will be conducted both, in a qualitative and quantitative way. Further forms of quantitative visualisation, for example spider charts, will be discussed and specified with ERAV. Additional suggestions for analytical instruments will be taken into consideration and discussed, for example radar charts or spider diagrams.

5.2 Overview of international best practices and recommendations for Vietnams improvement (Task 2)

As already mentioned, activities of task 1 and task 2 could start in parallel due to the overlapping of the methodologies in respect to overview and assessment. This will be evaluated in the kickoff mission. The methodology for task 2.1 and task 2.2 is sequential due the dependency of task 2.2 on the input of task 2.1.

5.3 Overview of international best practices and recommendation with respect to VRE development (Subtask 2.1)

Similar to task 1, the suggested track 1 is necessary to clearly define the scope of work. Before task 2 in track 2 is started, the evaluation and determination of the basic boundary conditions for the project are carried out.

Based on the fixed boundary conditions, the overview of international best practices on grid management with respect to VRE-development is started. For this case, again the assessment matrix and the comparison matrix, like in chapter 5.1, is applied.

What FICHTNER knows from task 1 is the answer to the question: Which country shows similar characteristics to Vietnam and how efficiently could the country integrate VRE into its power grid? Based on this the selection of the relevant countries and cite them as a suitable or not suitable example for dealing with VRE development is done.

In the next step, the practices that were used in the relevant countries to improve the efficient feed-in of VRE have to be related to Vietnam. Furthermore the potential of the individual practices regarding grid management solutions in Vietnam is assessed. Exemplary practices are listed in the following.

- Network reinforcement
- Market processes for power balancing
- Coupling of market simulation and grid strategy
- Reactive and active power control
- Curtailment of VRE-feed in
- Network reconfiguration
- Power plant redispatch
- Additional voltage control for transformer

Within the task 2.1, from FICHTNER´s point of view, many possible additional practices will be identified and must also be taken into consideration.

5.4 Recommendations for improvement on grid management (Subtask 2.2)

With the output of task 2.1 – a list of possible measures to improve the integration VRE-development for Vietnam – the structuring and prioritization of these measures is applied, to fulfill the requirement to make suggestions for improvement on grid management. Therefore, Fichtner will apply a 3-step approach as shown in Figure 4.

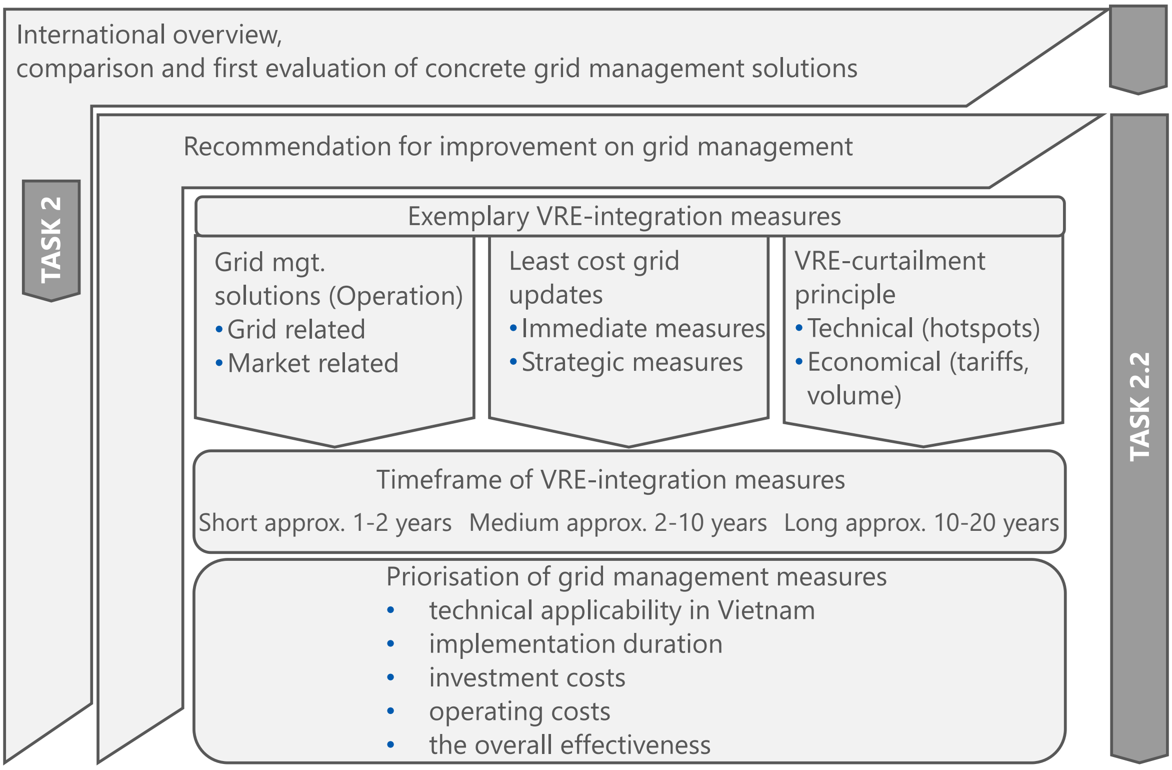


Figure 4: Evaluation of recommendations an improved grid management

Step 1: To estimate the technical complexity and costs of the possible measures, they are categorized as follows:

- Grid management solutions (Network operation)
    - Grid related
    - Market related
- Least cost grid updates
    - Immediate measures
    - Strategic measures
- RE-curtailment principle
    - Technical (Hotspots)
    - Economical (Tariffs, volume)

Step 2: To determine the time horizon for the pre-sorted measures, the following classification is suggested by FICHTNER

- Short (approx. 1-2 year)
- Medium (approx. 2-10 years)
- Long (approx.. 10-20 years)

Each time horizon will be evaluated with ERAV.

Step 3: The measures are prioritized by regulatory and financial impact as well as their approximated time horizon. It is suggested, to carry out the parametrization of the final priorization during the 1-week mission trip to Vietnam.

Chapter

06

TASK 1

6 Task 1

6.1 Introduction

Task 1 is divided into two main parts. The analysis of Vietnam's current electricity sector and the assessment of the country's current grid management. The analysis first aims to present the current state of the Vietnamese electricity system and to identify challenges of the grid. After the challenges of the Vietnamese electricity grid have been identified, a portfolio of grid management measures is presented. This portfolio is used in the second part of the first task, the assessment, to gain an overview of currently applied grid management measures in Vietnam. In addition, countries selected through a two-step selection process are used to identify experts in the different areas of grid management and to highlight gaps in Vietnam's grid management.

If the picture of the current situation in Vietnam is taken for the first time, it becomes clear that Vietnam is currently facing two major challenges in terms of grid management:

- The strong rise in electricity demand due to strong economic growth
- Integration of the sharply increasing share of VRE generation

With the rapid increase of demand, the transmission system is busy to balance the capacity of the system. One reason for this is the country's unequal distribution of demand and production. The north (with the Hanoi region) and the south (with Ho Chi Minh City) consume most of the energy, whereas the central part mainly serves as a transmission corridor and production facility. The trend in interregional transmission in 2019 was still from north to central and from central to south. The north-central transmission output (net) is 7.2 TWh and the central-south transmission output (net) 10 TWh [1]. Due to these regionally different levels of demand, there are frequently congestions on the transmission lines from north to south Vietnam.

In order to maintain the balance between electricity generation and consumption, the country's generation capacities had to be expanded as a result of the increase in consumption. VRE offer a sustainable and future-oriented option for this. It allows a country to become independent from the import of fossil fuels and at the same time avoid long construction periods of coal or nuclear power plants. In Vietnam, the potential for solar PV and wind power plants is great due to the large primary energy supply in the south of the country.

However, the integration of a large number of VRE is a further challenge for the country. When a large number of VRE is integrated into the electricity grid, the fluctuating generation of VRE creates new challenges for the transmission system. The electricity generated by VRE is not driven by demand. That means that the electrical power output is not always available when it is needed and vice versa is not always needed when it is available. Therefore, VRE are often affected by curtailments. The task within this project is to develop specific grid management solutions for Vietnam in order to minimize these curtailments and to lay the foundations for a more efficient integration of VRE in Vietnam.

6.2 Analysis of Vietnam´s current electricity grid & economy

As mentioned in the introduction, Vietnam's electricity system has to cope with a huge increase in electricity demand. The highest increase in the electricity consumption period was 2000-2016 with an increase of 12.8% per year and the demand does not seem to level off. This growing demand has to be met by the country's installed capacity.

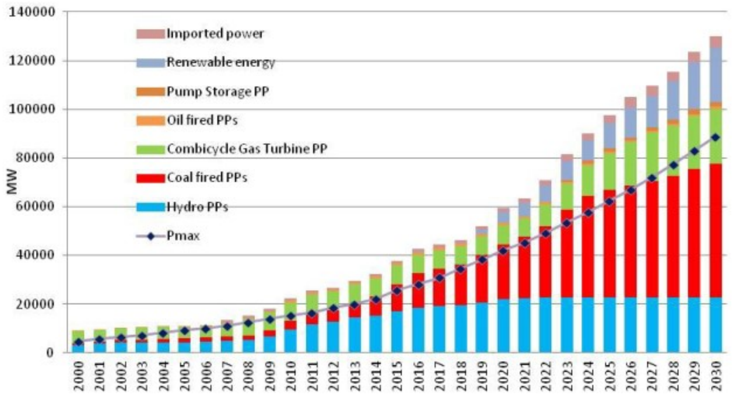


Figure 5: Energy mix and demand to 2030 [2] (Pmax = Peak Load)

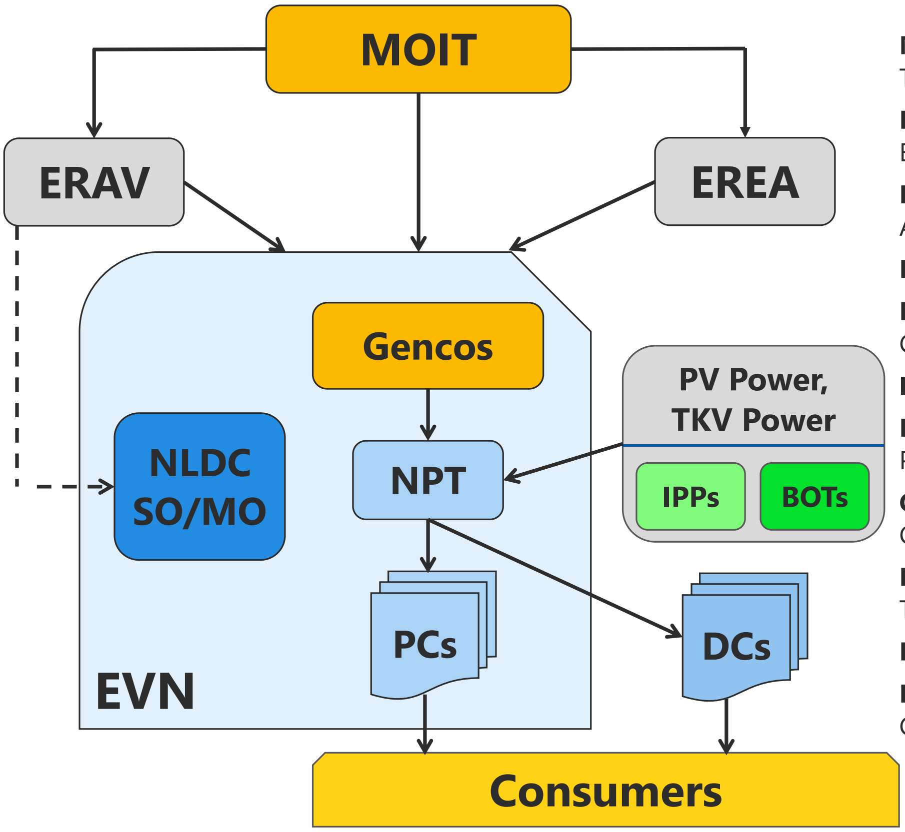
The graph shown in Figure 5 shows that the generation mix in Vietnam was characterized by a high proportion of hydropower plants in the early 2000s up to and including 2020. However, the expansion of hydropower plants in Vietnam is now reaching its limits in 2020.

In order to still be able to meet the increasing demand, other energy sources have to be expanded further. The figure, which has been made available by the "Ministry of Industry and Trade - Institute of Energy", assumes strong growth in coal and gas-fired power plants until 2030. However, these two types of power plants have long construction times and there are repeated delays – such as the coal-fired power plants Duyen Hai 2, Long Phu 2, Vung Ang 3 [2].

VRE, on the other hand, offer a relatively quick construction time which suits the dynamic environment in Vietnam well. Additional motivations for electricity generation from renewable sources include rising concerns over climate change and pollution, national security risks associated with fossil fuels, and a desire to promote innovation and increase the competitiveness of new energy sources. That's why many countries especially emerging economies rely on VRE. Figure 5 shows that the MOIT sees great potential in the field of VRE to keep pace with the sharp rise in demand in the future.

Against this background, an analysis of the current energy system in Vietnam is carried out below. First, the current electricity sector, the regulatory framework for VRE and the technical grid characteristics are analysed and presented. Current VRE hotspots are also discussed, as well as current grid congestions and regions that will be severely affected by congestions in the future are highlighted. Lastly, an analysis of the current market enviroment in Vietnam as well as feed-in management regulations is made. In the end a summary is provided, in which all challenges, outlooks and possible solutions are compared in a table. As an additional supplement, chapter 6.4 provides an assessment of the GMMs already applied in Vietnam by comparing them with selected countries.

6.2.1 Electricity Sector in Vietnam



MOIT – Ministry of Industry and Trade
EREA – Electricity and Renewable Energy Authority
ERAV – Electricity Regulatory Authority of Vietnam
EVN – Electricity of Vietnam
NLDC – National Load Dispatch Centre
IPP – Independent Power Plant
BOT – Built-Operate-Transfer Power Plant
GENCO – EVN Owned Generation Companies
NPT – National Power Transmission Corporation
PCs – Power Corporations
DCs – Join stock Distribution Companies

Figure 6: Structure of Vietnam´s electricity sector [3]

Figure 6 shows the interaction of the different actors in the Vietnamese energy sector. The arrows indicate the flow of information or instructions between or within the different hierarchical levels.

The Ministry of Industry and Trade (MOIT) is the central agency in Vietnams electricity sector. The MOIT develops and implements energy policies related to sub-sectors such as oil and gas, coal, electricity, renewable energy and energy efficiency. The two subordinate subsidiaries of the MOIT are, on the one hand, the Electricity and Renewable Energy Authority (EREA) and the Electricity Regulatory Authority of Vietnam (ERAV). The EREA was established in October 2017 and supports the MOIT in fulfilling state management responsibilities in energy planning, preparing development strategies and national master plans and monitoring them. ERAV, on the other hand, was established back in October 2005 and plays the role of a regulator of Vietnam's electricity sector. The key function of this subsidiary is to support the MOIT in developing a competitive electricity market and market-oriented sector reform. In order to meet these requirements, ERAV assumes tasks such as electricity price management and regulation, responsibility for the development of adequate generation resources to meet future demand, efficiency and conservation, smart grid development and the Demand Side Management (DSM) programme, as well as conducting international cooperation in the energy sector [3].

Vietnam Electricity (EVN) is the largest energy company in Vietnam. EVN was established as a state-owned enterprise by the Vietnamese government in 1994 and has officially operated as a single-member limited liability company since 2010 [4].

EVN operates its own hydropower and coal-fired power plants, controls three power generation companies (GENCOs 1,2,3), one power transmission company (National Power Transmission Corporation - EVNNPT) and five regional power distribution companies (for north, central, south and the two cities of Hanoi and Ho Chi Minh). In addition, EVN coordinates and manages the operation of the national electricity grid through the National Load Dispatch Centre (NLDC). The NLDC is responsible for performing load dispatching, power market trading and other electricity activities throughout Vietnam. The five regional power distribution companies, also known as Power Corporations (PCs), are responsible for electricity distribution and retail in their region.

6.2.2 Regulatory Framework

The regulatory measures analysed below include the feed-in tariffs for solar PV and wind energy introduced by the Vietnamese regulator. Furthermore, with regard to Vietnam's feed-in management, the design of mobilisation and curtailment of power plants, which is determined by regulations and provides clear guidelines for the actors (e.g. transmission system operators - TSOs), is analysed.

6.2.2.1 Feed-In Tariff

Under a Feed-in tariff (FIT) scheme, the generator is guaranteed to receive a fixed price per kWh generated and fed into the electricity grid. The tariff guaranteed covers both the electricity price and the additional subsidy. In Vietnam, this incentive mechanism was used for the development of PV solar and wind power plants. This fixed tariff generated great interest in solar projects in Vietnam, especially in the south, where the regions have the highest irradiance.
The fixed feed-in tariff (FIT) is described in the “DECISION On the support mechanisms for the development of solar power projects in Vietnam "as a " fixed tariff with which the electricity buyer pays the electricity seller " [5]. This means that the electricity buyer is obliged to purchase the entire electricity generated from the grid-connected solar projects at the specified amount of 9.35 US cents per kilowatt hour (this is converted using the current VND-USD exchange rate). Solar systems on the roof, on the other hand, can benefit from net metering. However, the FiT according to decision No.11 was only available to projects that went into commercial operation by June 30, 2019 [5].

In the last few months before the “feed-in tariff deadline” on June 30, 2019 was achieved, an enormous number of PV systems were put into operation. In the process, more than 4000 MW of PV capacity was installed in three months alone [6]. This strong expansion took place particularly in the south of Vietnam, due to the highest local irradiation in the country. The connection between this geographically very cantered extension in the two provinces of Ninh Thuan and Binh Thuan in 2019 and the high commissioning of 4000 MW solar PV power led to major challenges for power supply system in the south of Vietnam.

With decision no. 13/2020 / QD-TTg of April 6, 2020, the mechanisms for promoting the development of solar energy projects in Vietnam were revised and a new feed-in tariff (“FiT”) was decided [7]. Decision 13 clarifies that power consumer include Vietnam Electricity ("EVN"), EVN member companies and other companies that purchase electricity from the electricity seller. This is one of the biggest changes to the previous decision 11, in which only EVN and EVN member companies were entitled to purchase. This specifically applies to solar projects on the roof.

Although the output is limited to 1 MW, PPAs are now clearly possible for businesses between a rooftop solar generator and a non-EVN buyer. The producer can sell the electricity they generate directly to a company, for example, without having to feed it into the EVN grid beforehand. Both the tariff and the form of the corporate PPA are open to free negotiations. This provides more flexibility for smaller rooftop solar systems by giving them a new path to market maturity and the ability to negotiate their own PPA. With these new benefits, the expansion of rooftop solar will continue and force a reorganisation of the distribution grid in Vietnam [7].

Vietnam's more than 3,000 km long coastline holds great potential for wind energy. In order to exploit this potential the first decision approving the incentive mechanism for the development of wind power projects in Vietnam was issued in 2011 [8]. In 2018, the feed-in tariff increased from 7.8 to 8.5 $cents/kWh for onshore and 9.8 $cents/kWh for offshore wind power projects for a period of 20 years whose commercial operation date (COD) is before 31 October 2021 [9].The wind speeds are very high in the Highlands and in the south of the country. Therefore the current expansion of wind turbines has taken place to a very large extent in the south of the country. [6]

6.2.3 Grid analysis

The grid analysis first looks at technical characteristics such as voltage levels, substations, transmission technologies and national energy balancing – regional differences in demand/generation ratios. At this point, recommendations are made for the central coordination level regarding emerging congestions on the transmission lines between north and south Vietnam.

In the next step, the focus is placed on the variable renewable energy hotspots (VRE hotspots) of the country, taking into account the overarching task of the project – Grid management solutions to avoid RE curtailment (TOR's). This involves first analysing the region with the greatest solar PV and wind power potential. After this analysis, an overview of the provinces in this region that already feed an enormous share of VRE into the Vietnamese electricity grid is created. Based on this table and the geographical classification of the VRE hotspots, conclusions are drawn on the congestion that arise at the substations (SS) and transmission lines (TL) at the different voltage levels, and initial recommendations for reducing the congestion are presented.

At the end of this grid analysis, an analysis of the further development of these congestions is also made and initial recommendations are made for the emerging challenges.

6.2.3.1 Technical characteristics

In Vietnam, a distinction is currently made between the 500 kV, 220 kV and 110 kV high-voltage levels. The highest voltage of 500kV is used for transmission over longer distances – north-south connection. The 500kV lines are operated by the NLDC centre, while the 220kV and 110kV lines are operated by three regional load and dispatch centres, one each for the north, south and central geographical area. The five regional Power Corporations (PCs) own and operate all distribution grids 110kV and below.

In 2019, 100% of the SS at the 500kV and 220kV voltage levels and 96% at the 110kV level were connected to the national SCADA system, enabling the NLDC to better monitor available capacity. In the course of further development of the SCADA/DMS system, the distribution networks will also be equipped with information technology and telecommunication infrastructure [10].

Looking at the energy balances of the regions of north, south and central Vietnam, it becomes clear – as mentioned in 6.1 – that the load centres in the south and north of Vietnam are located around the cities of Ho Chi Minh City and Hanoi, while the central part mainly serves as a transmission corridor and production site. The trend in inter-regional transmission in 2019 was north to central and central to south. However, due to the extreme addition of VRE, especially in the south of Vietnam, load flow changes are becoming more frequent. The first load flow changes occur mainly in times when the hydropower plants in the north generate less electricity due to dry seasons – November to April. As a result, the transmission grid for transporting the generated electricity on the north-south connection is increasingly utilised.

If the currents over the lines and transformers in the transmission grid exceed the maximum current-carrying capacity of the lines or the transformer, this is referred to as a congestion. At the extra-high voltage level, the strong annual increase in demand for electricity in Vietnam therefore repeatedly causes congestion on the north-south connection.

In order to prevent these congestion and ensure grid security in the Vietnamese electricity grid, grid management solutions are required. After an initial assessment of the current situation of the north-south link, a high-voltage direct current link is recommended to support the existing 500 kV AC line. HVDC technology offers low-loss transmission of electrical energy over long distances. In addition, modern functions such as the VSC-HVDC (Voltage-Source-Controlled-HVDC) allow instantaneous power flow changes, as well as reactive and active power adjustments.

6.2.3.2 VRE-Hotspots

As already mentioned in chapters 6.2.2.1 and 6.2.3.1, there has been an enormous increase in VRE, especially in southern Vietnam. In Vietnam, the highest potential for the generation of electricity from PV solar as well as from wind plants is in the south of the country. The highest potential for both types of VRE refers to the greatest degree of possible generation – for solar, for example, the indicator would be the irradiance.

The introduction of the nationwide constant incentive schemes for solar and wind energy (FIT) led to a stronger expansion of VRE in the south than in the north due to the more attractive environment for investors, especially in the area of solar projects. Figure 10 shows, for example, that an irradiance of approx. 2000 kWh/m^2 is achieved in the south and only an irradiance of approx. 1300 kWh/m^2 in the north.

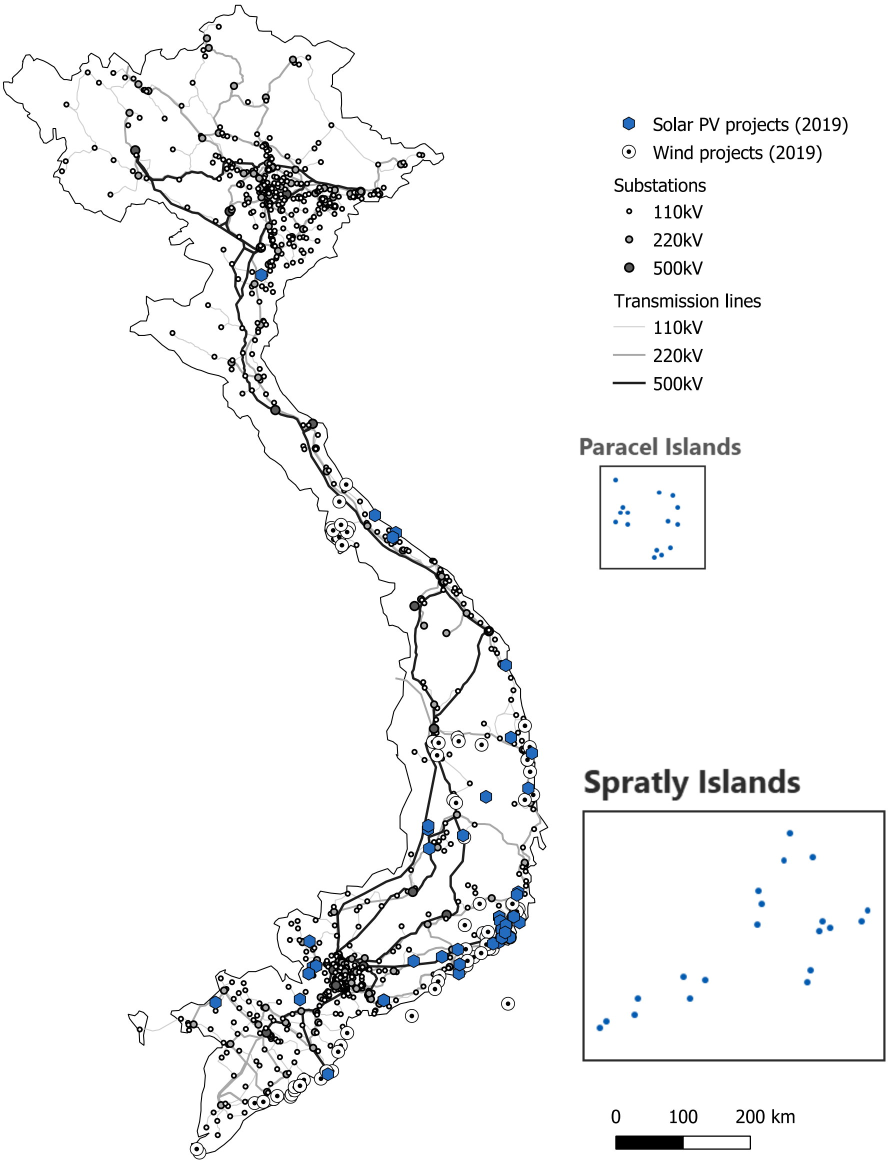


Figure 7: Vietnam's electricity grid [11] (Created with QGIS)

Figure 7 shows the status of solar PV and wind projects in Vietnam in 2019, confirming that investors have been attracted to the south of the country in particular due to the favourable conditions for solar PV and wind. Furthermore, it can be seen that the projects have been built almost exclusively in the east of Vietnam on the coast and preferably in the provinces of Ninh Thuan and Binh Thua – as already explained in chapter 6.2.2.1.

In contrast, in Germany, for example, the highest potential for wind is in the north of the country and the highest potential for solar PV is in the south. In Vietnam, the potential of VRE is therefore much more centred than in Germany. For the energy system, this means a much larger point load of VRE that the grid in the south of the country has to cope with. But there are also symbiotic effects – for example by merging the VRE into a virtual power plant – that can and should be used to ensure grid security and promote renewable energy projects.

Interim conclusion

In summary, it can be said that the VRE hotspot regions are mainly located in the south of the country. Due to the constant feed-in tariff, which applies to the entire country, it can be assumed that also in the future there will be an increased expansion of Solar PV and wind in southern Vietnam. The south currently offers the best environment for solar PV and wind projects, as this is where the highest generation capacities of the plants are achieved.
In order to avoid a regional concentration of VRE, measures such as regional differentiation of feed-in tariffs should be taken.

6.2.3.3 Analysis individual regions in South-Vietnam

Looking at the south of Vietnam, there are further differences between the individual provinces on a regional level.

There are provinces that have installed a very high proportion of VRE systems, such as the provinces of Lam Dong, Ninh Thuan and Binh Thuan. In these provinces, the share of PV solar energy predominates, which leads to high fluctuations in generation between day and night in these provinces.

The provinces in the southeast of the country around the city of Ho Chi Minh are the load centre of the south. Here, too, most of the installed renewable energy consists of PV solar energy.

The southwest of the country, which is characterised by a long coastline with high wind speeds and the Mekong River delta, is dominated by wind energy. In these provinces, energy consumption is very low compared to the other regions, which is why the available capacities are transferred from the southwest to the load centre in the southeast.

Interim conclusion

In summary, it can be said that in the south of Vietnam a distinction must be made between the RE hotspots and the consumption centres. Renewable energy is mainly found on the coast of Vietnam in the south centre. As most of the provinces in this region have a very low electricity demand, most of the electricity generated is transferred to the southern load centre of Ho Chi Minh City.

6.2.3.4 Congestions

Congestion in Vietnam's transmission system is mostly caused by the strong increase in demand in the load centres or by the highly centred generation of renewable energies wind and pv. To get an overview of the current situation of the grid, Figure 8 shows congested SS and transmission lines. In addition, the lines and substations that are critically loaded and could become overloaded in the event of a further increase in feed-in or a further increase in consumption are also marked.

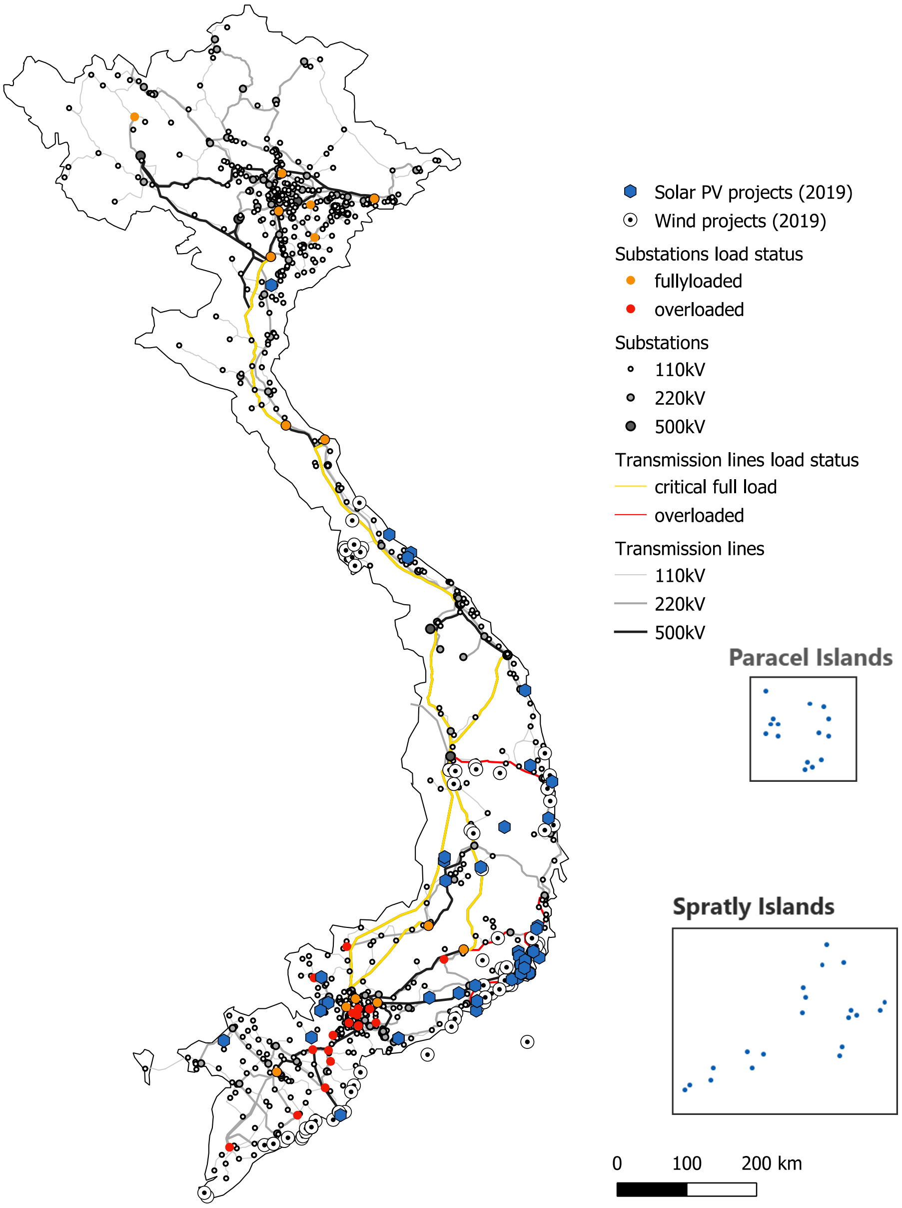


Figure 8: Overview of congestions in vietnam's energy grid [12] [94] (Created with QGIS)

It can be clearly seen that most of the 500 kV lines on the north-south connection, which has already been mentioned here several times, are critically charged.

One proposed GMM to counteract these congestions is high-voltage direct current transmission, which will be analysed in more detail in Task 2 in terms of cost efficiency and sorted into the time horizon. It can already be said that HVDC will be a long-term solution.

The further one follows the 500 kV lines into the south of the country, the greater the density of PV and wind plants will be. These are increasingly located along the coast of Vietnam. What is striking is that they are not strongly decentralised, but that most of the capacities are centred in individual provinces – Ninh Thuan and Binh Thuan. The 220 kV lines leading out of these areas are usually critically charged or overloaded. In addition, 5 transmission lines on the 110 kV and 2 lines on the 220 kV voltage level are overloaded daily in the provinces of Ninh Thuan [12]. The overloads here are caused by the strong peak generation of the VRE. As the electrical consumption in these areas is very low compared to the generation, the lines transporting the energy to the load centres are heavily loaded and congestion occurs – as discussed in chapter 6.2.3.3. It should be observed at which voltage level the power plants are connected. If the power plants are increasingly connected to the low-voltage level, a direct connection to the high-voltage level or extra-high voltage level should be considered to relieve the load on the transformers and lines. Furthermore, the centrality of the different technologies (PV & wind) lends itself to a merger into a virtual power plant. This can be optimised by local energy storage systems, which can be used by the grid operator to relieve the grid and avoid congestions. Other solar PV technologies that make it possible, for example, to shift peak loads using heat storage systems should also be considered as an alternative.

Furthermore, it can be seen from Figure 8 that there is increased transformer overload in the load center around Ho Chi Minh City. This can be explained by the strong increase in demand for energy. Load management of large consumers can be used to eliminate such demand-side congestions. Load management is the active control of electricity consumption. It is also called "Demand Side Management" or "DSM". Financial signals are sent to large consumers via the electricity market so that they adjust their electricity consumption in such a way that fewer grid congestions occur and grid security is guaranteed at all times.

Interim conclusion

In summary, on the one hand, the congestions in the south of Vietnam are due to the strong increase in production from VRE. This fluctuating supply of VRE has an impact on higher voltage levels, such as the 500 kV lines, in addition to their local transmission lines, as the provinces with the highest capacities of VRE have a comparatively very low demand for energy. So there are very clear load, generation and transmission areas. On the other hand, especially in the south around Ho Chi Minh City, there are congestions due to an enormous increase in energy demand.

6.2.4 Market environment

As an emerging country in the Middle East, Vietnam is forced to invest heavily in the development of power generation and transmission infrastructure to keep pace with rising electricity consumption. Foreign investors can increase the country's generation capacity at low cost. The introduction of a wholesale market combined with contractually guaranteed feed-in tariffs promotes competitive electricity generation and creates a more attractive and secure area for foreign investors.

In 2013 the Prime Minister of Vietnam approved an electricity market roadmap for the energy sector in Vietnam. In summary, the resolution is an implementation plan for the gradual transformation of the Vietnamese electricity industry into one that enables competitive electricity markets in wholesale and retail. In the first step of this roadmap, the competitive generation market (Vietnam Competitive Generation Market or VCGM) was introduced, which enables sales to wholesale retail buyers through a generation competition. The Vietnamese electricity industry is currently in the phase of implementing the wholesale market, which is to be supplemented by a competitive retail market (VREM) in 2021 [13].

Figure 9 below illustrates the interaction between the actors at Vietnamese Wholesale Electricity Market (VWEM) and shows what contractual relationship they have with one another.

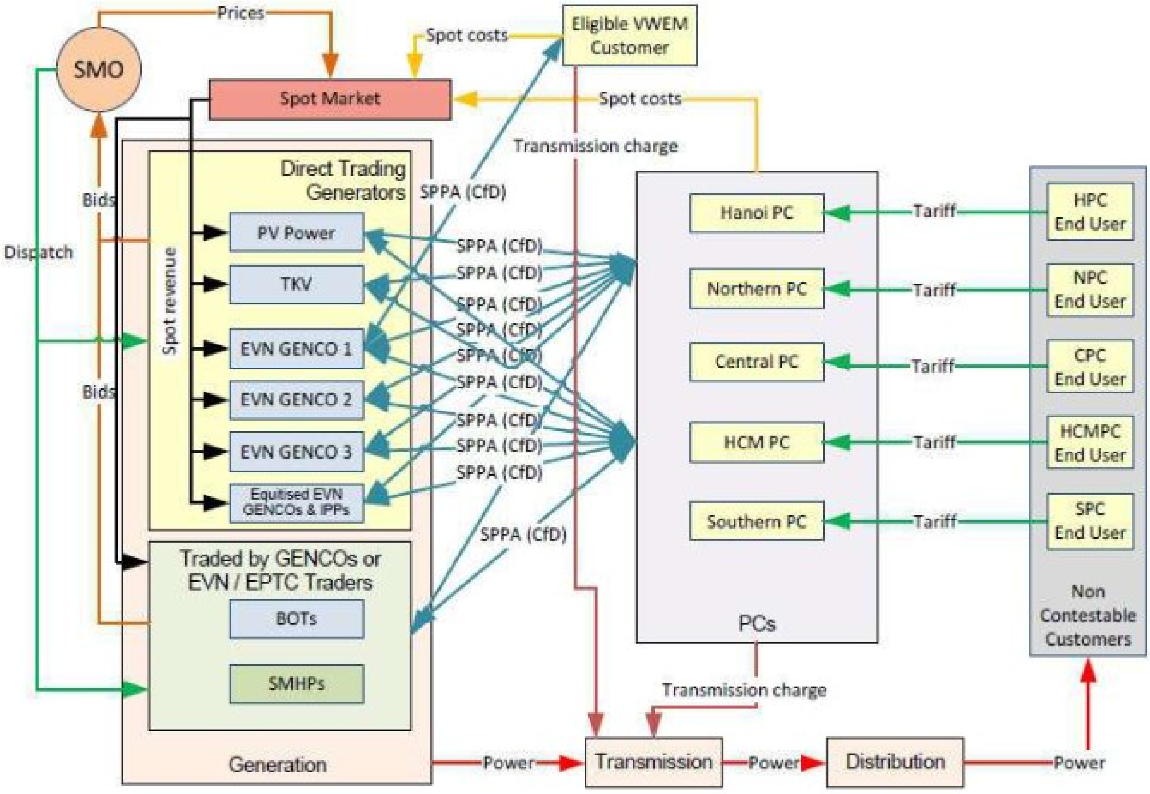


Figure 9: Outline of VWEM trading arrangements [14]

The figure shows the generators of the electricity system on the left. A distinction must be made between the Direct Trading Generators (DTG), the Build-Operate-Transfer (BOT)[2] and Strategic Multipurpose Hydropower Plants (SMHPs) which are especially only traded by the GENCO or EVN / EPTC traders.

The new trading agreements for the VWEM now provide that the producers can work and negotiate directly with the individual PCs. The cooperation between the two parties is mostly based on a Standardized Power Purchase Agreement (SPPA). SPPAs are standardised electricity purchase agreements in which one contracting party is usually a power plant operator or independent power producer and the other is a larger cus-tomer (company, electricity trader and supplier). The SPPA used here is based on a Contract of Differences (CfD). By providing a guaranteed CFD-base-price, the SPPAs grant the investors greater security with regard to their return on investment, as the risk of price fluctuations is avoided [14].

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[2] “Build–operate–transfer (BOT) is a form of project delivery method, usually for large-scale infrastructure projects, wherein a private entity receives a concession from the public sector (or the private sector on rare occasions) to finance, design, construct, own, and operate a facility stated in the concession contract.” [99]

Due to the direct contractual relationship that has now arisen in the VWEM between the individual producers and the PCs, the PCs are now able to compare their contract profiles with their load profiles in the respective areas. In the event of deviations, they can purchase the electricity they need on the established spot market. The electricity costs incurred for a PC therefore amount to a combination of transmission charge, SPPAs and spot market payments.

Another innovation made possible by the VWEM is that eligible customers can directly conclude contracts with generators or PCs other than their current PC. Eligible customers are existing or new customers who are connected to the transmission grid and are therefore considered part of the wholesale market. Eligible customers are required to pay transmission charge. The non-contestable customers, who can be found on the right-hand side of the figure, can only be supplied by the respective PC. The introduction of competition for these customers is planned for the VREM [14].

In the newly implemented VWEM, the NLDC assumes the tasks of the System and Market Operator (SMO). The main task in terms of market operation is to "regulate, coordinate the activities of energy transactions and ancillary services in the electricity market" (Vietnam Electricity Law VEL, 20).

The wholesale market introduced here has a general effect on the distribution of tasks and coordination in the electricity sector. Before the introduction of the wholesale market and the associated liberalisation of the energy sector, the monopolist – in Vietnam EVN – was exclusively responsible for electricity generation and distribution. The dispatching schedules of the power plants could always be controlled directly by them in such a way that the transmission lines were not overloaded, as they also owned the transmission system. External measures to coordinate with other companies to ensure grid security were therefore not necessary.
Now electricity is no longer produced exclusively by EVN companies, but also to a large extent by privately owned RES. As a result, EVN no longer has any influence on the entire generation capacity of the grid in order to make short-term feed-in changes. As a consequence, operational GMM are becoming more important. However, this introduction of competitive generation also creates a greater need for coordination between transmission system operators and generators.

6.2.5 Feed-in management regulation

In the area of grid management, there are various measures such as grid-related measures, market-related measures and the reduction of feed-in from renewable energy power plants – also known as the feed-in management. The order in which the individual measures are used is usually also determined by the regulatory framework.

Redispatch involves a curtailment of power plants before the congestion and a mobilisation of power plants after the congestion. In Vietnam, the circular on 30 August 2020 made an adjustment to the principle of mobilisation and curtailment of power sources in the event of grid congestion by the PCs and the NLDC. In the process, a grouping of the power plant types into four groups is made:

- Group 1: power plants under testing before commercial operation date (COD), hydropower plants that are releasing water

- Group 2: renewable energy power plants that are unable to store energy, which includes hydropower plants in risk of water releasing, small hydropower plants, wind and solar power plants
- Group 3: RESs that are able to store energy, which includes biomass and waste-to-energy power plants
- Group 4: dispatchable hydropower plants, fossil fuel power plants (coal, gas turbine, diesel, combined diesel and gas turbine)

This grouping now provides for a prioritisation order in which, in the event of mobilisation, Group 1 is to be mobilised first and Group 4 last. In contrast, the priority order is to be reversed when individual power plant capacities are curtailed [15]. The approach only takes into account the feed-in priority of RE. However, the impacts of the individual power plant types on the congestion are not considered here.

6.2.6 Outlook and summary of the emerging challenges in Vietnam

GMMs differ not only in the area of their implementation, such as market-related or grid-related measures, but also in their implementation time. There are GMMs that can be implemented quickly and others that need to be well planned and are associated with long implementation times - e.g. HVDC. Especially for these long term solutions it is important to take into account the development of demand and generation in the country.

Vietnam is currently in a very dynamic environment. The economy is growing at a GDP growth rate of 7% (2019) and the population is increasingly moving from the rural areas of the country to the big cities - rate of urbanisation (2015-2020) 3%. As a result, energy demand in the two metropolitan areas of Hanoi and Ho Chi Minh City continues to increase, putting increasing strain on the transmission lines and transformers around these areas.

A further increase in energy demand can be expected in the future. The economy in Vietnam will continue to grow and with it the demand for electricity. The trend towards urbanisation in the country will lead to a further increase in energy demand, especially in the two metropolitan areas of Hanoi and Ho Chi Minh City. Further GMMs will therefore be needed in the future to meet the increase in demand in these areas and to ensure grid security in Vietnam.

The expansion of renewable energy is currently taking place almost exclusively in the south of the country. This is partly because the south of Vietnam is an attractive environment for investors in solar PV and wind projects due to high wind speeds and high irradiance. In 2019, extreme PV growth rates of around 5000% were achieved due to the limited introduction of a feed-in tariff for solar PV technology – as explained in 6.2.2.1.

In the future, a further expansion of PV solar and wind generation can be expected, which will also increasingly take place in the south of the country due to the better conditions. Furthermore, it can be assumed that due to the adjustments of the feed-in tariffs and the introduction of the wholesale and retail markets, the rooftop solar systems will meet with more demand and there will be an increased expansion of this technology. This can lead to the current very centralised generation of PV systems becoming more and more decentralised, which will primarily lead to congestions at the low-voltage level. These scenarios should and will be taken into account in the further course of selecting the right GMMs.

6.2.6.1 Summary

The following table lists the results of the analysis of Vietnam's current energy network & economy. On the left side, the challenges are listed in the form of the affected action areas. Each challenge is explained in the table and an outlook for the future is given. The last table entry contains the first recommendations that could contribute to solving the challenge. In chapter 6.4, these first recommendations are then compared to other GMMs and it is seen which of the measures are already being applied in Vietnam.

Challenge	Main reason	Outlook	First recommendation
500kV Transmission Lines (north-south Connection)	Differences in peak generation times between hydropower in the north and PV solar in the south lead to congestions;	further increase in load flow changes on the north-south link;	HVDC
VRE-Hotspots (Ninh Thuan and Binh Thuan) -> Congestion at transmission lines to load centres -> Emerging congestion at the distribution grid level	Transmission lines designed to supply small provinces are expected to transmit strongly fluctuating generated power. Grid expansion is unable to securely transmit this power, which leads to congestions at VRE-Hotspots;	• Further expansion of VRE, especially in the south of Vietnam; • Rooftop solar systems are becoming more and more attractive for investors; • May lead to an increase in congestion at the low voltage level;	Virtual power plants; Observe power plant connections to Substations
Load centres (Hanoi and Ho Chi Minh City) ->Congestion at distribution level	• high economic growth in Vietnam • causing a high increase in electrical loads;	• Densification of the population in metropolitan areas; • further increase in GDP; • further increase in demand for electricity;	Digitalisation / Automation
Expansion of VRE limited to a few provinces in the south of Vietnam	The national feed-in tariffs created an incentive mechanism for investors, which led to a huge expansion of wind and solar PV in the south of Vietnam due to better conditions;	In the future, the development will not be different, as the potential for wind and PV is higher in the south due to higher wind speeds and solar radiation. Unless adjustments are made to the incentive systems through government regulation.	Time or region-dependent feed-in tariffs

6.3 Overview of GMMs

If the operating status deviates from normal operation, GMMs are required to restore normal operation. Grid management itself includes all measures that a grid operator can use to avoid or eliminate line congestion caused by grid congestions in its grid [16]. A distinction can be made between planning and operational GMMs at the distribution and transmission grid level. [17]

6.3.1 Planning GMMs

Planning GMMs are measures that can reduce the occurrence of a congestion in the grid, such as grid expansion, which reduces the probability of a congestion occurring by increasing transmission capacities. [17]

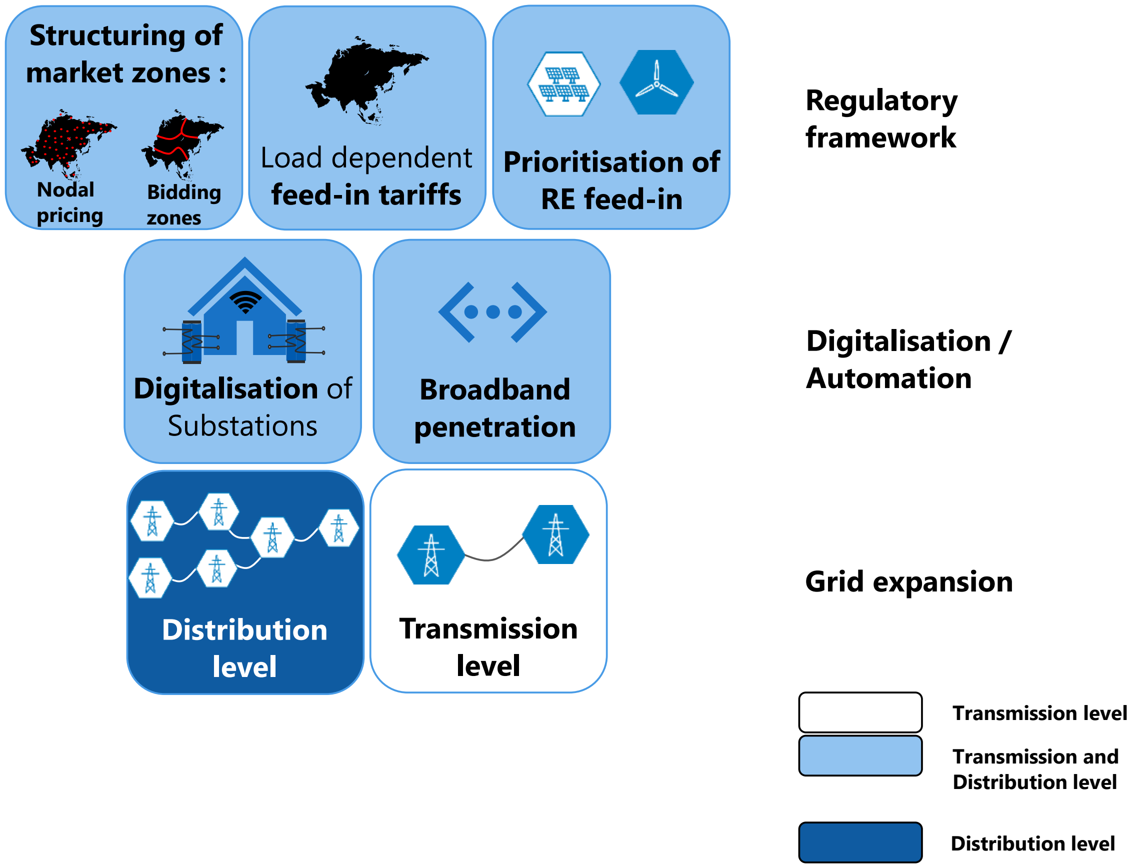


Figure 10: Overview of planning GMMs

6.3.1.1 Regulatory framework

Planning GMMs include the setting of regulatory framework conditions. The three measures of market restrictions, load-dependent feed-in tariffs and the prioritisation of feed-in from renewable energies are presented here as examples.

Structuring of market zones
Trading on the electrical markets is divided into two sub-areas by the terms implicit auction and explicit auction. In the implicit auction, the energy is auctioned together with the grid capacities. In comparison, in the explicit auction, both are auctioned separately from each other.

The structuring of market zones into smaller areas (bidding zones or price zones) down to the smallest unit of the nodes of a electricity grid counts as an implicit auction.

Bidding zones

Bidding zones are defined as grid areas within which electricity can be traded on the exchanges without taking grid congestion into account. If electricity trading on the market now includes the transport of electricity across bidding zones, it is limited by the available transmission capacities. This means that congestion is prevented by limiting trading through transmission capacities but there are also arising different electricity prices in the respective bidding zones. [17]

Nodal pricing

An extreme approach to preventing congestion by including transmission capacities in electricity trading is nodal pricing. With nodal pricing, the available transmission capacities at each node in the grid are included in the electricity trade. This results in higher electricity prices when there is a high demand for electricity transport in a region where transmission capacities are scarce and consequently congestion often occurs. In this way, financial incentives can be set for a sensible use of power plants, taking transport congestion into account. Furthermore, the introduction of this mechanism leads to the creation of regional markets for electricity, where supply and demand can meet on a regional level and thus avoid grid congestion.

The idea behind the introduction of these mechanisms is that electricity is not always worth the same, but often causes congestion relief costs in the case of insufficient grid expansion.

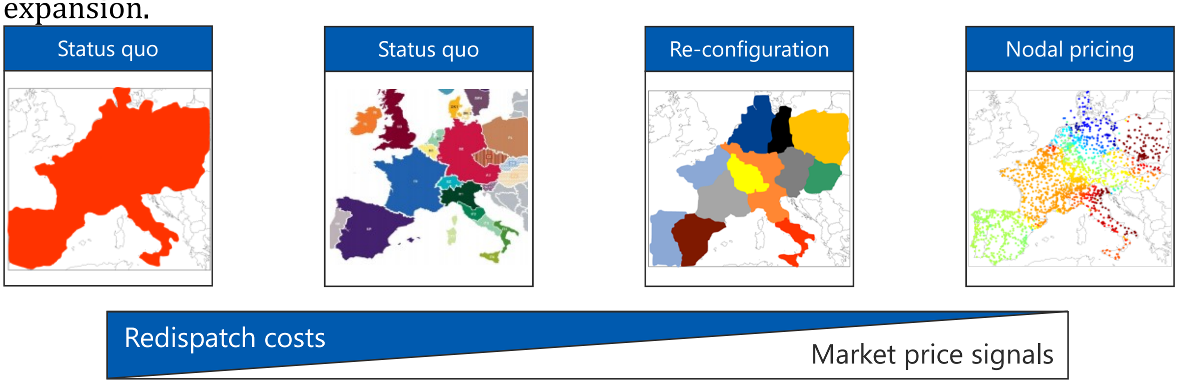


Figure 11: Structuring of market zones

Figure 11 shows that smaller subdivisions of a country or region into bidding zones result in a reduction of redispatch costs to compensate for congestion. Market signals are then sent through these increasingly smaller areas to support operational grid management. For example, the electricity price upstream of a congestion can become cheaper, so that more electricity is sold in the area, and the electricity price downstream of the congestion can become more expensive, so that less electricity is requested in the area.

Load dependent feed-in tariffs

Another regulatory measure is to influence investor´s investment decisions by choosing load-dependent feed-in tariffs.

Feed-in tariffs provide an incentive for investors in the country to invest in RE projects. The feed-in tariff can be adjusted in such a way that the tariff varies depending on the time of day. On the one hand, the feed-in tariff can be set at the lowest level at times when the grid load is low and there is a risk of overproduction by solar PV systems. The highest tariff, on the other hand, can be set at times when the load in the grid is also at its highest.

This gives investors an incentive to invest in storage options (e.g. BESS) or to change the orientation of the solar PV systems in order to receive a higher feed-in tariff. The advantage of this is that grid congestion and the resulting grid management costs at peak feed-in hours can be reduced.

Prioritisation of RE feed-in

In many countries, RESs are only used for grid management when the congestion removal measures of conventional power plants have been exhausted. This order of deployment is dictated by regulatory framework conditions in order to give priority to the feed-in from RE even in the event of grid congestion.

However, with an increasing share of decentralized RESs, the scenario often arises that a shutdown or curtailment of RESs would have a much more efficient impact on the congestion than curtailment of conventional power plants. The reasons for this are usually that the small, decentralized RESs are much closer to the congestion point and therefore have a greater impact than remote conventional power plants. [18]

A regulation that takes into account the effect on the congestion or the cause of the congestion could, on the one hand, save costs and, on the other hand, eliminate the congestion more quickly and efficiently.

6.3.1.2 Digitalisation / Automation

Another possibility for planning GMMs is the improvement of the digital infrastructure of the electric power system. The digitalisation of existing and new substations and the progressive expansion of broadband play an important role here.

In summary, the digitisation or the existence of a solid digital infrastructure is necessary for data collection and processing in an electrical supply system with a rapidly growing share of VRE. The reason for this is that in such a system, the information required by the grid operator to be able to operate the grid safely is also increasing. Examples for additional data required are

- weather data due to the fluctuating generation of VREs
- peak generation times of VREs
- local electricity demand behaviour
- the impact on substations and line capacities

In the course of solar PV expansion, this data to be collected is increasing, especially at the distribution grid level, which used to be very low in times of exclusive electricity generation from conventional sources. Data collection through the digitalisation of the substations at the distribution grid level is therefore becoming increasingly important and is essential for the efficient integration of the VRE from a certain proportion of solar PV systems with a connection at the distribution grid level.

An additional automation of these substations then makes it possible to additionally accelerate the processes, such as topology adjustments or OLTC level adjustments.

Digitalisation of distribution & transmission substations

In the context of grid control technology, the digitalisation of the substations means the connection of the substations to grid control centres with all important SCADA functions.

Broadband penetration

The telecontrol equipment (SCADA) is used for remote control and remote monitoring of geographically widely distributed systems. Different communication media can be used for data transmission to ensure a safe and fast application of the telecontrol technology. Examples are

- dedicated telephone lines
- fibre optic connections
- the Internet
- trunked radio
- carrier frequency telephony on high-voltage overhead lines (Powerline Communication – PLC)

The expansion of decentralised VRE results in a higher data demand and therefore a high data flow. In order to be able to transmit this large amount of data safely and quickly, it is important to select the right communication medium. Fibre optic connections are especially important for particularly fast transmissions, which can both save costs and increase supply security in the event of impending congestion. [19]

6.3.1.3 Grid expansion

Congestion occurs in the transmission or distribution grid when the currents exceed the existing current carrying capacities of the lines or transformers.

To avoid the congestions, it is a logical approach to increase the grid capacities so that more current can flow through the lines and transformers. This is ensured by a suitable grid expansion. However, network expansion is a measure that entails long construction times and high costs. Therefore, especially in emerging countries, it is often tried to reduce this measure to the minimum. [17]

6.3.2 Operational GMMs

Planning GMMs only help the grid operators to a certain degree to resolve congestion in bidding zones.

For the active elimination of congestion during grid operation, the grid operator therefore has operational GMMs at his disposal. These can be divided into grid-related and market-related measures. A special case is the feed-in management of RESs, which is subject to special regulation in many countries due to the prioritisation of RE generation. Figure 12 shows an overview of possible operational GMMs. A further distinction is made here between the application or availability of the measures on the two grid levels, the transmission grid and the distribution grid.

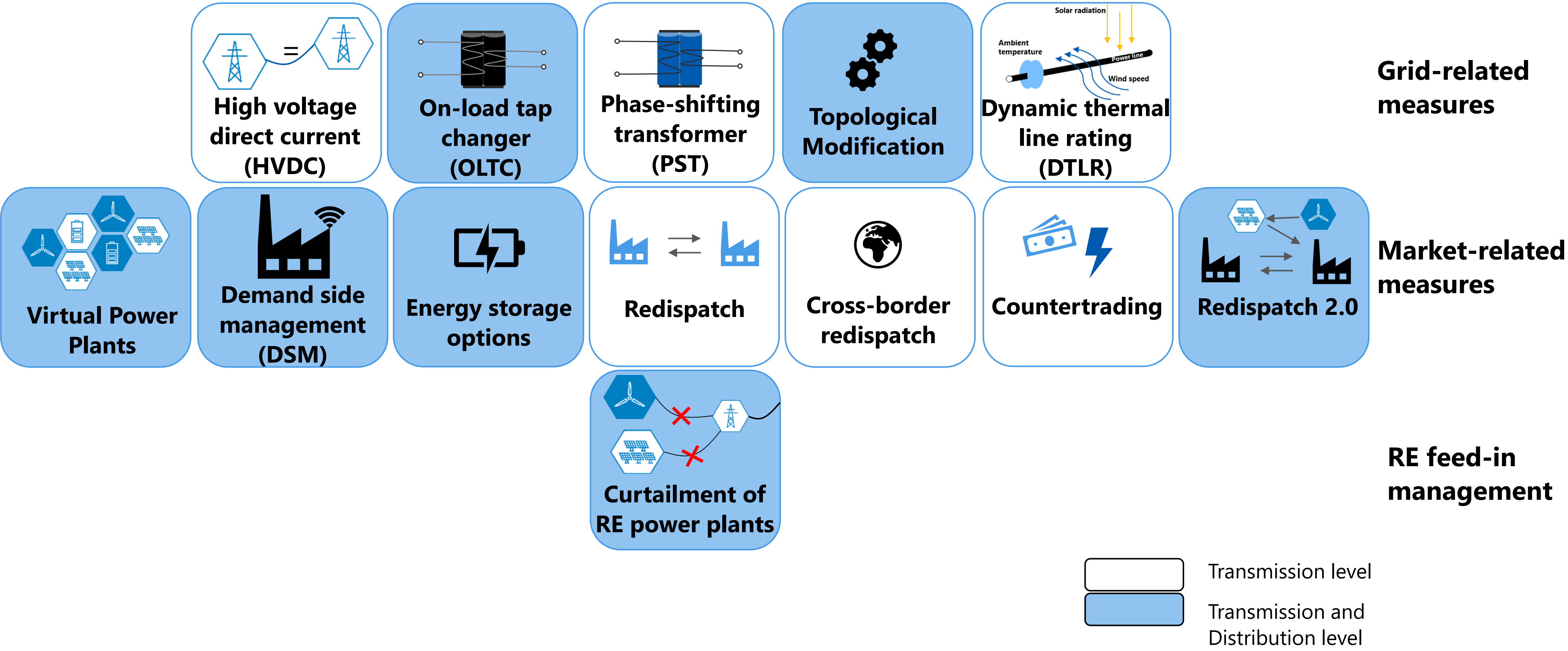


Figure 12: Overview of operational GMMs

6.3.2.1 Grid-related measures

Grid-related measures allow the load flow in the grid to be adjusted in order to relieve overloaded lines or transformers. Grid-related measures therefore include the grid-benefiting interconnection of RESs to form a virtual power plant, the adjustment of active power transmission via HVDC lines, the modification of the grid topology and the adjustment of the staging of phase shifting transformers (PST) and on-load tap changer (OLTC).

HVDC

High-voltage direct current transmission (HVDC) enables the low-loss transport of large amounts of electrical energy over long distances. The HVDC lines are connected to the rest of the AC grid via alternators/rectifiers at the start and end of the line.

HVDC technology offers the following advantages over AC transmission:

- No reactive power -> lines can also be used over long distances
- Stability independent of the line angle (no stability problems)
- Control of the power flow
- No skin effect

Furthermore, a distinction is made between the two technologies of classic Current Source Converter HVDC (line-commutated) and Voltage Source Converter HVDC (self-commutated). While line-commutated HVDC works with thyristors that can only be switched on but not off, self-commutated HVDC works with IGBT transistors that can be switched on and off. In this way, the VSC converter behaves like a controlled voltage source, which means it can be started up without a three-phase grid (black-start capable). In addition, compared to the classic variant, the VSC HVDC has important grid-stabilising properties such as active and reactive power control and immediate power flow reversal. [19]

HVDC lines are connected exclusively at the transmission grid level. Therefore, this measure is not used at the distribution grid level.

OLTC and PST

The grid operation desired by the transmission system operator is the normal operation in which all operational limits are complied with. Regulating transformers are used to compensate for the load-dependent voltage drop at the upstream and downstream grid and transformer impedances, to separate the voltage maintenance in the individual grids and to control the power flow. [20]

OLTC

These operational limits include compliance with the voltage band, which can be influenced by OLTC transformers to serve the grid. OLTCs have been used for many years in power transformers to regulate the voltage without interrupting the load current. In this case, part of their winding, the tap winding, is provided with taps, whereby the transformation ratio can be adjusted in an appropriate bandwidth. [20]

OLTC transformers can also be used at the distribution grid level in local grid stations for voltage regulation. The advantage of this technology is that if all local grid stations of a medium-voltage grid are equipped with controllable transformers, the voltage of the entire medium-voltage grid can be adjusted decoupled from the voltage maintenance of the lower low-voltage level.

PST

Phase-shifting transformers create a phase shift in the voltage between input and output by introducing an additional voltage. The active power flow via the transformer can be controlled through the level of this additional voltage. The switching process to initiate this phase shift occurs within a few seconds. In this way, heavily loaded lines can be relieved in a short time and congestion can be counteracted. By impressing an additional voltage, which leads to a change in the voltage-phase angle difference and therefore also to a change in the active power flow, the PST also contributes to compliance with the frequency limits. [17]

Topological modifications

Changing the grid topology, for example by connecting or disconnecting lines and transformers and changing the busbar configuration, enables congestion in the power grid to be eliminated.

The grid can be adapted to the load and feed-in conditions by switching operations and the associated change in the grid impedance. In this way, congestion in the grid can be eliminated. However, it must be ensured that the change in the grid topology does not lead to undesired side effects such as a violation of stability limits or overloads of other equipment. Depending on the switching operation to be carried out and the structure of the switchgear, a different number of different switches must be switched. [21]

Topology changes can also be carried out at local grid stations on the distribution grid level in order to relieve lines and keep the voltage stable.

Dynamic thermal line rating (DTLR)

Dynamic thermal line rating (DTLR) is an effective measure for the best possible use of the existing grid. By using this measure, higher transmission capacities can be achieved, especially in the windy and cold seasons. In this way, the operation of the existing grid can also make an additional contribution to the grid integration of variable renewable energies.

DTLR means that, depending on the weather conditions, power circuits of overhead lines can carry an operating current that can deviate from the standardised continuous current carrying capacity. The standardised continuous current carrying capacity is normally designed in such a way that the line temperature does not deviate from the standard conditions at any time of the year. In most cases, a high summer environmental is used to define the standardised continuous current carrying capacity.

The measure is made dynamic by determining the maximum possible load of overhead lines in real time depending on the current weather. The newly calculated current carrying capacity can deviate from the standardised continuous current carrying capacity of the lines. However, the safety regulations such as the maximum permissible operating temperature of the conductor cables and their minimum distances to the ground or to objects are always observed. Mains operation therefore changes from a static to a dynamic current carrying capacity.

The method is made possible, as already mentioned above, by strong weather and temperature fluctuations, especially between seasons. As a rule, the design temperature of aluminium/steel overhead lines is approx. 80 °C. This means that the individual lines must not exceed a temperature of 80 °C in continuous operation. Due to a special influence of the weather conditions, such as the

- wind speed
- wind direction
- ambient temperature
- Global radiation

higher transmission capacities can be realised without violating the line safety standards regarding line temperature and ground clearance. [22]

6.3.2.2 Market-related measures

Market-related measures are generally based on the principle of matching supply and demand via the price.

In the area of market-related measures, the adjustments of loads in the electricity system (Demand side management), the provision of battery storage on the market, the adjustment of the active power input of power plants in the country and beyond the borders (Redispatch), Countertrading and the inclusion of smaller RE power plants in Redispatch (redispatch 2.0) are briefly discussed here.

Virtual Power Plants
The integration of fluctuating generation from VRE is a challenge for a country's grid operation, as these fluctuations need to be constantly balanced to adjust load and generation.

One possible solution to reduce these balancing services is to combine the VRE generation units with other technologies such as conventional power plants, energy storage and demand. On the one hand, the combination can store the surplus electricity production at times of high VRE production and thus prevent the curtailment of energy. On the other hand, a deficit in electricity production can be compensated by the energy stored in the storages.

This interconnection of different electricity plants is called a virtual power plant (VPP). VPP can be defined as a set of electricity plants, including generation and consumption units, operated as one unit to optimise the use of energy resources. [23]

The combination of smaller generation and consumption plants in the form of a VPP can also be used to maintain voltage at the distribution grid level. VPPs can be composed of combined heat and power plants (CHP), energy storage and, for example, solar PV systems.

Demand side management
Demand side management (DSM) deals with the adaptation of the load to the supply-dependent volatile VRE generation. In the past, DSM was aimed solely at smoothing the daily load curve, thereby reducing mobilisation and curtailment of power plants.

Today, DSM is primarily focused on the rapid provision of flexibilities, a smoothing of the residual load and system services.

However, these area-wide optimisations are only possible at distribution grid level if the system is equipped with the corresponding grid control technology.

Energy storage options

Energy storage options can be used to balance generation and residual load peaks in the grid. An example can be illustrated with the residual load curve. At times when the solar PV generation is so high that a reduction of the power plants is imminent, the energy can be fed into the storage. In the evening, when the residual load of the grid rises sharply due to the decreasing generation from solar PV systems, the stored energy from the storage facilities can be fed back into the grid. In this way, lines at the transmission and distribution grid level can be relieved.

In the area of storage options, there are not only different areas, such as battery storage or pumped storages, but also different technologies in the respective areas, such as the composition of battery storages. Each different technology has a different area of application for example regarding the use for Costumers/Industries, Power Distribution, Power Transmission or Bulk Storage. Figure 13 provides an overview of the different technologies and their areas of application.

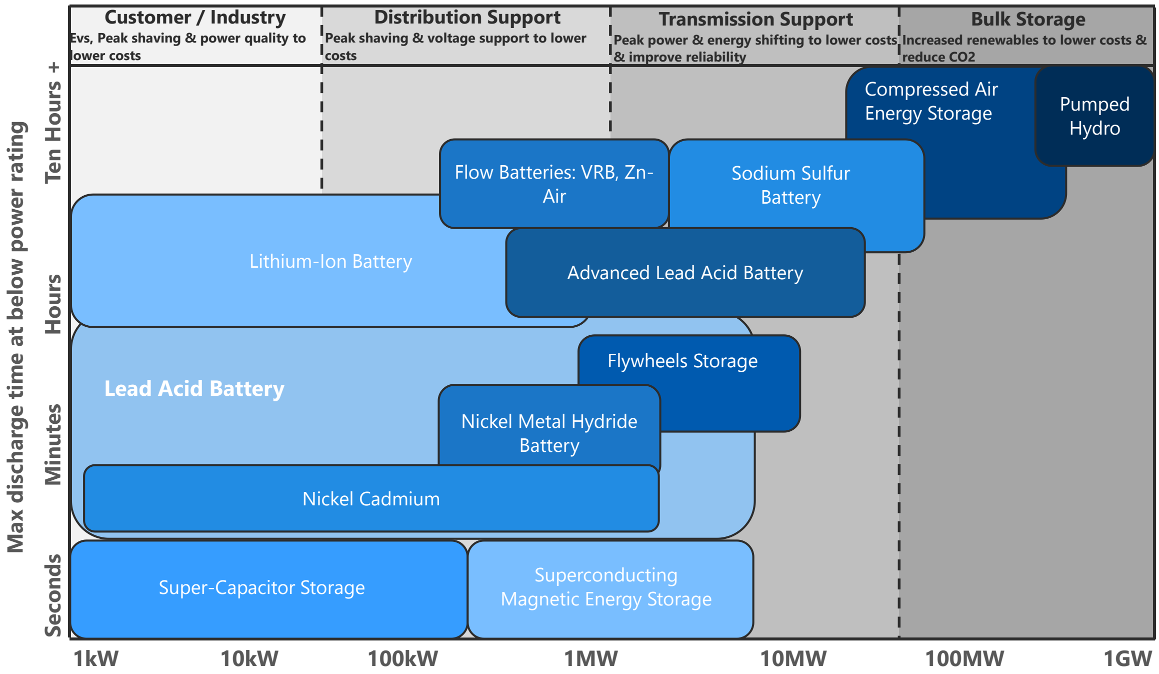


Figure 13: Energy storage options versus applications [24]

Redispatch

Another market-related measure is the adjustment of the active power output of thermal and hydraulic power plants as a result of trading on the electricity market. A specific request by the transmission system operators to reduce the generation of power plants upstream of a congestion and to increase it downstream of a congestion results in a lower power flow through the line or transformer under consideration. In this way, a possible overload can be eliminated. This measure of adjusting the generation capacity is called redispatch. [17]

By requesting a change in the feed-in deviating from the planned load schedule, the power plant operator incurs costs which the transmission system operator settles with him.

Cross-border redispatch

Cross-border redispatch is an extension of classic redispatch. However, power plant resources from neighbouring countries are used to change the generation capacity at short term. A basic requirement for the application of this measure is that the two systems are not galvanically separated from each other.

Countertrading

Countertrading is a measure to resolve congestion that occurs at short term. In this process, a redistribution of electricity flows that relieves congestion is made possible within a short period of time by means of a trading transaction across control areas. A control area represents the grid area for which a transmission system operator is responsible. Congestion between control areas occurs when market participants want to export more electricity from one control area to another control area than is technically possible with the existing transmission lines. In such cases, the transmission system operator can conclude an opposite electricity trade transaction so that the actual electricity flow to be physically transmitted is reduced.

Redispatch 2.0

As already mentioned, the curtailment of power plants before a congestion is regulated in Germany by the instrument of Redispatch. Until now, the transmission system operator could only use conventional plants.

Redispatch 2.0 is to be introduced on 1 October 2021 in Germany, which will include RESs up to 100kV. Through this measure, RESs are integrated into the Redispatch at the distribution grid level, which increases the need for coordination between the DSO and the TSO. [25]

In order to include the RES plants in the shutdown sequence, Redispatch 2.0 uses imputed costs & minimum factors for the RES plants. The advantage of this procedure is that by calculating the imputed costs for RESs, a value is available that can be compared with the marginal costs of conventional power plants. On the basis of these costs, a most cost-effective sequence for the curtailment of power plants can then be established. An important contribution to grid management is the introduction of so-called minimum factors. A minimum factor indicates how strongly a RES must act on the congestion in order to be shut down before a conventional power plant. This means that RESs are not subject to a general priority, but can also be switched off if they have a higher effect on the congestion.

6.3.2.3 RE feed-in management

Feed-in management refers to the curtailment of RESs to remedy a grid congestion.

In Germany, feed-in management may only be used for grid management if the other GMMs have been exhausted. If this is the case, the RESs may also be curtailed before a grid congestion occurs, similar to redispatch, in order to resolve it.

RESs are also increasingly being connected to the distribution grid level. As a result, the RE curtailment measures are available at the distribution grid level to maintain voltage.

In the case of feed-in management, the RES investor also incurs costs in the form of lost electricity sales revenues in the course of curtailment. These costs plus the foregone feed-in subsidy for RE are reimbursed to the investor by the transmission system operator in Germany. [17]

6.4 Assessment

In the following, an assessment of the current grid management in Vietnam is made. In order to identify a gap in the grid management of Vietnam so far, the GMMs listed in chapter 6.3 used there and in the countries of the Master Group so far are analysed and compared. Here, the measures are divided into 6 subgroups:

- Regulatory framework
- Digitalisation / Automation
- Grid expansion

- Grid-related measures
- Market-related measures
- RE feed-in management

Green boxes mark measures that have already been applied, yellow those that are being considered, and red those that are not yet being considered. A green rating is given if an already operating project of the respective GMM is found. A yellow rating is given if studies on the measure and plans for its application already exist but no project has been implemented yet. A red rating is given if no activities have yet taken place in context of this measure.

6.4.1 Country selection

The aim of this work is to find internationally proven GMMs for the dynamic environment in Vietnam. The selected measures should then be combined as a bundle to provide a solution or a possible blueprint for the authorities concerned in Vietnam. The basic requirement for the selection of the right measures is that they are applicable to Vietnam and improve the efficiency of the integration of a high proportion of RE.
For this purpose, a two-stage selection process is carried out in this part in order to identify the countries that are as similar as possible to Vietnam and have already gained a lot of experience with the efficient integration of RE.

6.4.1.1 Summary of the procedure

In Task 1, a two-step selection process is used to evaluate Vietnam's current energy network on a top level and to identify comparable international grid management solutions, which might be suitable to serve as a basis of comparison for Vietnam.

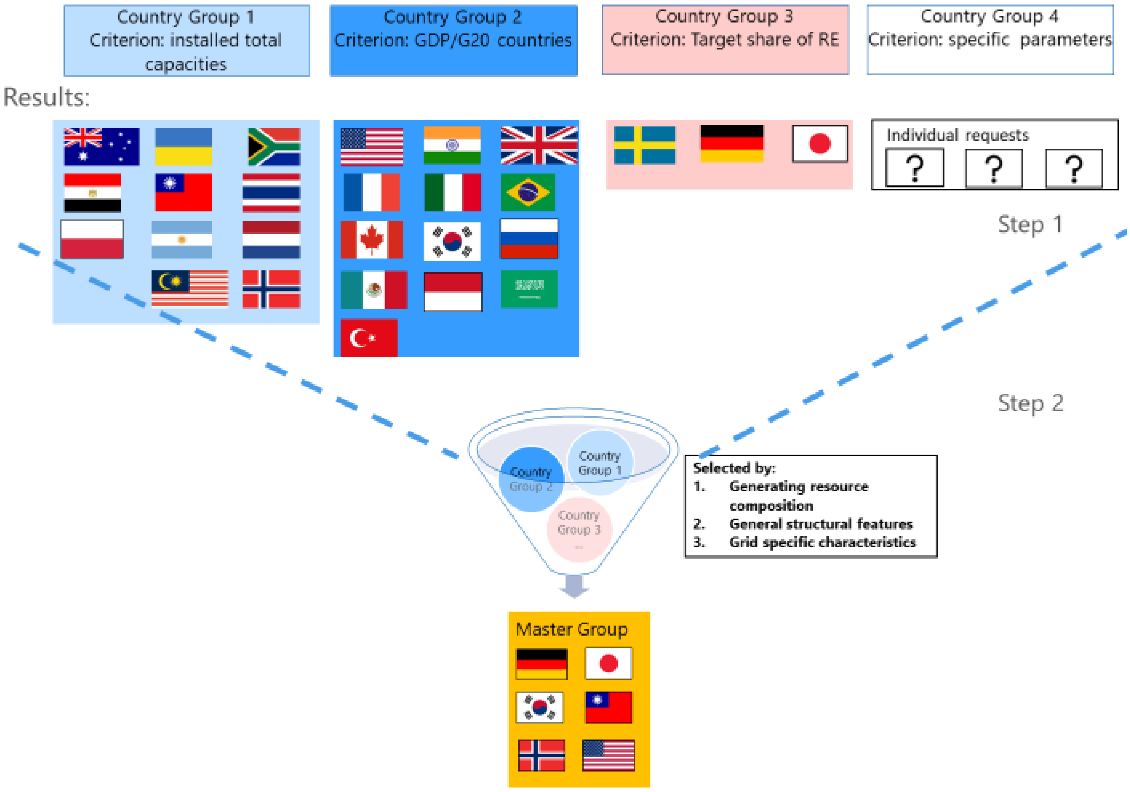


Figure 14: Summary of the process [26]

In the first step, country groups are formed on the basis of 3 initial structural characteristics. The individual country groups are filled in by means of an initial selection process with suitable countries that have the respective initial structural characteristics.

In the second step of the selection process, the individual countries in the country groups are compared with Vietnam in a Comparison Matrix in chapter 0.

The comparison criteria are made up of three groups of specific structural characteristics:

- Generation mix
- General structural characteristics
- Grid-specific characteristics

A number of countries is then grouped into a Master Group on the basis of a created range, which relates to the reference value of the respective specific structural characteristics in Vietnam.

FICHTNER´s two-step selection process ensures that the selected countries in the Master Group best reflect the required target characteristics – a lot of experience with the efficient integration of renewables and similarities with Vietnam.

In the concluding part of Task 1, the countries of the Master Group are then examined in an Assessment Matrix for GMM groups and compared with Vietnam. This gives an overview of which GMM groups the different countries use in compared to Vietnam.

On this basis, precise solutions for grid management and regulatory measures to support these solutions can then be identified in Task 2 and summarized in an overall recommendation for Vietnam.

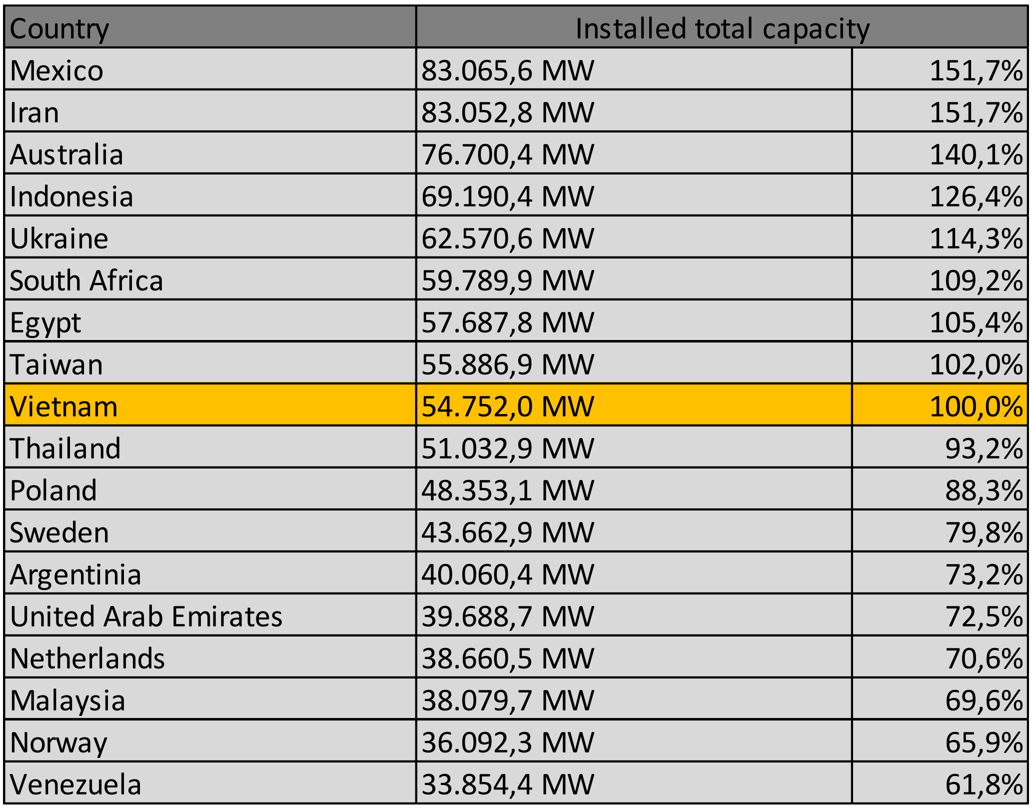
6.4.1.2 Country groups

The country selection starts with the set-up of comparable country groups based on the selection criteria of 3 initial structural characteristics (refer to Chapter 6.4.1). The countries in the various groups of countries all have one initial structural characteristic in common.

Group 1: Installed total capacity

In the first group of selected countries, the analysis focuses mainly on identifying countries with a similar installed total capacity as Vietnam. This ensures that countries are compared with Vietnam that have a comparable size of their energy system on the generation side. After defining countries that meet the condition mentioned above, the overall structure of the generation mix in each country is analysed in a Comparison Matrix in chapter 0.

In relation to the grid management in the respective countries, the generation composition and the installed total generating capacity have an impact on the respective scope of grid management solutions and their integration.
A list of countries with the corresponding installed total capacity is shown in Figure 15. From this list, countries will be selected for further analysis under defined criteria, which are explained in the following.

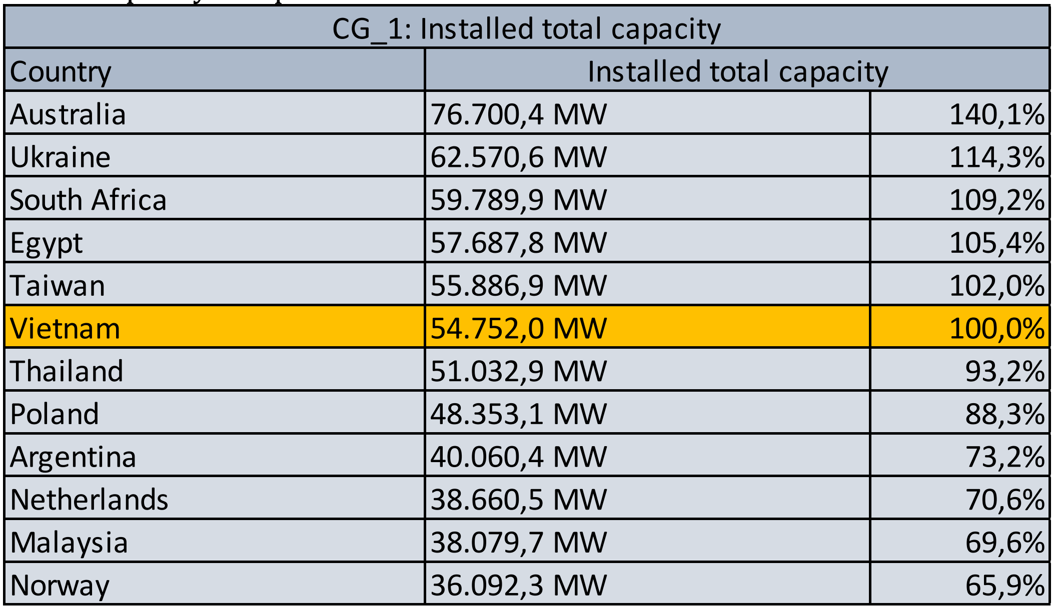


Country	Installed total capacity	
Mexico	83.065,6 MW	151,7%
Iran	83.052,8 MW	151,7%
Australia	76.700,4 MW	140,1%
Indonesia	69.190,4 MW	126,4%
Ukraine	62.570,6 MW	114,3%
South Africa	59.789,9 MW	109,2%
Egypt	57.687,8 MW	105,4%
Taiwan	55.886,9 MW	102,0%
Vietnam	54.752,0 MW	100,0%
Thailand	51.032,9 MW	93,2%
Poland	48.353,1 MW	88,3%
Sweden	43.662,9 MW	79,8%
Argentinia	40.060,4 MW	73,2%
United Arab Emirates	39.688,7 MW	72,5%
Netherlands	38.660,5 MW	70,6%
Malaysia	38.079,7 MW	69,6%
Norway	36.092,3 MW	65,9%
Venezuela	33.854,4 MW	61,8%

Figure 15: List of countries and corresponding installed total capacity [27]

A first selection of the countries is made by defining a maximum and minimum deviation from installed capacity in Vietnam. The range was determined in such a way that the countries with a maximum deviation of 50% above the value of Vietnam and 35% below the value of Vietnam were included in the first group of countries. The selection range is set to reduce the number of countries to a manageable size and to compare them on the basis of FICHTNER´s practical experience based on other benchmarking studies.

Furthermore, Sweden the United Arab Emirates and Indonesia are analysed under Group 2 and Group 3 – Chapter 0 – and therefore they are not considered here. Considering these exclusions, the following countries are preselected (which fall in the conserided range of +50% to -35 % of the installed capacity of Vietnam), which have a total capacity comparable to Vietnam.



CG_1: Installed total capacity		
Country	Installed total capacity	
Australia	76.700,4 MW	140,1%
Ukraine	62.570,6 MW	114,3%
South Africa	59.789,9 MW	109,2%
Egypt	57.687,8 MW	105,4%
Taiwan	55.886,9 MW	102,0%
Vietnam	54.752,0 MW	100,0%
Thailand	51.032,9 MW	93,2%
Poland	48.353,1 MW	88,3%
Argentina	40.060,4 MW	73,2%
Netherlands	38.660,5 MW	70,6%
Malaysia	38.079,7 MW	69,6%
Norway	36.092,3 MW	65,9%

Figure 16: Country-Group1 (Installed total capacity) [27]

Group 2: Most important G20 countries

The second group of selected countries refers to countries which are members of the G20, which is an international forum for the governments and central bank governors from 19 countries and the European Union (EU). The economies of the G20 account for approx. 90% of the gross world product (GWP). Their main focus is the international coordination of economic policy.

The analysis of countries within the G20, therefore, aims at a selection of countries based mainly on economic criteria. This enables a comparion to the worlds strongest economies at present and their measures for grid management. The members as well as their corresponding main economic criteria are summarized in the following table (sorted alphabetically): The economic criteria applied to select the countries within the G20 are:

1. Gross Domestic Product (GDP)

The Gross domestic product is the sum of all goods and services produced within the borders of a country minus the value of the goods and services used up in production. This index is measured in local currency and for comparison purposes generally converted to US dollars using the market exchange rate. This implies that the GDP reported in US dollars is affected by the volatility of the exchange rate. An economy that can be rated as strong in local currency might appear much weaker when presented in US dollars (which is the usual unit for comparisons).

2. GDP - Purchasing Power Parity (PPP)

The GDP expressed in PPP is an alternative measure for the GDP. In this case, instead of converting the GDP from local currency in US dollars at market exchange rates, the conversion is to international dollars – which is a hypothetical currency. One international dollar purchases the same basket of goods and services in a specific country as one US dollar does in the United States. It links the GDP to the real purchasing power in a specific country and is therefore not directly affected by changes in the market exchange rates. PPP rates are commonly much more stable than market exchange rates. From Table 4 it can be seen that the GDP - PPP is much higher than the GDP, with the exception of Australia. Since the USA is the country used as baseline, in its case both GDP are logically the same.

3. GDP per capita - PPP

The GDP gives an absolute number for a country but does not relate this value to the population of that country. The GDP per capita is the specific GDP of a country and can be measured as presented above either at market exchange rates and PPP. In this case, the GDP per capita in PPP is selected for further analysis. In this way two aspects are considered with one criterion: the real purchasing power of the countries - letting aside volatility of market exchange rates - and the specific value of GDP per inhabitant, which allows to compare countries with a similar economy but with different population sizes.

	Country	**Population**	**GDP**	**GDP - PPP**	**GDP per capita (PPP)**
		(millions)	**(Billions US$)**	**(Billions US$)**	**(int. US$)**
1.	Argentina	44.082[1]	637.557	922.572	20.918,10
2.	Australia	24.771	1.379,55	1.248,22	50.390,88
3.	Brazil	207.679[1]	2.055,14	3.247,50	15.637,12
4.	Canada	36.657	1.653,04	1.773,83	48.389,54
5.	China	1.390,08	12.014,61	23.208,22	16.695,60
6.	European Union[2]	-	-	-	-
7.	France	64.801	2.587,68	2.856,48	44.080,66
8.	Germany	82,66	3.700,61	4.199,41	50.803,55
9.	India	1.316,9[1]	2.602,31	9.473,76	7.194,01
10.	Indonesia	261.989	1.015,41	3.249,65	12.403,74
11.	Italy	60.589	1.938,68	2.316,55	38.233,48
12.	Japan	126.746	4.873,20	5.442,76	42.942,23
13.	Korea	51.454	1.540,46	2.034,91	39.548,07
14.	Mexico	123.518	1.151,05	2.462,76	19.938,39
15.	Russia	143.99	1.577,53	4.016,25	27.892,54
16.	Saudi Arabia	32.552	686.738	1.775,14	54.531,96
17.	South Africa	56.522	349.299	767.167	13.572,89
18.	Turkey	80.811	851.521	2.185,86	27.049,04
19.	United Kingdom	66.04	2.628,41	2.925,06	44.292,18
20.	United States	325.886	19.485,40	19.485,40	59.792,01

Table 4: Main economic criteria of the G20 countries - 2017 [28]

[1] For Argentina and Brazil the data are estimated (last available data for 2016), the same as for India (last available data for 2013)

[2] Even if the European Union is considered as one of the members of the G20, the current analysis will consider only single countries within it.

In the further course of the process, the country of China will not be considered as agreed in the kick-off meeting (Minutes 11.1). Furthermore, Germany and Japan are analysed in Group 3 (RE-targets) – Chapter 0 – and therefore not considered here. Also, Australia and Argentina are not considered here, because the countries are already member of the first Country-Group (Figure 16). Considering these exclusions, the following countries are preselected in Country-Group 2 (Figure 17). They all have a particularly strong economy.

CG_2: Most important G20 Countries
United States
India
United Kingdom
France
Italy
Brazil
Canada
South Korea
Russia
Mexico
Indonesia
Saudi Arabia
Turkey

Figure 17: Country-Group 2: Selected G20 countries

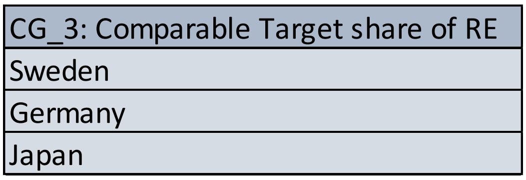
Group 3: Target share of RE

The third group refers to countries, that have already integrated a large number of RE into their energy system and/or have ambitious goals of integrating a large number of RE.

Germany and Sweden are chosen from the European Union. Sweden already has one of the highest proportions of RE in its energy system with a share of over 50%. Germany, on the other hand, has a very comprehensive mix of different RE. There is a high proportion of wind turbines in the north of Germany and a high proportion of PV systems in the south and the further goals for the development of RE are ambitious. Due to this regional distribution of the photovoltaic and wind turbines, there are also congestions on the north–south connection in Germany, a characteristic which is comparable to Vietnam. These congestions must be compensated for by certain GMMs. This will be analysed in more detail in Task 2.

In addition, Japan is added to this group after consultation in the kick-off meeting (Minutes 11.1). Japan is a country that has done a lot in the past for the integration of RE. So, Japan has been able to continuously increase its share of renewables. In addition, measures such as high electricity prices and government subsidies have helped Japan to lead the way in decentralized solar power with over 45 GW to date, and offshore wind is expected to grow exponentially to around 8 GW by 2030 and help displacing conventional base load power [29].

In summary, the third group of countries consists of the following countries:



CG_3: Comparable Target share of RE
Sweden
Germany
Japan

Figure 18: Country-Group 3: Comparable target share of RE

Group 4: Special cases (individual requests)

In the fourth and last group of countries, the countries are selected, differently from the previous sections, without comparison of parameters, but individual reasons.
This group is currently still empty, as all the countries proposed in the kick-off Meeting – Minutes Chapter 11.1 – have already been integrated into other groups. If new countries are to be used for comparison, these can be added to this group by arrangement.

Summary

The preselection of the countries by the country groups ensures that only those countries are included in the comparison with Vietnam, who fit FICHTNER´s overall task: Determination of proven international best practices on grid management with respect to RE development including analysis and compilation of internationally proven regulations (applicable to Vietnam's characteristics), in order to later on recommend further relevant improvements with purpose of reducing RE curtailment.

The first group, installed total capacity, ensures that countries with a similar installed capacity to Vietnam are considered. The second group includes some of the economically strongest countries in the world, which have to cope with a high energy consumption in the industrial sectors. In addition, the third group ensures that countries are taken into account that have already managed or are planning to integrate a large part of RE in their power system. The fourth and last group responds to individual requests. Due to the defined initial structural characteristics the countries can be assigned to several groups, exemplarely Norway regarding installed capacity and target shared of RE. In that case, the most suitable country group is chosen (exemplarely for Norway: Group 1, installed capacity).

6.4.1.3 Master Group

In the second step of the selection process, the individual countries in the preselected, initial structural characteristics based groups are compared to Vietnam in specific structural characteristics. It is important that the preselection of the country groups in Chapter 6.4.1.2 now guarantees a wide, but suitable range of different countries.

Determination of selection criteria

In order to be able to compare the individual countries in the country groups – as analysed in 6.4.1.2 – with Vietnam, a comparison matrix is created. Various specific structural characteristics can be found in the top line of this Comparison Matrix. Specific structural characteristics were used here in order to compare the countries more precisely.

The specific structural characteristics relate to:

- Energy system and its mix (e.g. mix of energy generation, PV growth rate, Figure 23)
- General characteristics of the country (e.g. country size, urbanization, Figure 24)
- Grid specific charactistics (e.g. T&D Losses, Figure 25)

An overview of all the characteristics that are used to compare the countries is given in Figure 20.

Range-based evaluation

A range-based evaluation means that one or more areas of deviation from a given value are defined. If a measurement of a specific structural characteristic of a country falls in a defined area, the country receives the rating specified for this area. In this way, the individual countries can be selected in a comprehensible and structured way. The ranges ensure that countries that have already integrated a large part of RE into their energy systems and countries with structural similarities to Vietnam are highlighted.

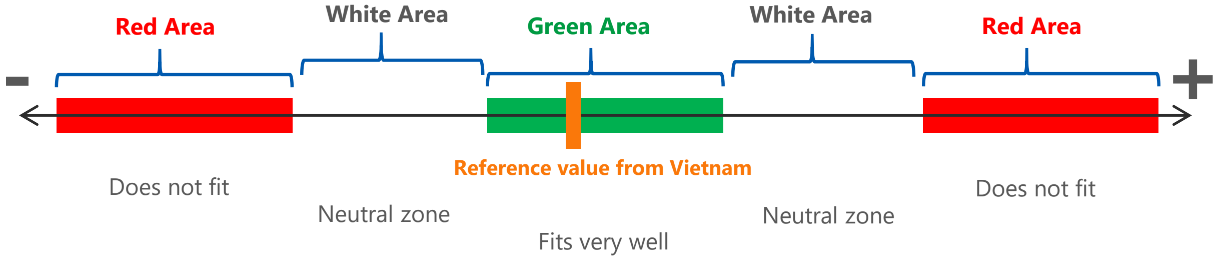


Figure 19: Overview of applied ranges

To first get an overview of the ranges introduced here, Figure 19 is presented. The starting point, or reference value, for each specific structural characteristic is the current value in Vietnam. The introduction of this reference value guarantees at all times that the first target criterion – similarities with Vietnam – is not lost sight of. This facilitates the subsequent adaptation of international best practices to Vietnam.

A green area is then initially defined around this value using our defined target criteria. Because of these target criteria, it often happens that the areas are not symmetrical around the reference value of the structural characteristic in Vietnam. After the green area, there is first a neutral area (white area). If a certain structural characteristic of a country is assessed with the colour white, it neither fits well with our defined target features, nor is it suitable at all. The outermost area is the red area. The red area is defined by a certain minimum and maximum. Above this certain threshold, a country's specific structural feature falls into the red zone. If a country's value in a specific structural characteristic falls into this red range, the country deviates enormously from our defined target characteristics in this structural characteristic and it is unclear whether it should be considered further in the assessment.

Country selection based on reference value in Vietnam						
Specific structural characteristics			Unit	Vietnam	Range (-)	Range(+)
Generating resource mix	Comulative installed total capacity %share	Thermal (Coal, Gas, Oil)	[%]	48.6%	80%	10%
		Hydro	[%]	34.7%	20%	100%
		Solar PV	[%]	14.5%	20%	200%
		Wind	[%]	0.9%	20%	3500%
	PV growth rate (2018-2019)		[%]	5353.7%	50%	50%
General characteristics	GDP growth rate (2019)		[%]	7.0%	30%	30%
	Rate of urbanization (2015-2020)		[%]	3.0%	28%	28%
	Land area		[km²]	310,070	20%	70%
	Population density at hotspots		[people/km²]	4220	30%	90%
	Urban population share (2020)		[%]	37.3%	20%	90%
Grid specific characteristics	Electricity consumption per capita (2019)		[MWh/(capita*a)]	2.1733	70%	70%
	Installed capacity (2019)		[MW]	54752	70%	70%
	T&D losses (2019)		[GWh]	16,088	70%	70%
	(T&D losses)/(Installed generation)		[%]	7.0%	70%	10%

Figure 20: Country selection based on reference value in Vietnam [27] [30]

Figure 20 shows the specific structural characteristics introduced on the left, which will be used to select the pre-selected countries in a second step. The individual specific structural characteristics are divided into clusters.

The first cluster deals with the composition of generation capacity, with particular attention being paid to the share and growth rate of PV and wind.

The second cluster describes the general characteristics of the countries. For example, land area usually plays a large role in a country's grid structure, and population density combined with the urban population share could be a good indicator of the power transmission distance required. The same applies for sparsely populated countries with few densely populated urban areas.

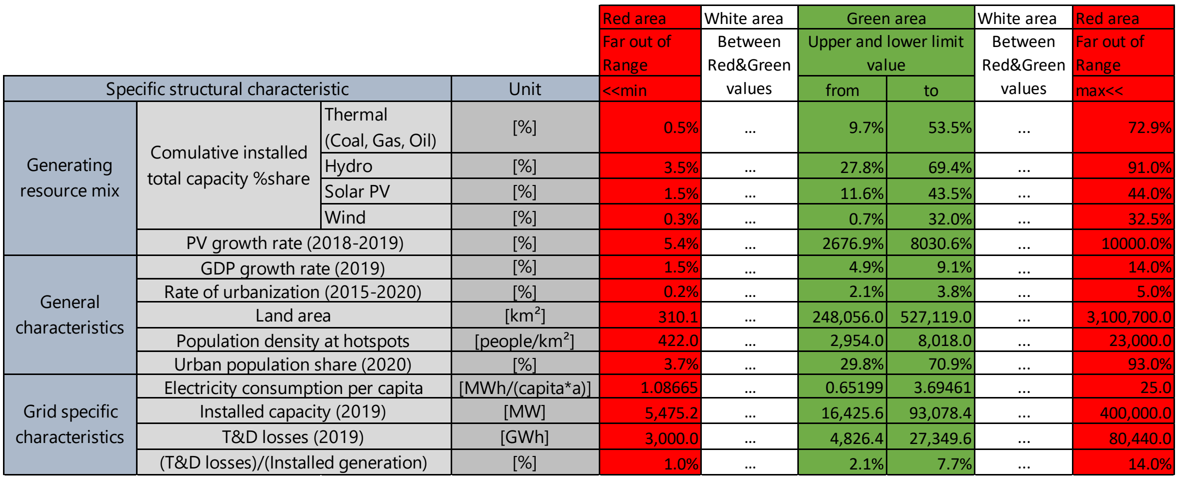
The third cluster then goes into more detail regarding the electrical losses in the countries. The indicator (T&D Losses) / (Installed generation) was introduced, which relates the transmission and distribution losses to the energy generated. This means that the countries can be compared in terms of transmission losses regardless of the amount of energy generated.

On the right side of Figure 20, the green area is defined first. The figure shows a deviation downwards (Range-) and a deviation upwards (Range+). Countries that do not deviate further downwards or upwards from the Vietnamese reference value in the respective specific structural characteristic than the deviation defined here fall into the green area. The green area is considered positive and indicates that the country fits well with the defined target criteria in the specific characteristic.

Vietnam is in a very dynamic environment and is currently in the process of integrating RE into its energy grid. Therefore, the existing share of RE is not yet very remarable (wind 0.9%). However, the country has an enormous PV growth rate, which shows that the country has great ambitions to increase the share of RE (Figure 20).

In order to not only compare countries with similarities to Vietnam in the later assessment, but also pioneers in the field of RE, the green range varies enormously upwards in the proportion of PV and wind. A country that, like Germany, has already integrated more than 22% wind energy into its energy system (Vietnam 0.9%) should not be neglected because of this feature. A high proportion of integrated RE output namely means that the country has GMMs to deal with the fluctuating generation of PV and wind. For this reason, the range for each specific structural characteristic is individually adapted.

In order to emphasize the characteristics of the different countries, which absolutely do not match the defined target characteristics – a lot of experience with the efficient integration of renewable energies and similarities with Vietnam – an additional area is introduced. This additional area is known as the red area and indicates an individual, extended upper and lower limit for each specific structural characteristic – Figure 21.



				Red area	White area	Green area		White area	Red area
				Far out of Range	Between Red&Green values	Upper and lower limit value		Between Red&Green values	Far out of Range
Specific structural characteristic			Unit	<<min		from	to		max<<
Generating resource mix	Comulative installed total capacity %share	Thermal (Coal, Gas, Oil)	[%]	0.5%	...	9.7%	53.5%	...	72.9%
		Hydro	[%]	3.5%	...	27.8%	69.4%	...	91.0%
		Solar PV	[%]	1.5%	...	11.6%	43.5%	...	44.0%
		Wind	[%]	0.3%	...	0.7%	32.0%	...	32.5%
	PV growth rate (2018-2019)		[%]	5.4%	...	2676.9%	8030.6%	...	10000.0%
General characteristics	GDP growth rate (2019)		[%]	1.5%	...	4.9%	9.1%	...	14.0%
	Rate of urbanization (2015-2020)		[%]	0.2%	...	2.1%	3.8%	...	5.0%
	Land area		[km^2]	310.1	...	248,056.0	527,119.0	...	3,100,700.0
	Population density at hotspots		[$people/km^2$]	422.0	...	2,954.0	8,018.0	...	23,000.0
	Urban population share (2020)		[%]	3.7%	...	29.8%	70.9%	...	93.0%
Grid specific characteristics	Electricity consumption per capita		[MWh/(capita*a)]	1.08665	...	0.65199	3.69461	...	25.0
	Installed capacity (2019)		[MW]	5,475.2	...	16,425.6	93,078.4	...	400,000.0
	T&D losses (2019)		[GWh]	3,000.0	...	4,826.4	27,349.6	...	80,440.0
	(T&D losses)/(Installed generation)		[%]	1.0%	...	2.1%	7.7%	...	14.0%

Figure 21: Green, white and red areas of the criteria

The red area is divided into two ranges. The first range is defined below a defined minimum and the second above a defined maximum. Looking more closely at the individual specific characteristics, it becomes clear that the maxima and minima are individually adjusted for each specific structural characteristics.

For the proportion of thermal energy, a very small proportion of 0.5% is chosen as the minimum. This corresponds to a rounded-up deviation of 99,9% from the reference value in Vietnam. The maximum share of thermal energy, on the other hand, is chosen to be 72.9%, which corresponds to a 50% deviation from the reference value in Vietnam. Values that are less than 0.5% or greater than 72.9% are marked in red in the Comparison Matrix and fall into the red area. The Comparison Matrix is intended to identify countries that have a lot of experience with integrating a large share of renewable energy into their energy system. A large share of thermal energy is not interesting, which is why deviations of up to 99,9% downwards and only 50% upwards are possible without receiving a red rating.

Vietnam is characterised by a high share of hydropower generation, especially in the north of the country. In dry periods, however, there is often a reduced feed-in from this energy source. In order to take these seasonal fluctuations in energy production into account in the selection process for the countries, the maximum is set at 92%. A large share of hydropower does not mean that the country does not fit our defined target criteria in this specific structural characteristic. It rather means that it has great experience in integrating hydropower intelligently and efficiently into its energy system. The maximum is therefore chosen so that none of the pre-selected countries with a higher share of hydropower than Vietnam would be eliminated in the characteristic. The minimum, on the other hand, is chosen with a deviation of 90% from the Vietnamese value. Since Vietnam already has a high share of hydro with 34.7%, this downward deviation ensures that countries with a very low share of hydro are excluded.

Vietnam is very ambitious in the area of solar PV generation. It already accounts for 14.5% of the total generation mix. Here, too, the interest is in finding countries with a high share of PV, as these countries have to deal with the fluctuations in generation and the dependence on supply – no storage of primary energy is possible. Therefore, the maximum is chosen so that no preselected country with a high share of PV solar is left out. The minimum, on the other hand, is also chosen with a deviation of 90% from the Vietnamese reference value and is 1.5%.

Wind energy is a resource that is currently not very developed in Vietnam. However, there are many incentive mechanisms – as explained in chapter 6.2.2.1– that promote the generation of electricity from wind power plants. Vietnam also has great potential for this technology due to its long coastal regions with fast wind speeds. For this reason, the maximum for wind energy is also chosen so that none of the pre-selected countries, which already have a larger share of wind energy than Vietnam, falls into the red area. The minimum, on the other hand, is chosen at 0.3%, which is 67% of the Vietnamese value. The values are chosen because an increase in the share of wind energy can be expected in the future.

Vietnam's PV growth rate in 2019 makes the country a very special case. No other country even comes close to this enormous rate of 5353.7%. Therefore, the minimum is chosen with a deviation of 99% to really exclude only countries that are currently not showing dynamic development in their PV solar sector. The maximum is chosen at 10000% so that no country falls outside this upper limit.

In the comparison based on the general characteristics, the areas are chosen to highlight countries with similarities to the current dynamic environment in Vietnam. Furthermore, the areas of the characteristics that indicate a greater challenge for grid management are customised. Furthermore, given Vietnam's uniqueness in the general structural characteristics, the red area are customised in the different characteristics.

For the GDP growth rate, a minimum of 1.5% is chosen, which is already a high growth rate for industrialised countries. The maximum, on the other hand, is defined as a deviation of 100% from the Vietnamese value of 14%, which is not reached by any country in the reference year 2019.

The minimum rate of urbanisation (2015-2020) is defined as 0.2%, which corresponds to a deviation of 93% from the Vietnamese value. This value is chosen to exclude countries that are in a stagnant environment or on the way to counter-urbanisation. In contrast, the maximum is again chosen so that no country with a higher urbanisation rate than Vietnam is excluded.

For the land area, the minimum is chosen with a deviation of 99.9% to 310.1 km^2. Since Vietnam is not very large in terms of land area, but has an enormously narrow and elongated shape, the country also has long and wide power transmission lines. It is therefore important to define the maximum for consideration at a deviation significantly higher than 100%, so that countries with similarly long electricity transmission routes can be taken into account. The maximum set here is therefore defined at a deviation of 900% to 3,100,700 km^2.

The minimum for population density in hotspot regions is defined at a deviation of 90% from the reference value of 4,220 [people/km^2] in Vietnam. The maximum is also set in such a way that none of the pre-sorted countries with a higher population density in the hotspot regions is excluded. This was decided because Vietnam's major load and industrial centres consist of a region in the north (Hanoi) and a region in the south (Ho

Chi Minh City). The trend in Vietnam is towards greater population density in these areas – see urbanisation. Countries that already have hotspot regions with high population density may therefore have best practices applicable to Vietnam to meet the highly centred demand. The selection of the red area for the share of urban population is based on the same consideration.

In the following, the two load variables of the energy grid – consumption on the one hand and generation on the other – are integrated into our range-based comparison under the cluster grid specific characteristics.

The first parameter used here is the electrical consumption per capita. Enormous economic growth, such as that experienced by Vietnam, is usually associated with an increase in per capita energy consumption. In today's world, the most convenient form of energy is electricity, which is increasingly needed in both the private sector due to advancing digitalisation and in the industrial sector. As a result, the electrical supply system of emerging countries is increasingly burdened. Based on these assumptions, and taking into account Vietnam's stagnant economic growth, the red area for per capita electrical consumption is decided. The maximum on one side is chosen with a deviation from the Vietnamese reference value of 1050% so that no country with a much higher consumption per capita than Vietnam is excluded. This high maximum is chosen because a further increase in per capita consumption in Vietnam is to be expected, which will have a major impact on electricity demand. The minimum for the red area is chosen at a deviation of 50% from the Vietnamese reference value in order to exclude countries with a low level of electrification.

The installed capacity characteristic gives a good indicator of the size of the energy system. In order to exclude countries with a very different size of their energy system from that of Vietnam, the minimum of the red area is set at a deviation of 90% from the reference value in Vietnam and the maximum at a deviation of 630% from the reference value in Vietnam. The strong difference between the deviation of the minimum and the maximum from the reference value is due to the fact that the energy sector in Vietnam is currently undergoing strong growth, in which many MW of power will be connected to the Vietnamese grid in a few years. In order not to exclude industrialised countries with a significantly larger energy system, the deviation upwards is defined as significantly larger.

The T&D losses characteristic provides an indicator of the level of transmission and distribution grid losses. The maximum is defined as a deviation of 400%. Since only the level of losses in [GWh] is considered here. The minimum is chosen at a deviation of 81% so that no country with a comparable size of energy sector – installed capacity – and less T&D losses is excluded.

In the last specific structural characteristic, the ratio of T&D losses to installed generation is considered. This characteristic is more meaningful with regard to the efficiency of the grids than the consideration of pure T&D losses. The focus is on selecting countries with a low (T&D losses)/(installed generation) ratio. For this purpose, the minimum is set so low that none of the pre-selected countries with a ratio lower than Vietnam are excluded. The maximum, however, is set much lower than the pure T&D losses maximum, with a deviation of only 100%, in order to identify countries with highly lossy transmission lines and to mark them accordingly in the Comparison Matrix.

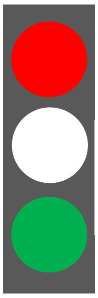
Between the green area, which highlights the characteristic values that best fit the defined target criteria, and the red area, which marks those characteristic values that do not fit the defined target criteria at all, there is another area, the white area. This white area is to be regarded as neutral, as it marks the characteristic values that neither fit well nor do not fit at all to the defined target criteria.

In summary, there are three areas or ratings:

- *Green area*
  Countries that received a green rating for one of the criteria are very well suited for our further analysis
- White area
  The white area is to be viewed neutrally. The country is not in the respective range of the characteristic, it is also not very far from it
- Red area
  Countries with a red rating of specific structural characteristics do not match the defined target characteristics in this criterion

The Comparison Matrix

In the Comparison Matrix, the countries are compared based on statistical evaluations, international statistics and databases [27]. The Matrix is divided into the different groups of specific structural characteristics – as explained in chapter 0. The evaluation for each individual characteristic is made on the basis of the range explained in Chapter 0 which is applied via a traffic light system (Figure 22).



= Red area: differs greatly from the defined target characteristics

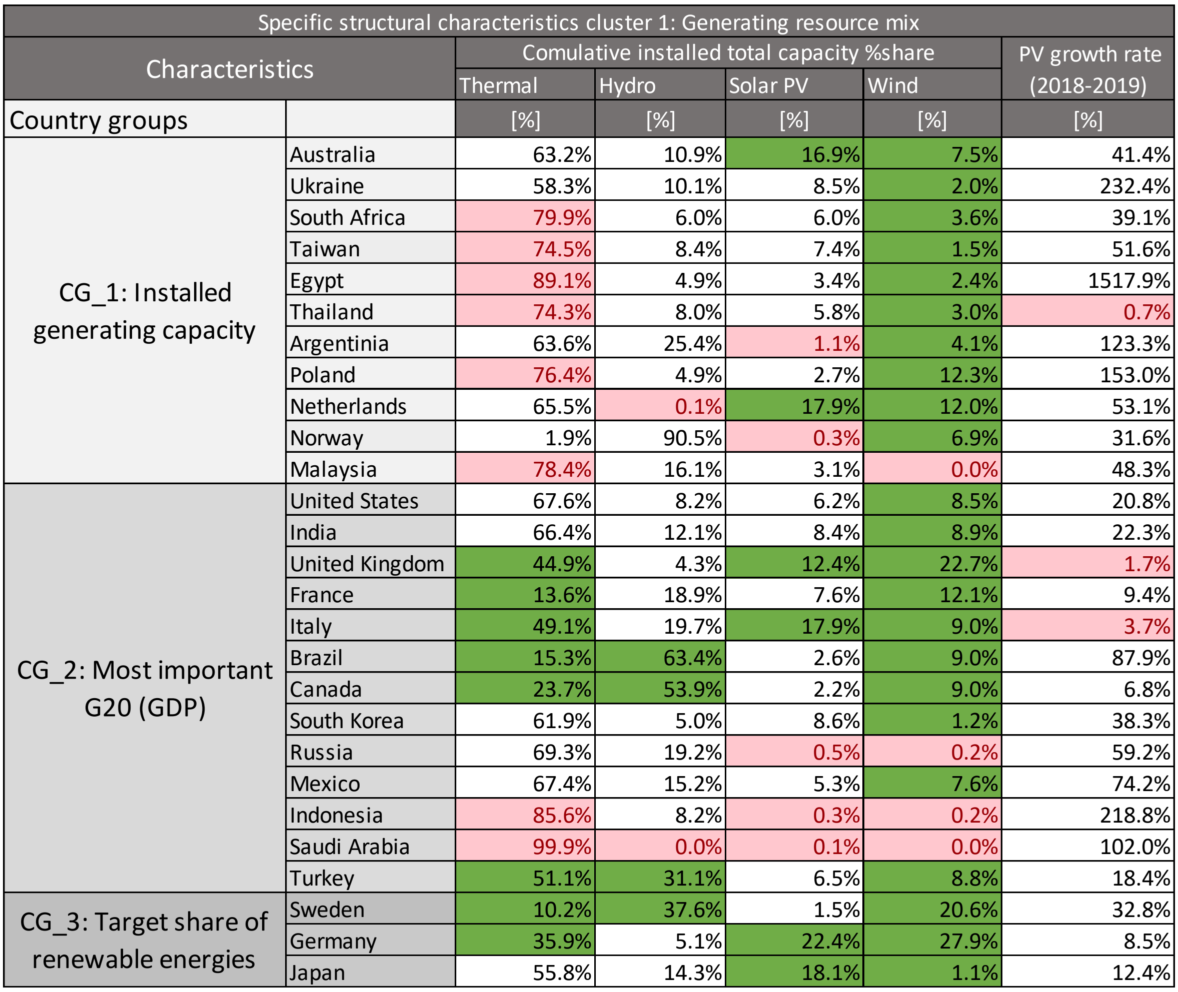
= White area: neutral zone (slightly deviates from the green range)

= Green area: fits well with the defined target characteristics

Figure 22: Traffic light system to clarify the different areas

Based on the results of the Comparison Matrix, the next step is to select countries that have performed well in most of the criteria (color green or white). These countries are then put into the Master Group and are examined in more detail for the GMM groups used in speficic country.

Specific structural characteristics cluster 1: Generating resource mix



Specific structural characteristics cluster 1: Generating resource mix						
Characteristics		Comulative installed total capacity %share				PV growth rate (2018-2019)
		Thermal	Hydro	Solar PV	Wind	
Country groups		[%]	[%]	[%]	[%]	[%]
CG_1: Installed generating capacity	Australia	63.2%	10.9%	16.9%	7.5%	41.4%
	Ukraine	58.3%	10.1%	8.5%	2.0%	232.4%
	South Africa	79.9%	6.0%	6.0%	3.6%	39.1%
	Taiwan	74.5%	8.4%	7.4%	1.5%	51.6%
	Egypt	89.1%	4.9%	3.4%	2.4%	1517.9%
	Thailand	74.3%	8.0%	5.8%	3.0%	0.7%
	Argentinia	63.6%	25.4%	1.1%	4.1%	123.3%
	Poland	76.4%	4.9%	2.7%	12.3%	153.0%
	Netherlands	65.5%	0.1%	17.9%	12.0%	53.1%
	Norway	1.9%	90.5%	0.3%	6.9%	31.6%
	Malaysia	78.4%	16.1%	3.1%	0.0%	48.3%
CG_2: Most important G20 (GDP)	United States	67.6%	8.2%	6.2%	8.5%	20.8%
	India	66.4%	12.1%	8.4%	8.9%	22.3%
	United Kingdom	44.9%	4.3%	12.4%	22.7%	1.7%
	France	13.6%	18.9%	7.6%	12.1%	9.4%
	Italy	49.1%	19.7%	17.9%	9.0%	3.7%
	Brazil	15.3%	63.4%	2.6%	9.0%	87.9%
	Canada	23.7%	53.9%	2.2%	9.0%	6.8%
	South Korea	61.9%	5.0%	8.6%	1.2%	38.3%
	Russia	69.3%	19.2%	0.5%	0.2%	59.2%
	Mexico	67.4%	15.2%	5.3%	7.6%	74.2%
	Indonesia	85.6%	8.2%	0.3%	0.2%	218.8%
	Saudi Arabia	99.9%	0.0%	0.1%	0.0%	102.0%
	Turkey	51.1%	31.1%	6.5%	8.8%	18.4%
CG_3: Target share of renewable energies	Sweden	10.2%	37.6%	1.5%	20.6%	32.8%
	Germany	35.9%	5.1%	22.4%	27.9%	8.5%
	Japan	55.8%	14.3%	18.1%	1.1%	12.4%

Figure 23: Specific structural characteristics cluster 1: Generating resource mix [27]

The first comparison of the countries on the basis of the generating resource mix shows that the countries South Africa, Taiwan, Egypt, Thailand, Poland, Malaysia, Indonesia and Saudi Arabia received a red rating due to a very high proportion of thermal electricity generation. Furthermore, it is noticeable that the countries Indonesia, Saudi Arabia and Russia have only integrated a very small proportion of PV and wind energy into their energy system. However, in the countries Ukraine, United Kingdom, Italy, Germany and Japan, are many green ratings. These countries are characterized above all by a solid proportion of PV and wind energy. It is also noticeable that Brazil, Canada, Turkey and Sweden have a similarly high proportion of hydropower generating as Vietnam. An absolute special case in this area is Norway with over 90% hydroelectric power generating.

In summary, the countries Indonesia and Saudi Arabia are rated low in this first comparison with regard to the generating resource composition, so they not further considered. The two countries Germany and Japan, on the other hand, are good examples.

Specific structural characteristics cluster 2: General characteristics

Specific structural characteristics cluster 2: General characteristics						
Characteristics		GDP growth rate (2019)	Rate of urbanization (2015-2020)	Land area	Population density at hotspots	Urban population share (2020)
Country groups		[%]	[%]	[km^2]	[people/km^2]	[%]
CG_1: Installed generating capacity	Australia	1.8%	1.4%	7,692,000	588	86.2%
	Ukraine	3.2%	-0.3%	603,628	138	69.6%
	South Africa	0.2%	2.0%	1,220,000	3,494	67.4%
	Taiwan	2.7%	0.8%	36,193	9,785	78.9%
	Egypt	5.6%	1.9%	1,010,000	22,148	42.8%
	Thailand	2.4%	1.7%	513,120	1,410	51.4%
	Argentinia	-2.2%	1.1%	2,780,000	3,611	92.1%
	Poland	4.1%	-0.3%	312,679	506	60.0%
	Netherlands	1.8%	0.7%	41,543	1,096	92.2%
	Norway	1.2%	1.4%	385,207	261	83.0%
	Malaysia	4.3%	2.1%	329,847	3,000	77.2%
CG_2: Most important G20 (GDP)	United States	2.3%	1.0%	9,834,000	1,063	82.7%
	India	4.2%	2.4%	3,287,000	18,519	34.9%
	United Kingdom	1.4%	0.9%	242,495	4,274	83.9%
	France	1.2%	0.7%	643,801	1,024	81.0%
	Italy	0.3%	0.3%	301,338	2,635	71.0%
	Brazil	1.2%	1.1%	8,516,000	2,311	87.1%
	Canada	1.6%	1.0%	9,985,000	1,036	81.6%
	South Korea	2.0%	0.3%	100,210	15,865	81.4%
	Russia	1.3%	0.2%	17,100,000	3,263	74.8%
	Mexico	-0.2%	1.6%	1,973,000	4,287	80.7%
	Turkey	0.9%	2.0%	783,562	2,917	76.1%
CG_3: Target share of renewable energies	Sweden	1.2%	1.1%	450,295	359	88.0%
	Germany	0.6%	0.3%	357,386	1,324	77.5%
	Japan	0.7%	-0.1%	377,915	7,134	91.8%

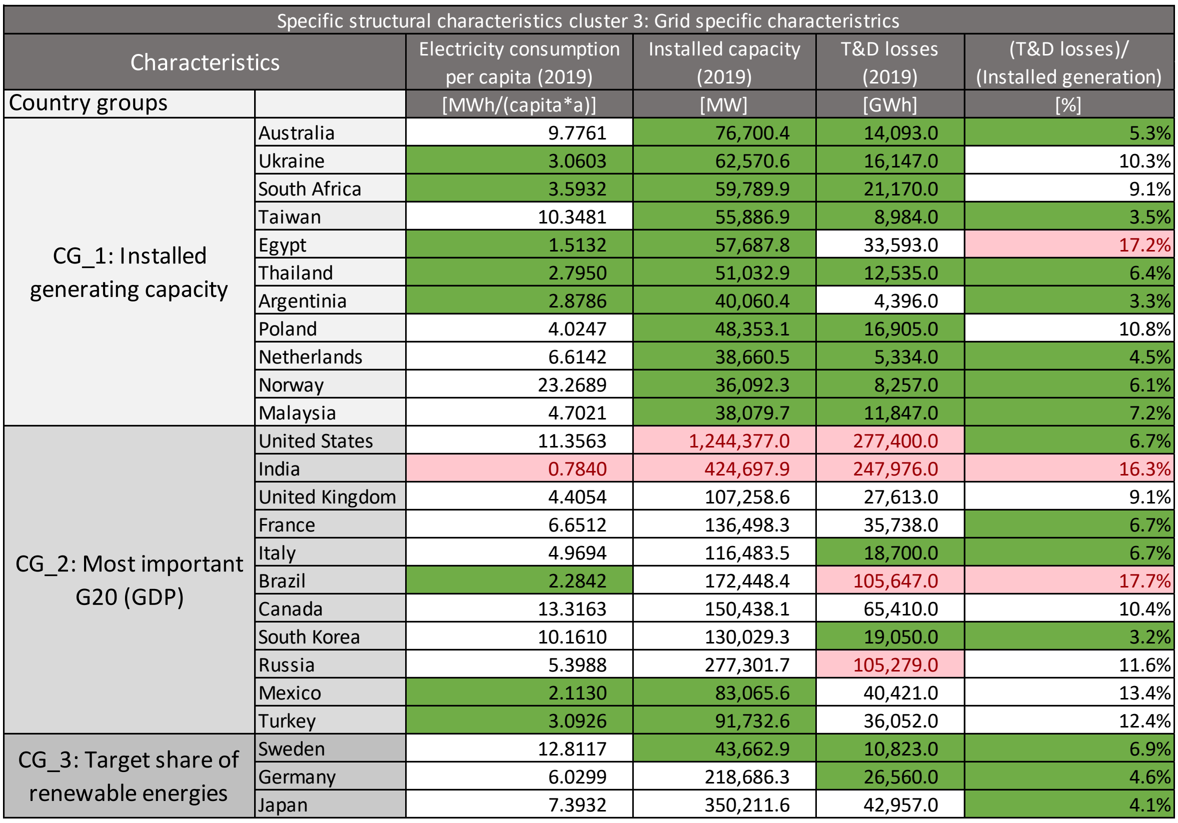
Figure 24: Specific structural characteristics cluster 2: General characteristics [27] [31] [32]

When comparing the general characteristics of the countries with Vietnam, it is noticeable that there is very little match with the other countries in the areas of GDP growth rate and urbanization rate. Here, the countries that were rated good in the first comparison cannot be compared with the extreme economic growth of Vietnam.

There are only a few countries that did not fall into the red zone in at least one criterion in this comparison. Although they do not reflect the exact conditions in Vietnam, they come closest to them overall. The countries are: Taiwan, Egypt, Thailand, Netherlands, Malaysia and South Korea. It should also be emphasized that the USA also matches in this comparison. The USA is a very large country, which is why it fell out of the range of the land area, but it also has many different states with very different weather conditions and RE-Projects.

Russia, as in shown in Figure 23, does not match the general characteristics in Vietnam. In summary, Russia has a small share of RE and cannot be compared well with Vietnam in terms of general characteristics. With regard to the search for internationally proven solutions for grid management that are suitable for Vietnam, the country of Russia cannot be considered any further.

Specific structural characteristica cluster 3: Grid specific characteristics



Specific structural characteristics cluster 3: Grid specific characteristics					
Characteristics		Electricity consumption per capita (2019)	Installed capacity (2019)	T&D losses (2019)	(T&D losses)/ (Installed generation)
Country groups		[MWh/(capita*a)]	[MW]	[GWh]	[%]
CG_1: Installed generating capacity	Australia	9.7761	76,700.4	14,093.0	5.3%
	Ukraine	3.0603	62,570.6	16,147.0	10.3%
	South Africa	3.5932	59,789.9	21,170.0	9.1%
	Taiwan	10.3481	55,886.9	8,984.0	3.5%
	Egypt	1.5132	57,687.8	33,593.0	17.2%
	Thailand	2.7950	51,032.9	12,535.0	6.4%
	Argentinia	2.8786	40,060.4	4,396.0	3.3%
	Poland	4.0247	48,353.1	16,905.0	10.8%
	Netherlands	6.6142	38,660.5	5,334.0	4.5%
	Norway	23.2689	36,092.3	8,257.0	6.1%
	Malaysia	4.7021	38,079.7	11,847.0	7.2%
CG_2: Most important G20 (GDP)	United States	11.3563	1,244,377.0	277,400.0	6.7%
	India	0.7840	424,697.9	247,976.0	16.3%
	United Kingdom	4.4054	107,258.6	27,613.0	9.1%
	France	6.6512	136,498.3	35,738.0	6.7%
	Italy	4.9694	116,483.5	18,700.0	6.7%
	Brazil	2.2842	172,448.4	105,647.0	17.7%
	Canada	13.3163	150,438.1	65,410.0	10.4%
	South Korea	10.1610	130,029.3	19,050.0	3.2%
	Russia	5.3988	277,301.7	105,279.0	11.6%
	Mexico	2.1130	83,065.6	40,421.0	13.4%
	Turkey	3.0926	91,732.6	36,052.0	12.4%
CG_3: Target share of renewable energies	Sweden	12.8117	43,662.9	10,823.0	6.9%
	Germany	6.0299	218,686.3	26,560.0	4.6%
	Japan	7.3932	350,211.6	42,957.0	4.1%

Figure 25: Specific structural characteristica cluster 3: Grid specific characteristics: [27]

In the third and last part of the Comparison Matrix, it is evident that the first group of countries fits well in the installed power category. In the (T&D Losses) / (Installed generation) criterion, Taiwan, Argentina, the Netherlands, South Korea, Germany and Japan in particular do well. India scores strikingly poorly on most of the criteria in this group of criteria.

Building the Master Group

The selection of the countries in the Master Group now takes place on the basis of the three tables with the different groups of specific structural characteristics (cluster). The aim of this comparison was to identify those countries that are similar to Vietnam and, ideally, have a lot of experience with solutions for grid management in order to reduce the RE curtailments.

In the the first cluster (Figure 23) therefore was investigated the composition of energy generation. The special focus was on the share of RE and the PV growth rate. Ukraine, United Kingdom, Italy, Germany and Japan came out on top.

The second cluster (Figure 24) went into more detail regarding the general characteristics of Vietnam and compared them with other countries. The key finding from this figure is that Vietnam is currently in a very dynamic and very special environment, which cannot be easily compared with other countries. Nevertheless, Taiwan, Egypt, Thailand, Netherlands, Malaysia and South Korea proved to be a good compromise to the special conditions in Vietnam. In addition, the USA was discovered here as a particularly interesting and very helpful country in terms of grid management.

The third and final cluster (Figure 25) investigated the specific network-related characteristics of the individual countries. Taiwan, South Korea, Germany and Japan again performed well.

In summary, the following countries are included in the Master Group:

- *Germany and Japan*
  The two countries performed well in most of the specific structural characteristic clusters and have a large proportion of RE

- *Taiwan and South Korea*
  These two countries are very similar to Vietnam in general characteristics In addition, they have a low (T&D Losses) / (Installed generation) ratio

- *USA and Norway*
  These two countries are special cases. USA is chosen on the basis of its innovative projects in the most varied of regions of the country (different weather conditions), as well as its economic strength and population density in hotspot regions. Norway most important for comparsion regarding its high propoartion of hydropowerplant in their generation mix

Master Group
Germany
Taiwan
Norway
United States
South Korea
Japan

Figure 26: Master Group

The countries of the Master Group, which were selected very structured and comprehensible at the very top level, are now analyzed for possible solution groups for grid management, which is described in the next chapter.

6.4.2 *Assessment-Matrix-Part-1: Regulatory Framework*

A first possibility to relieve the operational grid management of the transmission system operators is through regulatory framework conditions. Regulatory frameworks include the planning of suitable feed-in tariffs, which can be adjusted both constantly as a fixed cascade and variably with respect to the current load of the grid, or the restructuring of the market, in which the transmission capacities of the grid can be included in trading on the market through bidding zones or nodal pricing. This conditions can be used to bypass or compensate for congestion at the transmission grid level as well as at the distribution grid level.

Measure		Regulatory framework			
		Feed-in tariff		Structuring of market zones	
		Constant	Load depending	Bidding zone	Nodal Pricing
Vietnam		🟩	🟥	🟥	🟥
Master Group	Germany	🟩	🟥	▨	🟥
	Taiwan	🟩	🟥	🟥	🟥
	Norway	🟥	🟥	🟩	🟥
	United States	🟥	🟩	🟥	🟩
	South Korea	🟥	🟥	🟥	🟥
	Japan	🟩	🟥	🟥	🟥
		🟩 Implemented	▨ Crossborder trade	🟨 Under investigation	🟥 No further action planed

Table 5: Assessment-Matrix-Part-1: Regulatory framework [15] [33] [34] [35] [36] [37] [38] [39] [40] [41]

Table 5 shows that there is currently no load depending feed-in tariff approach in Vietnam. There is a fixed feed-in tariff for solar PV and a fixed tariff for wind. In America the state of California has already resorted to varying the feed-in tariff over time. There the feed-in tariff is adjusted according to the load on the grid. This gives investors an incentive to invest in storage options to receive a higher feed-in tariff and relieves the congestion caused by extreme solar PV generation during midday.

The effects of market structuring were discussed in detail in chapter 6.3. Table 5 shows that only Norway has a domestic bidding zone division. In the European interconnected grid, there is also a bidding zone division in which the national borders of Germany represent a bidding zone section. However, there is no domestic bidding zone division in Germany itself. In Vietnam, there is currently no subdivision into smaller bidding zones either. Nodal pricing is currently only used as a measure in the United States.

6.4.3 *Assessment-Matrix-Part-2: Digitalisation / Automation*

Another possibility to relieve the operational grid management through planning measures is the upgrading of the digital infrastructure. Two indicators were used to assess the current status of the countries' digital infrastructure, as well as projects dealing with the digitalisation or automation of substations.

Measure		Digitalisation / Automation				
		Broadband penetration rate (2020)	Automation Readiness Index (2017)	Distribution Substations		Transmission Substations
				Low -/Middle voltage (< 110kV)	High voltage (110kV)	Extra high voltage (>110kV)
Vietnam		15.93%	38.4	🟨	🟩 ca. 60%	🟩
Master Group	Germany	42.05%	89.6	🟩	🟩	🟩
	Taiwan	24.39%	No data available	🟨	🟩	🟩
	Norway	42.65%	No data available	🟩	🟩	🟩
	United States	36.71%	72.8	🟩	🟩	🟩
	South Korea	42.80%	91.3	No data available	🟩	🟩
	Japan	33.81%	83.7	🟨	🟨	🟩
			0 - 100	🟩 Implemented	🟨 Under investigation	🟥 No further action planed

Table 6: Assessment-Matrix-Part-2: Digitalisation / Automation [42] [43] [44] [45] [46] [47] [48] [49]

Table 6 shows that Vietnam has connected its substations and power stations to the SCADA system on the high and extra high voltage levels. In order to be able to use flexibilities and to benefit from demand site management as well as from Redispatch 2.0, however, it is above all a matter of digitising the distribution grid level. Table 6 shows the broadband expansion in Vietnam does not seem to be sufficiently advanced for these measures compared to the other countries from the Master Group.

Another indicator is the Automation Readiness Index (ARI), which is also introduced here. The ARI measures countries preparedness for the coming wave of automation and artificial intelligence. The index provides a snapshot of current government-led efforts to anticipate the resulting changes and to shape the outcomes of technological progress across a set of 25 countries. The ARI-benchmarking model contains the results of the research based on 52 indicators (both qualitative and quantitative) which were determined through consultation with a panel of experts. The majority of the indicators have been scored by the Economist Intelligence Unit and are based on examination of publicly available sources and expert interviews [44].

According to the index, Vietnam is classified as “Emerging”. Vietnam still has a lot of potential to advance its digitalisation and automation, which is not just limited to the energy sector. By using this potential, fast and inexpensive GMM can be integrated into the energy system and new innovations can be created.
Vietnam is currently working on digitising its energy system, as can be seen from the fact that a new SCADA system was introduced in 2013, which is connected to all power plants (above 30 MW) and substations (from 110 kV and above) [43]. In addition, the application of all EMS functions was mastered in 2016 and the introduction of SCADA / DMS for all provincial power companies was set as the goal for 2022 [43].
As shown in Table 6, Vietnam still has potential to expand the digitalisation of the energy system at the distribution grid level. The promotion of generation plants based on solar PV and wind will lead to electricity in Vietnam being increasingly generated off-load in the next few years. Above all, the progressive expansion of rooftop solar plants will lead to an increased feed-in of electricity at the distribution grid level, for which the transformers and lines are not designed.

6.4.4 Assessment-Matrix-Part-3: Grid Expansion

In section three of the Assessment Matrix, grid expansion measures to eliminate congestion are considered.

Measure		Grid expansion (Growth rate 2012-19)				
		Distribution substations	Distribution lines	Distribution capacity	Transmission lines	Transmission capacity
Vietnam		80.7%	33.6%	86.8%	76.6%	190.0%
Master Group	Germany	4.0%	1.8%	No data available	3.7%	13.6%
	Taiwan	4.4%	9.9%	8.7%	6.6%	6.8%
	Norway	No data available	1.3%	9.2%	20.1%	11.8%
	United States	13.9%	13.9%	14.0%	5.9%	20.2%
	South Korea	No data available	13.4%	20.2%	9.3%	22.2%
	Japan	2.1%	1.8%	11.5%	1.3%	4.4%
		🟩 100-70%	🟨 70-30%	🟥 30-0%		

Table 7: Assessment-Matrix-Part-3: Grid expansion [50]

This part of the Assessment Matrix shows that Vietnam has already made an expansion of the energy system in the last few years compared to the selected countries from the Master Group. In the period from 2012–2019, the existing distribution capacity was expanded by 86.8 % and the transmission capacity by 190 % [50]. Compared to the other countries, the grid expansion of Vietnam´s power grid is very high within the last years. However, this can also be attributed to the economic growth and the strong increase in energy demand. Nevertheless, Table 7 shows that Vietnam is committed to grid expansion.

It can be said that insufficient grid expansion can cause congestion at both the transmission and distribution grid levels. For some time now, Vietnam has been in an environment in which the electrical load is increasing due to economic growth as well as electrical generation. As a consequence, the grid has already been expanded in recent years. In order to be able to operate the existing grid capacities efficiently, the focus in the further course of this work will be placed on the other GMMs.

6.4.5 Assessment-Matrix-Part-4: Grid-Related Measures

The fourth part of the Assessment Matrix asses the grid-related measures. They include HVDC technology, on-load tap-changers (OLTC), phase-shifting transformers (PST), topological modifications and the dynamic thermal line rating (DTLR). These grid-related measures allow the load flow in the grid to be influenced in order to relieve overloaded lines or transformers (see chapter 6.3). In order to apply these measures, however, the infrastructure mentioned above must be available. The following table shows which of the countries already use these grid-related measures.

Measure		Grid-related measures					
		HVDC	On-load tap-changers (OLTC)		Phase-shifting transformers (PST)	Topological Modification	DTLR
			Transmission	Distribution level			
Vietnam		🟨	🟩	🟥	🟥	🟩	🟥
Master Group	Germany	🟩	🟩	🟩	🟩	🟩	🟩
	Taiwan	No data available	🟩	🟩	No data available	🟩	No data available
	Norway	🟩	🟩	🟩	No data available	🟩	No data available
	United States	🟩	🟩	🟩	🟩	🟩	🟥
	South Korea	🟨	🟩	🟩	No data available	🟩	No data available
	Japan	🟩	🟩	🟩	🟩	🟩	No data available
	Legend:	🟩 Implemented	🟨 Under investigation	🟥 No further action planed			

Table 8: Assessment-Matrix-Part-4: Grid-related measures [51] [52] [53] [54] [55] [37] [56] [57] [58] [59]

What can be seen from Table 8 is that HVDC technology is already being discussed as a possible solution for grid management in Vietnam [51]. Table 8 shows that the OLTC transformers at transmission grid level and the possibility to change the grid topology are implemented in all countries. In Vietnam, however, there is still potential in the expansion of OLTC transformers at the distribution level, as the final report "Technology Assessment of Smart Grids for Renewable Energy and Energy Efficiency" shows [56]. In Chapter 6.2.2.1, it was analysed that there will be an expansion of rooftop solar installations in Vietnam in the future.

Similar to HVDC converters, phase-shifting transformers (PST) offer the possibility of power flow adjustment. Table 8 shows that power flow adjustment by PSTs is not yet available for the TSO in Vietnam but already offers a grid-serving advantage through power flow adjustments in Germany, the United States and Japan.

As already mentioned in chapter 6.3.2.1, the DTLR offers the possibility to temporarily increase the transmission capacities of the currently existing transmission grid under certain conditions. According to our research, Germany has experience in this area. In order to better understand the potential and possible applicability in Vietnam, an example project from Germany is presented in chapter 7.1. At present, this measure is not applied in Vietnam.

6.4.6 Assessment-Matrix-Part-5: Market-Related Measures

As presented in chapter 6.3, market-related GMMs include energy storage options (in Germany), redispatch measures, VPP, DSM and countertrading.
In addition, there are market restrictions imposed by the government. These market restrictions mostly attempt to reduce the need for downstream grid management by the transmission system operator. Examples of such restrictions have been addressed in the first assessment matrix for the regulatory framework.

Measure		Market-related measures part 1					
		Energy storage options			Redispatch		
		Pumped storage	Battery	Heat	Redispatch	Redispatch 2.0	Cross-border redispatch
Vietnam		🟨	🟨	🟥	🟩	🟥	🟥
Master Group	Germany	🟩	🟩	🟩	🟩	🟨	🟩
	Taiwan	🟩	🟩	🟩	🟩	🟥	🟥
	Norway	🟩	🟩	🟥	🟩	🟥	🟩
	United States	🟩	🟩	🟩	🟩	🟥	🟩
	South Korea	🟩	🟩	🟥	🟩	🟥	🟥
	Japan	🟩	🟩	🟥	🟩	🟥	🟥
	Legend:	🟩 Implemented	🟨 Under investigation		🟥 No further action planed		

Table 9: Assessment-Matrix-Part-5: Market-related measures part 1 [42] [50] [60] [15] [42] [61] [62] [63] [64] [37]

In the first part of the market-based GMMs, the battery storage options of the countries were compared. It is striking that currently no active energy storage systems are used for energy supply in Vietnam. In relation to the other countries, this is to be assessed as a gap, since the selected countries of the Master Group all fall back on storage options. Especially in the area of increasing the feed-in of VRE, the availability of storage options is extremely important, as it can compensate for fluctuations in generation and ensure flexibility.
Another possibility is to link the storage systems directly on site with the PV or wind power plants so that a virtually constant energy is passed on to the grid. On the other hand, they can also be used to regulate the power frequency [65].
Redispatch refers to interventions in the generation output of power plants in order to protect line sections from overload (see chapter 6.3). It is to be distinguished from the simple reduction of the feed-in of RE, which is known in Germany as "feed-in management" (Einspeisemanagement). Table 9 shows that the classic principle of redispatch is applied in almost all countries. Cross-border redispatch was introduced here as a further indicator. Through international grid connections, congestion between neighbouring countries can be balanced out in this way. For example, through

expanded cooperation between Laos and Vietnam or Cambodia and Vietnam, congestion could be prevented by cross-border redispatch on Vietnam's north-south connection by Laos or Cambodia counteracting the resulting congestion through feed-in. In this process, the technical boundary conditions of the connecting lines must first be checked and incorporated into the solution. However, as Table 9 shows, cross-border redispatch is not yet applied in Vietnam and has not yet been considered.

Measure		Market-related measures part 2		
		VPP (Virtual Power Plants)	Demand side management	Countertrading
Vietnam		🟥	🟨	🟥
Master Group	Germany	🟩	🟩	▨
	Taiwan	🟩	🟩	🟥
	Norway	🟩	🟩	🟩
	United States	🟩	🟩	🟥
	South Korea	🟩	🟩	🟥
	Japan	🟩	🟩	🟥

🟩 Implemented
🟨 Under investigation
🟥 No further action planed
▨ Crossborder trade

Table 10: Assessment-Matrix-Part-5: Market-related measures part 2 [37] [66] [67] [68] [69] [70] [71] [72] [73] [74] [61]

Redispatch 2.0 is to be introduced in Germany on 1 October 2021 as a supplement to redispatch. The difference to the previous redispatch is that RESs up to 100kV are now also included in the redispatch planning. Table 10 shows currently only Germany is pursuing such a goal at the national level.

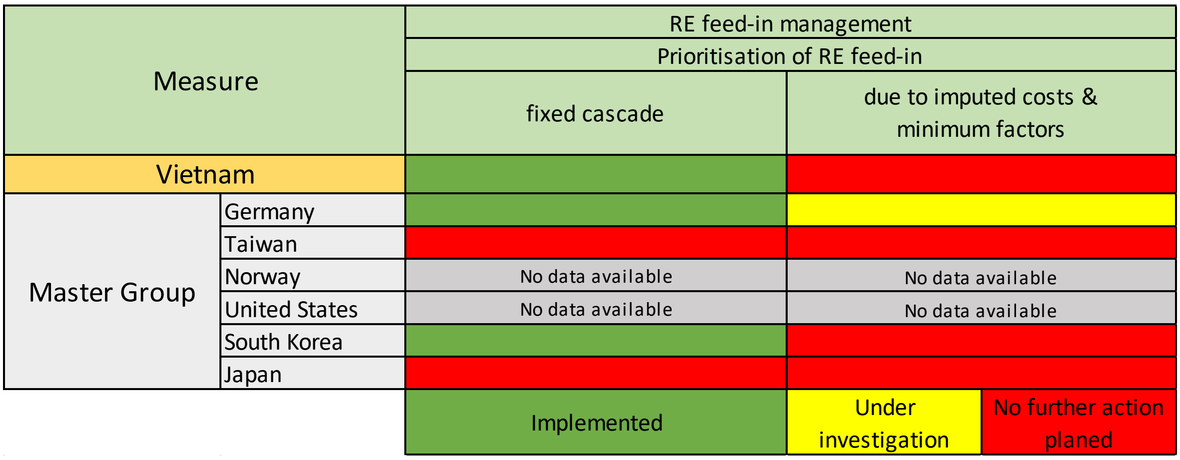
It is not only the generation capacity that can be used to relieve congestion, but also the load. Within the framework of DSM, loads from consumers can be used to serve the grid. In Vietnam, initial studies are already being conducted on the implementation of a demand site management programme in the country. The countries in the Master Group, on the other hand, already have first programmes in operation.

As mentioned in 6.3.2.2, countertrading refers to counteracting congestion between bidding zones. As the only country that has a national division into bidding zones is Norway, it is also the only country that can resort to this measure.

For the targeted use of the measures presented, a high level of digitalisation is often required at the distribution grid level. The use of flexibility on the generation and consumer side also depends enormously on the degree of digitalisation in the country.

6.4.7 Assessment-Matrix-Part-6: RE Feed-In Management

The last part of the assessment matrix relates to the feed-in management of the RES plants. The feed-in from RE can be regulated in such a way that it is determined by a fixed cascade. This means that RE are always the last to be curtailed within the framework of grid management and are always given priority. Another possibility is to prioritise the RE by means of imputed costs in connection with minimum factors.



Measure		RE feed-in management	
		Prioritisation of RE feed-in	
		fixed cascade	due to imputed costs & minimum factors
Vietnam		🟩	🟥
Master Group	Germany	🟩	🟨
	Taiwan	🟥	🟥
	Norway	No data available	No data available
	United States	No data available	No data available
	South Korea	🟩	🟥
	Japan	🟥	🟥

🟩 Implemented
🟨 Under investigation
🟥 No further action planed

Table 11: Assessment-Matrix-Part-6: RE feed-in management [75] [76] [77] [78]

Table 11 clearly shows that in most countries, the feed-in of RES is regulated by a fixed cascade. Furthermore it becomes clear that based on the underlying research, Germany is the only country from the Master Group that follows an approach with the creation of imputed costs for the generation from RES for deployment planning within the framework of Redispatch 2.0. In Vietnam, only a prioritisation based on the classification into power plant groups is carried out.

6.5 Key findings

Vietnam is currently facing two major challenges in terms of grid management, the increasing demand for energy and integration of VRE generation. Due to the fluctuating infeed of VRE, measures are required to keep and if necessary restore the balance in the electrical system.

The reason for the increasing energy demand in Vietnam is the fast-growing economy. In order not to stop the economic growth, Vietnam needs to keep up with the increasing demand for electricity. A faster increase in generation capacity can take place here by adding Renewable Energy. Due to the increase in consumption and generation, the demand for tansmission capacity also increases. If the transmission lines and cables are not designed for this high transfer, there will be overloads on the transmission lines like actual in Vietnam.

In the course of the report on Task 1, an analysis of the current Vietnamese energy system was carried out. The market environment in Vietnam, as well as issued regulations and the current energy network were analysed. Four challenges for grid management in Vietnam emerged from this analysis:

- The north-south connection in Vietnam is increasingly burdened by the differences in the generation peak times of the hydropower plants in the north and the PV solar plants in the south
- The VRE hotspot regions cause congestion in the south of the country due to their fluctuating generation, as the regions themselves usually have low consumption and the generated electricity has to be transported to the load centres. The congestions caused by the VRE hotspot regions are therefore mostly found on the transmission lines leading out of the VRE hotspot regions
- The load centres are increasingly affected by congestions in the south of Vietnam around Ho Chi Minh City. This is due to the high economic growth in Vietnam, which leads to a high growth in the electrical load in the cities. Here, the congestions are mainly noticeable in the overloading of the transformers in the load centres
- The final challenge arises from the very high installed capacities of VRE systems in only a few provinces in Vietnam's south, which further amplifies the congestion during the peak production periods of the VRE systems

For each of these challenges, at least one first recommendation was made in the area of grid management. These first recommendations should provide the focus for the assessment of Vietnam's grid management in chapter 6.5.

In a next step, in order to find internationally proven GMMs for the efficient integration of Renewable Engery into the energy system, suitable countries were searched in a two-step comparison and selection process.

It turned out that there is no country that reflects the current conditions in Vietnam comprehensive. Especially due to the combination of the two criteria GDP growth rate and PV growth rate, no comparable country could be found. As a consequence, no country that fits Vietnam perfect in all specific structural characteristics can be found.

However, with the selection procedure presented in Task 1, a Master Group from different countries could be determined. The advantage of this Master Group is that the individual strengths of the countries in the area of grid management can be summarized and, in a second step, compared to Vietnam. As a result of the this project, best possible recommendations for grid management for Vietnam can be derived from the selected countries in the Master Group.

The following countries were selected and put into the Master Group:

- *Germany and Japan*
  The two countries performed well in most of the specific structural characteristic clusters and have a large proportion of RE
- *Taiwan and South Korea*
  These two countries are very similar to Vietnam in general characteristics. In addition, they have a low (T&D Losses) / (Installed generation) ratio
- *USA and Norway*
  These two countries are special cases. USA is chosen on the basis of its innovative projects in the most varied of regions of the country (different weather conditions), as well as its economic strength and population density in hotspot regions. Norway most important for comparsion regarding its high propoartion of hydropowerplant in their generation mix

In the last step of Task 1, Vietnam's grid management could now be assessed. For this purpose, the selected countries from the Master Group were used to identify gaps or expandable GMMs in Vietnam. In addition, pioneers for international best practices were identified in the individual GMM groups. The assessment led to the following recommendations:

- *Regulatory framework*
    - *Load dependent feed-in tariffs*
      The national feed-in tariffs created an incentive mechanism for investors, which led to a huge expansion of wind and solar PV in the south of Vietnam due to better conditions. By varying the feed-in tariffs according to the time of day or through regional differentiation, congestion can be bypassed by providing incentives to investors. In this area, California in the USA is particularly noteworthy. There, the feed-in tariffs are adjusted to the peak load times of the regions. A similar approach is recommended for Vietnam, since, as mentioned in 6.2, on the one hand, the VRE systems are prioritised in the south of the country due to a higher primary energy supply and on the other hand, the generation peaks of the solar PV plants and the load peaks are far apart. A region- or time-dependent feed-in tariff could solve this problem
    - *Structuring of market zones*
      The structuring of Vietnam into smaller bidding zones could counteract the structural congestion on the north-south connection in Vietnam. The wholesale market in Vietnam already allows free trading on the market. Restrictive limits on transmission capacities between areas could eliminate congestion and strengthen the cooperation of the wholesale market and grid management.

- *Digitalisation/Automation:*
    - *Strengthening the digital components in Vietnam's distribution system*
      As shown in 6.4.3, Vietnam still has potential to expand the digitalisation of the energy system at the distribution grid level. The promotion of generation plants based on solar PV and wind will lead to electricity in Vietnam being increasingly generated remote from load-centers in the coming years – which is already partly the case today. Above all, the progressive expansion of rooftop solar plants will lead to an increased feed-in of electricity at the distribution grid level, for which the transformers and lines are not fully designed. In order to avoid congestion and to efficiently integrate electricity from VRE sources into the grid, a high level of coordination is now required between the generators, the distribution grid operator and even the transmission grid operator. For this, digitalisation of the distribution grid level is necessary. It is therefore recommended that the development of a solid digitalized infrastructure is extended to the distribution grid level. Internationally proven standards can be taken into account. Norway is a very advanced and innovative country in this field
- *Grid expansion: Focus now on the other areas*
  According to initial assessments, Vietnam is already very active in the area of grid expansion. It is recommended to now look at the other areas of grid management in order to use the existing grid capacities as efficiently as possible
- *Grid-related measures:*
    - *HVDC connection between north and south Vietnam (long term)*
      HVDC transmission offers a good alternative for the transport of electrical energy over long distances without many losses. New HVDC technology also has grid-stabilizing properties such as reactive power compensation. HVDC technology is a GMM that can relieve the lines on the north-south connections in Vietnam and at the same time deliver a positive grid input through its grid-stabilizing properties in the north and south. Therefore, HVDC technology is recommended as a GMM for the expansion of the north-south connections in Vietnam. The technology is used for example in the European network and is an important backbone of the German energy transition
    - *PST solutions to avoid congestion at nort-south link*
      PST are a technology that should be considered in transmission grid substations in Vietnam. This technology could make a significant contribution to grid management, especially on the 500kV north-south interconnector in Vietnam
    - *DTLR solution to increase the current transmission capacities*
      The DTLR makes it possible to increase the transmission capacities of the existing power lines. This is made possible by benefiting from changes in the meterological conditions on the overhead lines. This technology is also mainly a solution for the transmission grid level.

- *Market-related measures:*
    - *Spread and expand energy storage options*
      In the field of storage options, Vietnam has a gap compared to the other countries in the Master Group – as shown in 6.4. Energy storage options are particularly important in the field of an efficient integration of VRE, as they can compensate for fluctuations VRE feed in and create flexibility in operation. Furthermore, storage options can be used to store surplus energy at times of peak VRE generation and re-use it at times of peak demand. Therefore, the spread and expansion of energy storage options in Vietnam is recommended in order to more flexibly adjust the generation peaks of the VRE to the load peaks. Germany and the USA stand out among the countries in the Master Group that have already experience with innovative projects in the field of storage options
    - *Demand side management*
      Demand side management is an innovative GMM that can have a great input by flexibly adjusting the loads, especially in the load centres of a country. In all countries of the Master Group, there are already pilot projects in this area in cities or large regions.
- Priorization of RE feed-in
  Beyond the feed-in tariff, there is a prioritisation of Renewable Energy in Vietnam in terms of mobilisation and curtailment of generation. In order to relieve a congestion, renewable energy sources are only used for curtailment when the potential of conventional power plants has been exhausted. In the course of the introduction of Redispatch 2.0, Germany is now pursuing an expanded approach in which imputed costs are calculated for the RESs in order to compare them with the marginal costs of the conventional power plants. To ensure a prioritisation of the RESs nevertheless, so-called minimum factors are introduced, which indicate by how many times the RES must have a more efficient effect on the congestion than a conventional plant in order to be switched off before the conventional plant. This approach, which links the imputed costs with the minimum factors for prioritising the RESs, is also recommended for Vietnam. It optimises costs and improves grid management. The basic prerequisite for the application of this measure is a digitalised distribution grid level

The concrete technical and economical potential of the measures described above for Vietnams grid management are investigated in Task 2.

Chapter

07

TASK 2

7 Task 2

Task 2 now outlines concrete measures to improve Vietnam's grid management. The Task is divided into two subtasks. Task 2.1 first provides an overview of international best practices and approaches to grid management based on the countries selected and gaps in Vietnam's grid management analysed in Task 1. Task 2.2 then provides specific recommendations for improving grid management in Vietnam.

7.1 Task 2.1

In the following an overview of international best practices and approaches on grid management in relation to RE development is provided.
For this purpose, Task 1 identified the grid management areas in which Vietnam is currently not very active. In addition, experts or pioneers from the Master Group countries were identified in each of these areas. Now, in Task 2.1, best practices from the identified experts are presented.

7.1.1 Load dependent FIT

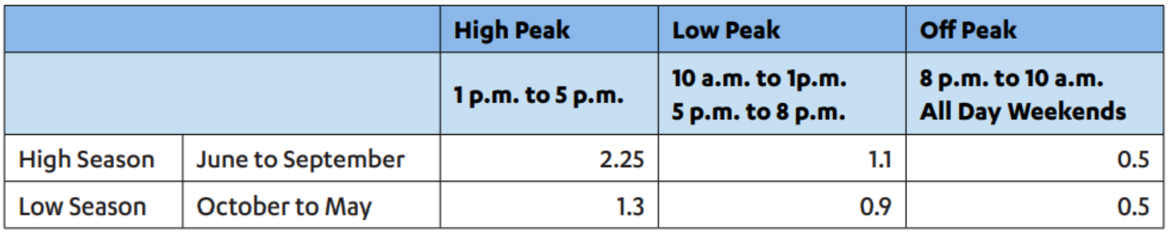
The fourth and final area of challenge is the strong expansion of VRE facilities in only a few provinces in southern Vietnam. One proposed solutions to address congestion relate to the adjustment of the country's FIT program. The USA, and more specifically the state of California, is identified as an expert for this approach.

7.1.1.1 United States

In America, the state of California is one of the most committed states in terms of REs and their integration into the electricity grid. In 2013, solar PV already accounted for 3,131 MW and wind generation for 5,785 MW in California. In 2013 alone, the share of solar PV grew by more than 290%. The resulting challenge can be compared to the divergence of solar PV generation peaks and energy demand in Vietnam. In California, this also led to the application of complex and expensive redispatch measures [79].

The problem is that solar plants in a region produce the most electricity at the same time because they are usually oriented in exactly the same direction (south). The Los Angeles Department of Water and Power (LADWP) found that at constant capacity, the south-facing panels produce the most electricity, but the southwest-facing panels result in more avoided costs. A constant FIT incentivises south-facing panels because they maximise total generation output. However, in terms of total avoided costs, west-facing panels offer the utility a lower net cost per kWh, which is why a load-based FIT was introduced. This load-based FIT reflects the highest benefit for the utility and the generators.

For these procedures, a base feed-in price was set, to which a multiplier was then applied for the respective load times. The weighting of the multipliers was determined on the basis of the load curve. Figure 27 shows the exact weighting of the LADWP.



		High Peak	Low Peak	Off Peak
		1 p.m. to 5 p.m.	10 a.m. to 1p.m. 5 p.m. to 8 p.m.	8 p.m. to 10 a.m. All Day Weekends
High Season	June to September	2.25	1.1	0.5
Low Season	October to May	1.3	0.9	0.5

Figure 27: LADWP´s TOD Multipliers [80]

As a benefit of this practice, Figure 28 illustrates how electricity generation and the average avoided cost per kWh of distributed generation vary throughout the day in the Los Angeles metropolitan area. It is clear that southwest-facing panels generate more avoided costs than south-facing panels because they generate more electricity between 5 and 7 pm. The red and blue graphs show the daily course of the production end of the south and southwest facing panels. The green dashed line visualises the impact of southwest facing panels on avoided costs.

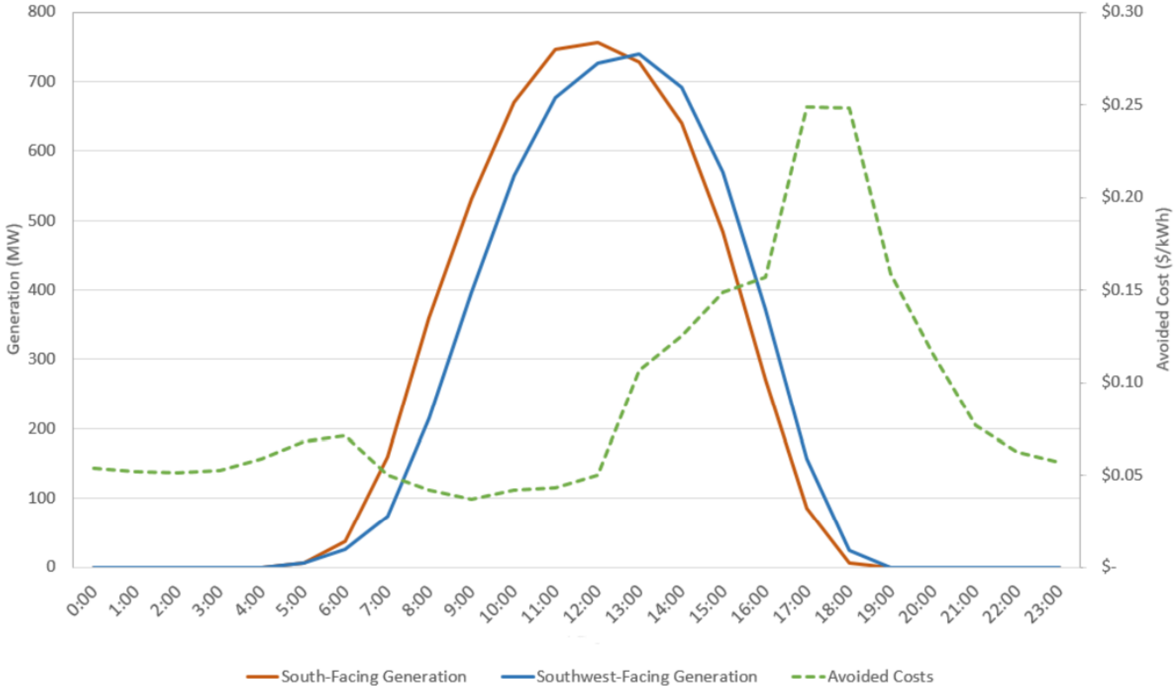


Figure 28: Avoided costs and generation for south-facing versus southwest-facing installations [80]

As can be seen, a large amount of costs can be avoided, especially in the evening, by incentivising the south-west orientation of the panels.

Unlike Los Angeles, the TOD multipliers can also be designed to encourage the inclusion of battery storage.

7.1.2 Structuring of market zones

As described in chapter 6.3.1.1, the structuring of market zones is one of the planning GMMs. Structural congestion in energy supply systems can be eliminated in this way through market signals.

One structural congestion in the Vietnamese electricity grid is the 500kV AC north-south connection. This area of challenge will be addressed here. For this purpose, international experiences of market zone structuring from Norway and the United States are presented.

7.1.2.1 Norway

Norway occupies the western part of the Scandinavian peninsula. The country has a unique shape that can be compared to the elongated area of Vietnam.

The country's electricity supply is divided into load centres and generation areas, similar to Vietnam. The north of Norway has a large number of generation capacities, while the south is the country's consumption centre.

Norway in the 90s

In the 1990s, so-called “Price Zones” were introduced for the first time by the system operator Ståtnett Norway to eliminate a congestion in the electricity grid. For this purpose, two price zones were formed when the line capacities were exceeded at a certain point in the grid. As a result, the electricity price was reduced in the surplus area and increased in the deficit area.

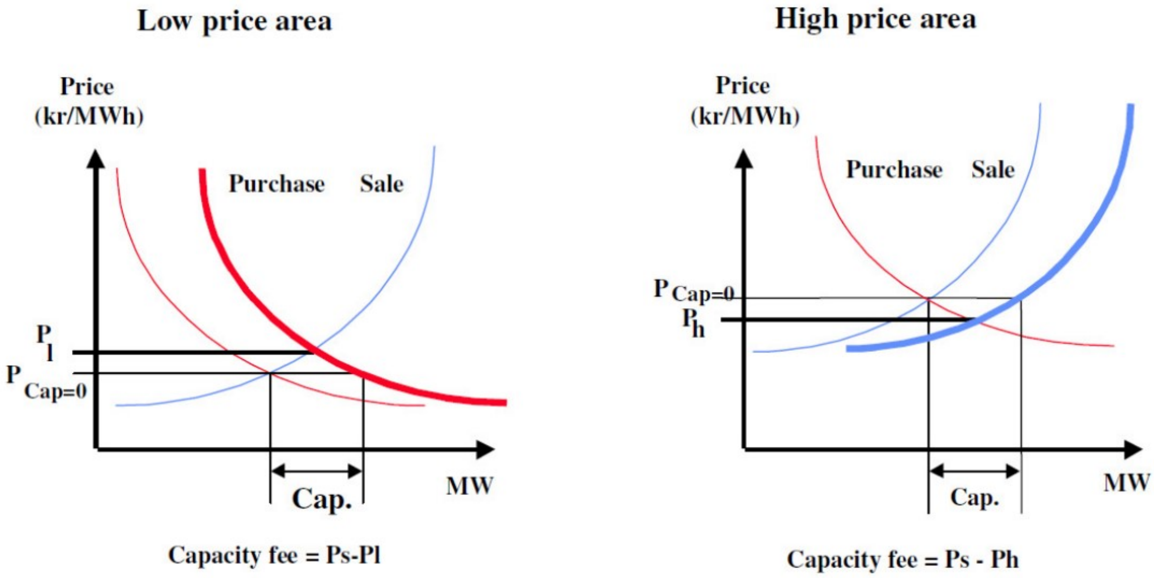


Figure 29: Determination of prices in Norway when a congestion occurs [40]

As Figure 29 shows, higher purchases were reached in the surplus area and higher sales in the deficit area. In addition, Ståtnett specifies the available transmission capacity so that both prices can align in relation to the available capacity. In this way, an emerging grid congestion could be relieved. [40]

Norway as part of the Nord Pool Market

Today Norway is part of the Nord Pool day-ahead market. Within this day-ahead market, the countries Norway, Sweden, Denmark, Finland, Estonia, Latvia and Lithuania are divided into bidding zones. Norway is divided into five different bidding zones.

The different electricity prices are made up of a system price and the respective zone price. The system price is determined by the supply and demand ratio of the entire Nord Pool market and is generated for each hour. The zone prices, on the other hand, reflect the regional market conditions of the different bidding zones (production surplus, etc.). [40]

7.1.2.2 United States

The system operation of the energy grids of the American states is divided among so-called Independent System Operators (ISOs). Many of these US ISOs, such as the Electric Reliability Council of Texas (ERCOT), have already converted to a nodal pricing system.

In order to work out the benefits of introducing the nodal pricing system, the costs must be weighed against the advantages. The largest share of these costs is made up of the additional need for special IT software and hardware as well as personnel costs, e.g. for training. On the other hand, there are benefits from the transition to an integrated structure, such as better grid management, higher grid reliability, improved grid access for end customers and more competition, lower transaction costs, better planning and better coordination with regulators. [81]

A concrete example of the implementation of nodal pricing in the United States is the ERCOT system (Electric Reliability Council of Texas). In 2003, ERCOT transitioned from a wholesale electricity market with four major zones to a marketplace consisting of more than 4 000 nodes. This breakdown, called the Nodal Project, improved the efficiency of the grid by increasing the amount of specific information available for different locations across the state. As Figure 30 illustrates, the one-time implementation cost of the Nodal Project in ERCOT is equivalent to the annual benefit to consumers. [82]

Figure 30: ISO-NE: Independent System Operator New England; NYISO: New York Independent System Operator; ERCOT: Electric Reliability Council of Texas; MISO: Midcontinent Independent System Operator; PJM: Pennsylvania New Jersey Maryland Interconnection – Note: GW = Gigawatts [82]

7.1.3 Digitalisation & automation

Measures to digitise and automate the supply infrastructure were recommended in Task 1 as a congestion relief measure. Experts or pinoiers from the selected Master Group are given with Norway.

With the increase of distributed generation such as solar PV and wind, the distribution and control of electricity needs to be reorganised. A solid digital infrastructure is particularly important here. The goal is efficient, fast and automated processes – see chapter 6.3.

7.1.3.1 Norway

Smart meter Rollout

The challenge Norway is facing is an increase in electricity demand due to advancing electrification, especially of the transport sector. In addition, there is an increased need for flexibility at the distribution grid level due to an increase in distributed generation plants in Norway. This challenge also matches the addressed challenge area in Vietnam, the challenge of increasing electricity demand in the load centers.

To address this challenge, the digital infrastructure in Norway has been upgraded for a demand response program through regulation by the energy regulator. For this, the Norwegian Energy Regulatory Authority stipulated in 2016 that all electricity consumers in Norway will receive smart meters by 1 January 2019. The responsibility for installing the meters as a result of the smart meter rollout was placed on the DSOs by the authority [83].

The benefit of this programme was that customers have more information and incentives to use energy more efficiently through a smart metering system. They are able to adjust their consumption to price fluctuations and the load on the grid, and the possibility of hourly billing will allow them to benefit financially. This will align the interests of the grid operator with those of the consumer, as electricity is also cheapest when there is overproduction from solar PV systems – see Duck Curve Figure 36. [84]

Digital substation and fibre optic

The fact that the countries in our master group are relying on digital substations with a fibre optic solution in the area of network control technology is illustrated by an example from Norway.

In the city of Bergen in western Norway, ABB will supply a so-called digital "ABB Ability™ substation" with a voltage of 132 kilovolts (kV) to BKK Nett, one of Norway's largest energy suppliers. The substation will be built in Arna, outside Bergen.

BKK Nett's electricity transmission and distribution network covers more than 16,500 kilometres, including Bergen and the surrounding residential and commercial areas. The utility is considered a leader in the implementation of future technologies that support the development of renewable energy and efficient infrastructures.

In addition to the digital substation in Langedalen, neighbouring substations will also have new communication networks and remote terminal units (RTUs) installed. The RTUs will transmit important data about the status of the assets in the field to the digital substation and the operator in the control room, who will monitor the power grid with the SCADA/DMS (Supervisory Control and Data Acquisition/Distribution Management System) system. This data can then be sent to the APM (Asset

Performance Management) software, which enables predictive and preventive maintenance. This software is provided by ABB.

The reason for choosing the digitalisation of the substation is the infrastructural advantages that the technology offers, especially in the case of grid integration of renewable energies. Other advantages are that a digital substation is more compact, more reliable, safer, cheaper and easier to maintain over the life cycle of the substation than a conventional substation. To facilitate the increased data flow associated with VRE's grid integration, ABB uses a fibre optic connection to connect the substation to the Scada system. The fibre optic cables replace the conventional copper connections and also enable digital communication while reducing installation time, costs and environmental impact. [47]

7.1.4 HVDC

From the analysis of the current status of the power grid in Vietnam, it emerged that one area of challenge is the 500kV transmission line between the north and the south. High-voltage direct current transmission was suggested as a possible congestion solution.

In chapter 6.3.2.1, the advantages of high voltage DC transmission over AC transmission have already been discussed. Two example projects from two countries of the Master Group are now presented here. On the one hand, these are intended to illustrate different areas of application and, on the other hand, to underline the benefits of this technology.

7.1.4.1 Japan

Japan's Hokkaido island is increasingly affected by earthquakes. These earthquakes increasingly endanger the availability of the electricity grid on the island of Hokkaido. Furthermore, after the Fukushima nuclear disaster, Japan has drastically increased its targets for RESs. Hokkaido offers a high potential for wind power plants. This challenge matches the addressed challenge area in Vietnam, the challenge of efficient connection between to regions which are separated from each other by hurdles – long distance or sea.

To improve the security of supply on the island of Hokkaido, a new VSC-HVDC connection between the islands of Hokkaido and Honshu will be built in 2019. The VSC HVDC technology is now expected to increase the reliability and availability of the grid. A very helpful capability of the VSC HVDC is the black start capability, which supports network restoration. In addition, VSC HVDC technology enable reactive and active power flow adjustments, which increases grid stability.

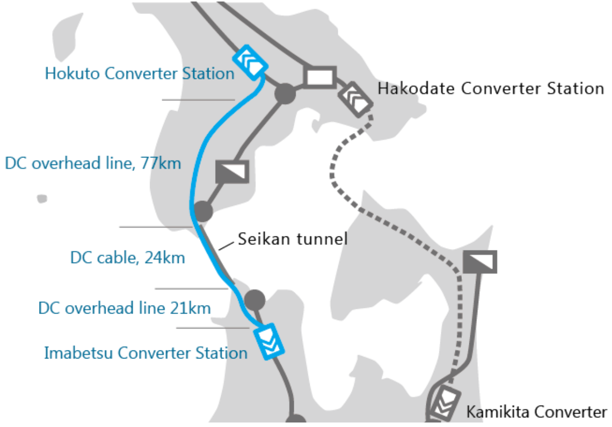


Figure 31: New Hokkaido-Honshu HVDC Project [98]

The benefit of the new VSC link in Japan is that during a blackout situation in Hokkaido, the transmission of power from Honshu to Hakkaido can restore grid operations faster. In addition, the wind turbines on the island of Hokkaido will be efficiently connected to the load centres in the south of Japan, such as Tokyo. [85].

7.1.4.2 Germany

The technology of high-voltage direct current transmission is also being used more and more in Germany.

The challenges that Germany is trying to solve with this technology are the off-load generation of wind power plants in the north of the country and the use of synergy effects of solar PV plants in the south and wind power plants in the north of the country for a better intergation of VRE. The highest potential of wind power plants is in the north of the country, which has led to a concentrated development of wind power plants in the north of the country. However, Germany's load centres are concentrated in the central-west and south of the country. This leads to an increased demand for transport of the generated electricity.

This challenge also covers the scope of work addressed in Vietnam, but more specifically addresses the challenge of increasing demand for transporting generated electricity on the north-south link.

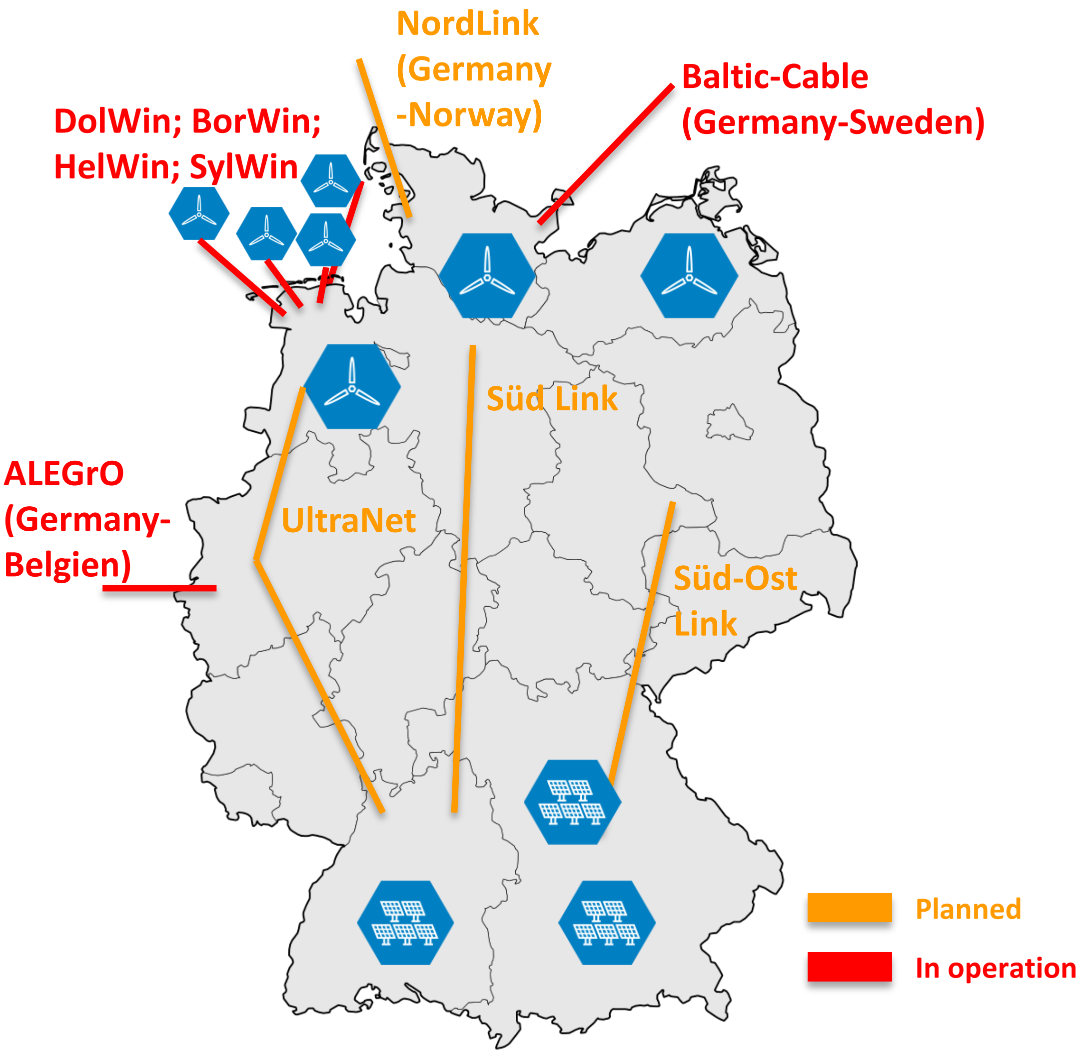


Figure 32: HVDC in Germany [95] [96] [97]

To solve these challenges, Germany has already built HVDC transmission lines to neighbouring countries. One example is the ALEGrO VSC-HVDC link between Germany and Belgium, which was connected to the grid in November 2020. The HVDC link is intended to increase the transmission capacities of the European interconnected grid on the one hand and the security of supply of the load centre around Cologne and Aachen on the other.

In addition, three HVDC links, UltraNet, Süd Link and Süd-Ost Link, are planned between the north and the south of Germany. These lines will increase the efficiency of integrating VRE wind and solar PV by connecting the wind-centred north with the solar PV-rich south. On the one hand, synergy effects of the two variable generators can be exploited to achieve a higher share of RESs in the country in the future, and on the other hand, the off-load generation capacities in the north will be connected to the load centres in the south of Germany.

Without the construction of the HVDC link, there would be increasing grid congestion in many federal states. As a result, offshore or onshore wind energy plants and photovoltaic plants in these regions would be affected by curtailments. By using DC technology, the grid concept enables the integration of further renewable energies and at the same time avoids an extensive expansion of the AC grid in the affected regions. Particularly in the case of long-range energy transport, the use of DC technology significantly reduces the reactive power requirement. Furthermore, the HVDC converters provide additional reactive power to ensure voltage stability in the AC transmission grid.

Another area where high voltage direct current transmission is used is the connection of offshore wind farms to the mainland in Germany. The reason for this is that direct current in submarine cables has much lower losses than alternating current.

7.1.5 PST

Phase-shifting transformers (PST), as well as HVDC lines, enable better utilisation of existing grid capacities as power flow control elements in coordinated deployment - cf. chapter 6.3.2.1. This enables the transmission system operators to enable a much more even utilisation of the lines, for example from the north of a country to the south, which means that lines are overloaded less frequently.

PSTs are therefore a possible solution to congestion on the 500kV transmission line from north to south Vietnam.

7.1.5.1 Germany

In Germany, PST technology is already being used. The German grid development plan of 2017 - 2030 confirmed the expansion of PST technology at the following locations:

- M253PST: Load flow controlling measure in Borken
- M489: Phase-shifting transformers in Uchtelfangen
- M522: Phase-shifting transformers in Kruckel (ad hoc measure)
- M556:Phase-shifting transformers in Hamburg/East (ad hoc measure)
- M557:Phase-shifting transformers in Haneckenfähr (ad hoc measure)
- M558: Phase-shifting transformers in Oberzieher (ad hoc measure)
- M559:Phase-shifting transformers in Wilster (ad hoc measure)
- M560:Phase-shifting transformers in Würgau (ad hoc measure)
- M561: Phase-shifting transformers in Pulverdingen (ad hoc measure)

At the same time, phase-shifting transformers are already in operation in the Diele and Röhrsdorf substations. [86]

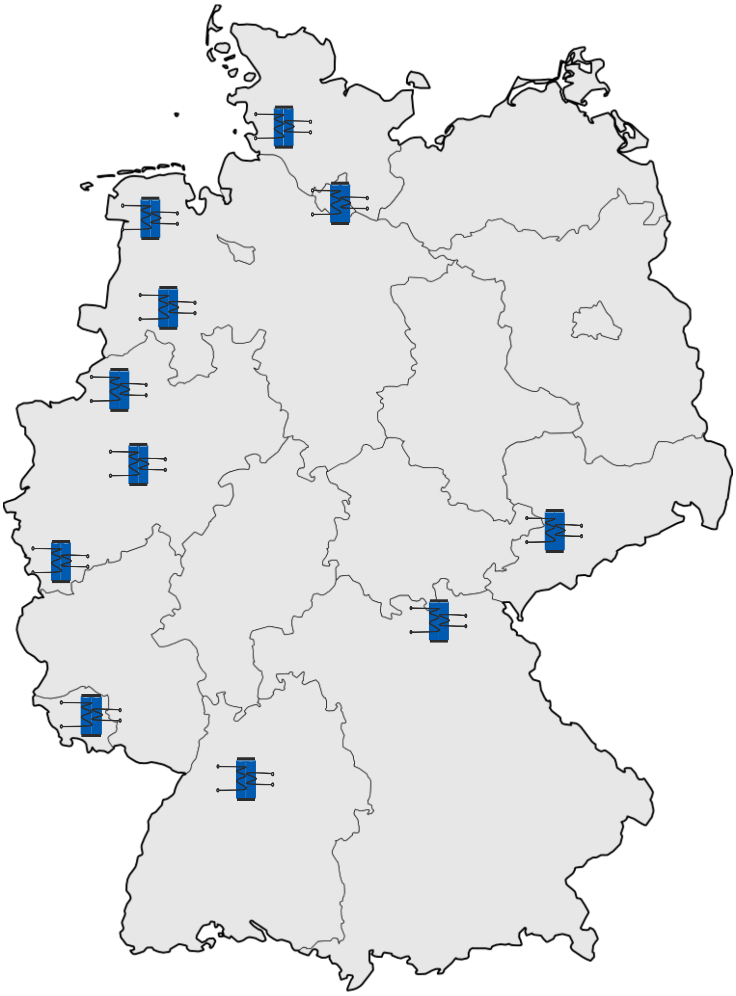


Figure 33: PST locations according to the German grid development plan (2017 - 2030) [86]

The figure shows the geographical distribution of the PST in Germany. The phase-shifting transformers have different tasks. Many PSTs close to the border prevent so-called loop flows through neighbouring countries to the south of Germany due to the strong demand for transport of the wind energy generated in the north of Germany. For this reason, a few PSTs are located on the German-Polish and German-Czech borders.

More central PSTs, on the other hand, ensure that the transmission lines on the north-south link are used efficiently and evenly. In this way, the existing transmission capacities can be used more efficiently.

Case study

A case study from 2017 on the siting of PSTs in the German transmission grid determined that the redispatch demand can be reduced by 50% through a clever choice of 5 PST locations.

The case study was based on an energy scenario for the year 2025 in order to analyse how the integration of phase-shifting transformers affects the redispatch demand. The locations of the PSTs in the German transmission grid determined by the placement procedure are shown in Figure .

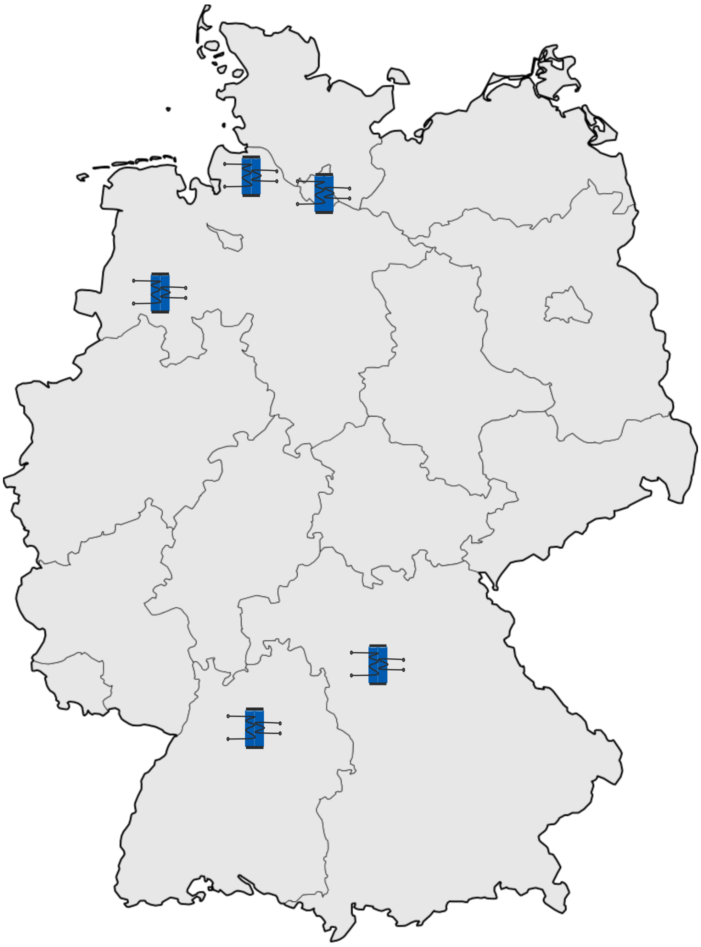


Figure 34: Identified PST locations in the German transmission grid [87]

By including the negative and positive redispatch capacities at the locations, it was possible to calculate the effects of the PST. The result was that by integrating the PST at the five identified locations, the redispatch demand can be reduced by more than 50% from 15.6 TWh to 7.5 TWh. Furthermore, the study showed that especially the curtailment of renewable feeders can be drastically reduced by 75%. [87]

7.1.6 DTLR

As already explained in chapter 6.7, the DTLR enables the best possible utilisation of the existing electricity grid. For the safe application of the measure, the climatic conditions such as temperature and wind strength along the overhead line must be known. For this, a corresponding digital infrastructure must be in place.

7.1.6.1 Germany

International experience in the field of DTLR can be found in Germany at the transmission system operator TenneT. TenneT is one of four transmission system operators in Germany. The company is responsible for operating the German extra-high voltage electricity grid between Schleswig-Holstein and Bavaria with a total length of around 12,992 km.

In order to ensure a safe application of the DTLR in its grid area, Tennet has divided its grid area into climate and subclimate zones as a first step. To support this classification and subdivision, Tennet had a meteorological expertise prepared.

In a second step, Tennet itself installed main and substitute weather stations in these climate and subclimate zones in order to be able to react to changes in weather conditions. For more accurate and better coverage, weather data is also obtained from distribution system operators in the individual zones.
When this collected weather data is available to Tennet employees, it is verified in a final step using data from the weather services, which ensures high availability and reliability of the grid.

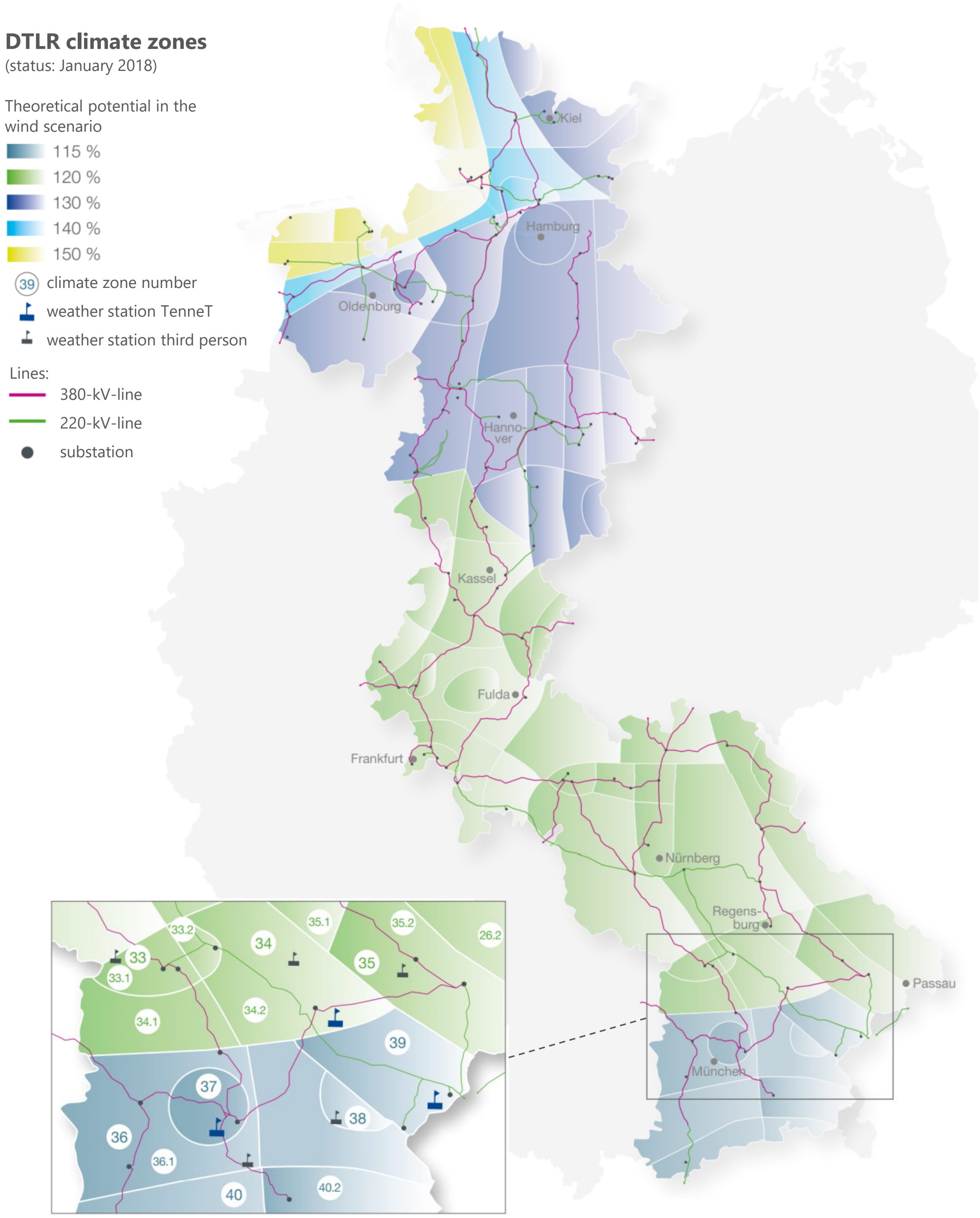


Figure 35: DTLR climat zones in Germany (Grid area TenneT) [22]

An overview of TenneT's grid area in Germany and the subdivision of the area into climate zones is given in Figure 35. The theoretical potential of the individual zones for the DTLR naturally depends on the seasonal course of the temperatures and wind patterns in the zones. The coloured backgrounds of the individual zones show the possible overhead line utilisation under the weather conditions occurring in the zone (see legend on the left side of the figure). [22]

7.1.7 Energy storage options

The second challenge area identified in Task 1 as a result of the analysis is the VRE-Hotspot regions in Ninh Thuan and Binh Thuan provinces. In VRE-Hotspot regions, congestion often occur due to fluctuating VRE production. Energy storage solutions are recommended to compensate for the fluctuations and prevent congestion in these areas and the creation of congestion between these regions and the load centres.

The assessment in chapter 6.4 showed that the United States has already been very active in this field, which is why the US emerged as an expert in energy storage projects.

7.1.7.1 United States

Two example projects from the USA are identified as international best practices at the distribution and transmission grid level. The south and westcoast of America around the states of California and New Mexico offer a very high potential for electricity generation from solar PV systems, which has led to a strong expansion of PV systems in the regions over the last few years. The high use of solar energy presents utilities with the challenge of balancing supply and demand on the grid. One of the biggest challenge is to meet the increased demand for electricity generation when the sun goes down and the contribution from solar PV decreases. To do this, energy production must be ramped up faster and faster as the share of solar PV generation increases. Figure 36 illustrates the challenge.

Another challenge with a high share of solar PV generation is the possibility that the PV system produces more energy than can be used at one time. This leads to grid operators curtail PV generation, which reduces its economic and environmental benefits. This challenge matches the addressed challenge area in Vietnam, the challenge of increasing curtailment of VRE power plants at VRE-Hotspots.

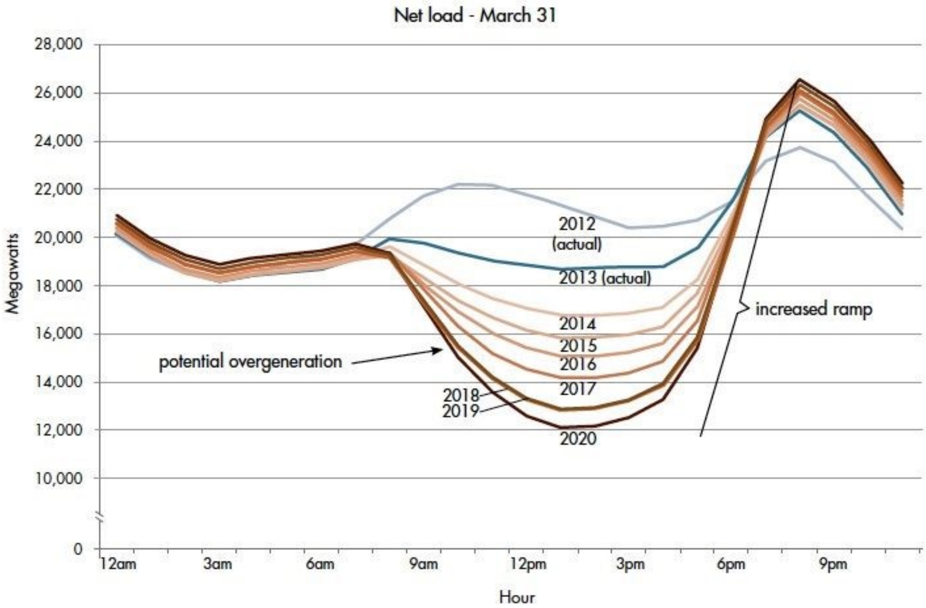


Figure 36: Duck curve of Solar PV generation in California (USA) [88]

Figure 36 shows the Duck Curve – named after its curvilinear shape – which represents the difference in electricity demand and the amount of available solar energy during the day. When the sun shines during the day, electricity production from solar PV systems is at its highest and floods the market. This means that other conventional power plants have to be shut down or the excess production from the solar PV plants has to be curtailt. Towards the evening, however, when the demand for electricity is at its highest, the electricity production from the solar PV plants drops sharply as the sun goes down. This leads to a sharp increase in the demand ramp, which must now be met by the conventional plants. To do this, they have to be ramped up again at an increasing rate. Figure 36 is a snapshot of a 24-hour period in California during spring – when this effect is most extreme because it is sunny but temperatures remain cool, so demand for electricity is low because people do not need electricity for air conditioning or heating. [24]

Pacific Gas & Electric Co. (Elkhorn Battery Storage Facility) – California

Pacific Gas and Electric Company's (PG&E) Elkhorn Battery Energy Storage System (BESS) Project (Project) is a large scale battery storage project designed to provide reliable and flexible power to the electric transmission system in and around PG&E's 115 kV Moss Landing Substation. A 182.5 MW lithium-ion BESS with the capacity to store and inject up to 730 MWh of energy will be provided. The BESS will be designed, built and maintained by PG&E and Tesla and operated by PG&E – San Francisco's utility.

The benefit of the project will be made possible by storing electricity during off-peak hours and feeding it back into the grid for use during peak hours. On the one hand, this should relieve the grid at times of high production from solar PV systems and low electricity consumption, and on the other hand, reduce the existing demand for natural gas power plants. Natural gas power plants are used a lot in California to cover peak loads – increased ramp of the duck curve – because they have fast start-up times. A BESS with lithium-ion components is at least as fast in providing the required energy.

For fast command execution, near real-time monitoring and control of the BESS is possible through a single interface, a site controller using a Supervisory Control and Data Acquisition (SCADA) control system. The Elkhorn BESS project uses the SCADA software to be able to act quickly during peak load operations.

The BESS will participate in California Independent System Operator (CAISO) markets and provide energy and ancillary services – such as an operating reserve.

PG&E projects that the Moss Landing BESS will save more than $100 million over the 20-year life of the project when compared to the projected local capacity needs and associated procurement costs that would have been necessary without the BESS. [89]

As a specific input of a large scale battery, a reference is made here to a comparative project in Australia:

One of the main problems with the overproduction of solar PV systems or the strong increase in load in the evening is that the balance between generation and consumption is disturbed. This results in deviations in the frequency of the electricity grid, which, if they become too large, can impair the function of the grid resources and lead to grid collapse. These deviations are therefore corrected by an automated adjustment of the generated power.

The Ballarat Battery Energy Storage System example project uses 30MW / 30MWh lithium-ion battery technology and is connected to the 220kV transmission grid in the state of Victoria, Australia. The Ballarat system is designed to operate as a 30 MW generator, as a 30 MW load and to provide frequency control ancillary services (FCAS) to raise and lower the frequency.

The results of the project show that the system has provided 7,312 MWh to the power and FCAS market. In the process, the system was able to generate $6.07 million in revenue, with revenue in the energy market meeting expectations and revenue in the FCAS market exceeding expectations. The overall availability of the system was 86.36%.

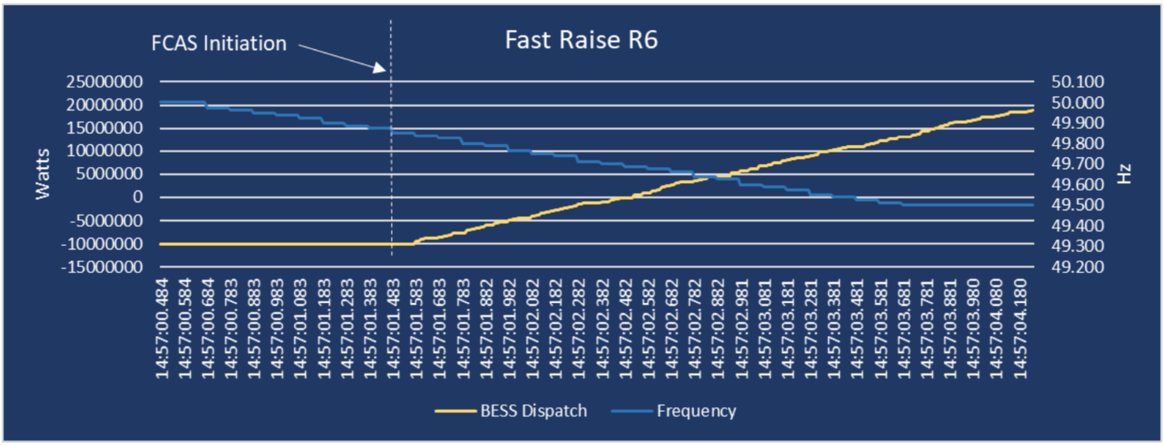


Figure 37: FACS results [90]

Figure 37 shows the rapid availability of frequency control through a high-speed data acquisition system. The BESS system responded to an instantaneous change in frequency from 50 Hz to 49.5 Hz by switching dispatch from 10 MW load to 20 MW generation in less than 1.75 seconds. In this way, the BESS system prevents a more severe frequency crash. [90]

PV Plus Battery for Simultaneous Voltage Smoothing and Peak Shifting – New Mexico

The Public Service Company of New Mexico (PNM) demonstration project was chosen as an example project for battery solutions at distribution grid level.

The demonstration project installed an energy storage system consisting of two elements: a 0.5 MW smoothing battery with ultra batteries and a 0.25 MW/0.99 MWh peak load shifting battery with advanced lead acid batteries. This energy storage system was thereby installed at a distribution grid substation in physical connection with a 500 kW PV resource to create a dispatchable RE source.

The smoothing batteries are designed to "smooth" the output of the solar PV system. Solar PV systems do not produce a constant output due to the dependence on the sun. For example, when a cloud casts a shadow on the solar panels, they produce less power. At this moment, the battery storage intervenes and compensates for the loss of generation so that the solar PV system produces an almost smooth output. The reliability improvements resulting from smoothed PV focus on the reduced operation of load tap changers (LTC/OLTC) to maintain voltage in the distribution grid.

The results of the project show that smoothing PV generation is particularly worthwhile in areas with high solar PV penetration. Solar PV systems cause voltage deviations at the distribution grid level due to their fluctuating feed-in, which must then be adjusted by measures such as the adjustment of LTC/OLTC. In areas where solar PV penetration is particularly high, more and more LTC/OLTC switchovers can be avoided through smoothing. Figure 38 visualises the smoothing effect based on daily measurements of the project in New Mexico.

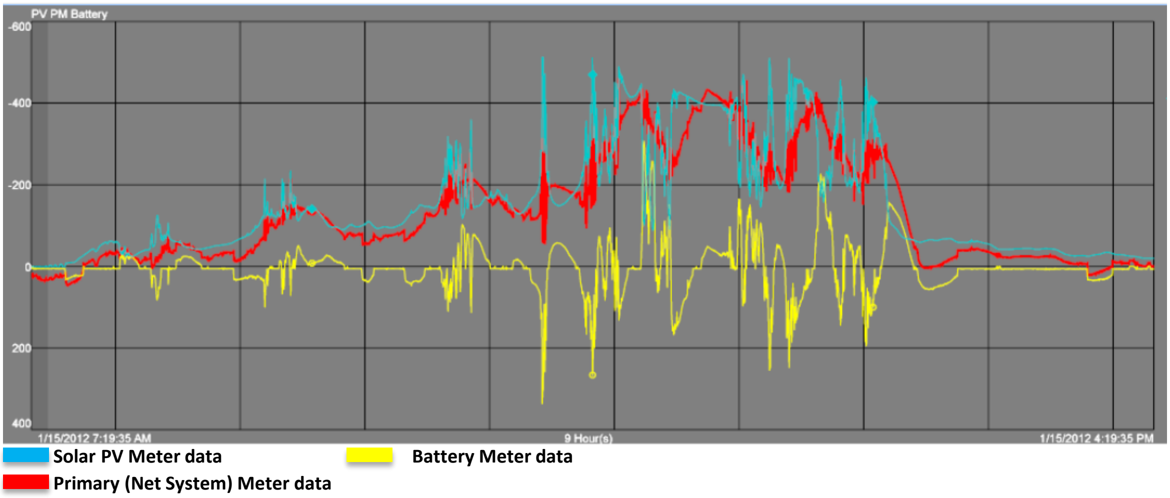


Figure 38: Magnified view of 1/15/12 Smoothing [91]

By storing energy, the advanced lead-acid batteries make it possible to balance the peak demand of the grid at times of peak consumption by customers. In doing so, the energy storage system can take over the role of natural gas power plants, which are also used to meet peak demand due to their fast start-up times – compare battery storage at transmission level in the californian project. This allows PNM to use renewable energy when it is needed most and prevents curtailment of the solar PV system at times when PV generation is too high – duck curves example.

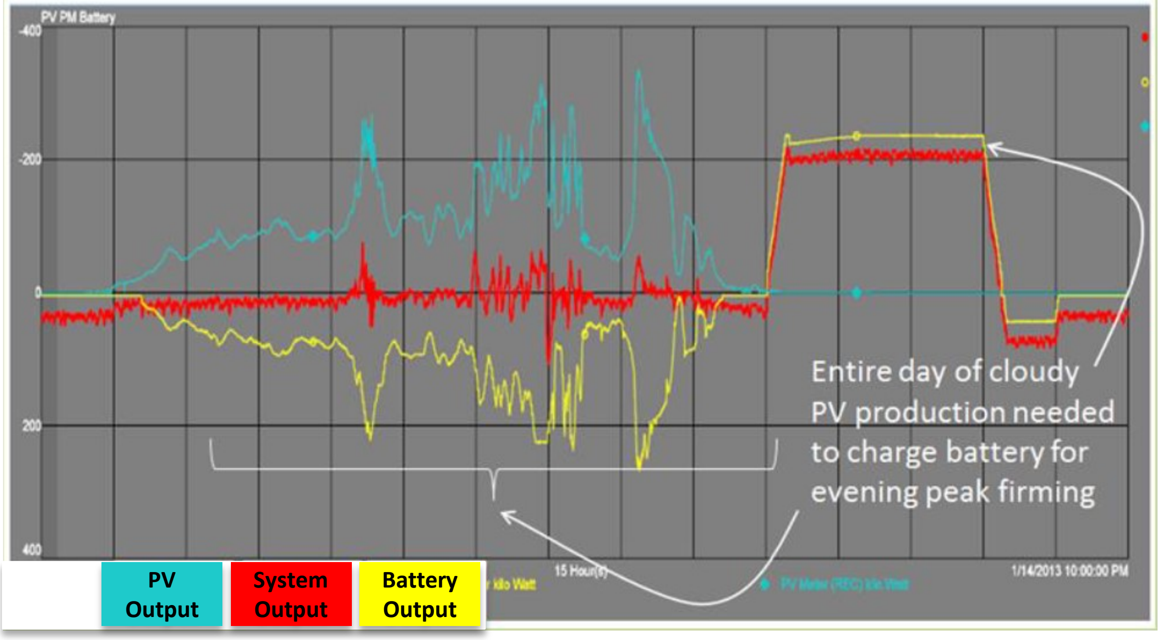


Figure 39: On January 13, 2014, cloud cover made the PV plant's output especially variable. Instead of sending this variable energy directly to the grid, PNM used it to charge batteries housed in the energy storage system. In the evening, when electricity demand rose and solar irradiance waned, PNM discharged the batteries to accomplish firming of the PV, as the graph below shows. [91]

The result of the study was a hybrid resource that provides simultaneous voltage smoothing and peak shifting through advanced control algorithms at distribution level. Data collection and analysis provides information for a wide range of applications, including grid expansion shifting. In addition, the project has also been able to produce modelling tools that are used to optimise battery system control algorithms and further the understanding of feeders with storage and distributed generation. The site is located in southeast Albuquerque. [91]

The difference between large-scale battery storage on the transmission grid and smaller-scale storage on the distribution grid is that for the distribution grid battery storage, voltage maintenance is also a priority. Unlike in the transmission grid, the active power input of the power plants in the distribution grid is in direct proportion to the voltage maintenance. The presented smoothing capability of the battery storage systems therefore has an input at the distribution grid level that is negligible at the transmission grid level due to the neglect of the conductor losses compared to the reactance of the lines.

7.1.8 Demand side management

The third identified challenge area is the strong increase in demand in Vietnam's load centres.

Adjustments to loads can relieve congestion in a similar way to adjustments to generation. Within the framework of a demand side management or demand response programme, such load adjustments are made in a grid. An example is presented here from South Korea.

7.1.8.1 South Korea

The challenge in South Korea is increasing electricity demand due to increasing electrification. In this context, this increasing exacerbates peak loads and poses a major challenge in mobilizing power plants at peak times – the Duck Curve example. This challenge matches the addressed challenge area in Vietnam, the challenge of increasing electricity demand in the load centers.

One exemplary practice is the demand response market programme in South Korea. The demand response market provides the opportunity to trade demand resources. That means that a retailer can offer the curtailment of its demand for purchase in a market. DR aggregator collects these consumers to organise demand resources. Then demand resources are tendered daily against generation resources, and when sold, demand curtailment begins. The exact process is outlined here in Figure 40.

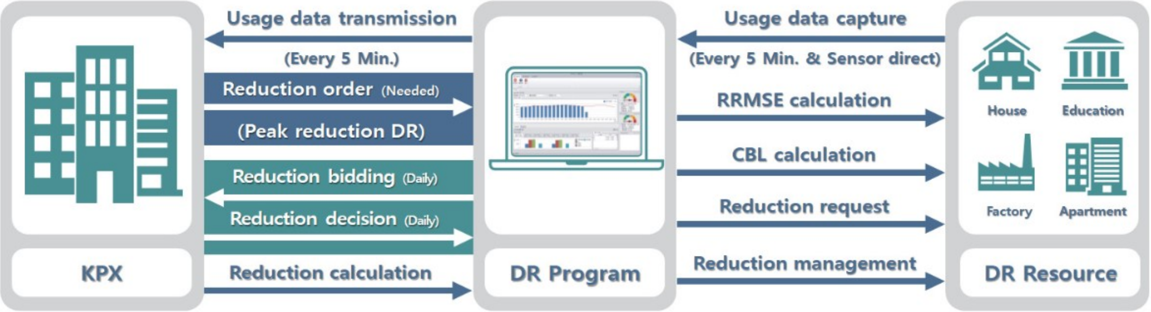


Figure 40: The structure of a demand-side management solution [92]

The demand-side management solution (DSMS) collects the usage data of demand resources such as house, building, flat and factory directly by sensor every 5 min. Then this usage data is sent to the Korea power exchange (KPX) server every 5 min. KPX has the task of controlling the operation of the South Korean electricity market and system. When congestion occurs due to excessive demand, the KPX sends a reduction request to the DSMS. When the request is generated by the KPX, the DSMS calculates the customer baseline load (CBL) of the DR duration and then contacts the DR resources to request the contracted power reduction quantity. Thereafter, demand reduction begins. In system operation, consumers are required to curtail demand within one hour of the dispatch request. The DSMS also regularly calculates the RRMSE (relative root mean square error), the CBL of DR resources to maintain DR resources in the Korean electricity market. The CBL is the prediction of the amount of electricity that would generally be consumed if electricity consumption had not been reduced by the KPX policy.

This approach has allowed the demand response market to grow and provide a large amount of available curtailment energy. For example, the number of consumers increased from 90 to 3592 and the amount of curtailed energy increased from 513 MWh to 175,771 MWh, an increase of 342.6 times.

However, for this practice, there must be a certain level of digital infrastructure that includes DSMS and collects usage data of demand resources such as house, building, flat and factory by sensor every 5 minutes.

The benefit of introducing a demand response market, as in South Korea, is that demand resources are used as an alternative to mobilising generation for short periods such as 5 minutes. [92]

7.1.9 RE Feed-in

Another congestion solution for the fourth challenging area ist the adaption of the RE priority.

7.1.9.1 Germany

As already mentioned in 7.1.1, electricity generation from decentralised, RESs has also increased in Germany in recent years. This large number of new, mostly decentrally distributed, small electricity generators poses a major challenge, especially to the GMM, redispatch, which has been tried and tested for years. In the old redispatch, the RESs were not included and were only called in for grid management under the so-called feed-in management when the conventional resources were exhausted. Now, due to a higher share of RESs, the prices for redispatch in Germany have risen sharply. On the one hand, there are more and more congestion in the distribution grid and on the other hand, the capacities available for redispatch are decreasing with the increasing shutdown of conventional power plants in Germany.

This challenge is primarily in line with the expected increase in rooftop solar PV installations in the south of Vietnam. Since it can be assumed that the expansion will continue to be concentrated in only a few provinces, the VRE hotspot regions will initially be affected by this challenge.

To solve this challenge, Redispatch 2.0 will be introduced in Germany on 1 October 2021. This new redispatch will now also include RESs from 100 kW. [18]

The deployment order in Germany is determined according to the Merit-Order. The Merit-Order refers to the order in which power plants are deployed, which is determined by the marginal costs of power generation of the power plants.

Now, as a result of Redispatch 2.0, there is supposed to be a Redispatch-Merit-Order in which the order of curtailment in the event of grid congestion is determined. In the case of curtailment, the curtailment costs are calculated from the power plant´s shutdown and start-up costs. This can be very expensive for coal and nuclear plants. In contrast, RESs have very low to no curtailment costs, which is why they would always be the first to be curtailed as a result of the Redispatch-Merit-Order.

Therefore, a calculatory balancing price is calculated for these plants. This is made up of the imputed costs, which are set each year by the transmission system operator, and the minimum factor for RE and CHP plants. The minimum factor indicates by how many units the RES must have a more efficient benefit on the congestion in order to be switched off before the conventional power plants. [25]

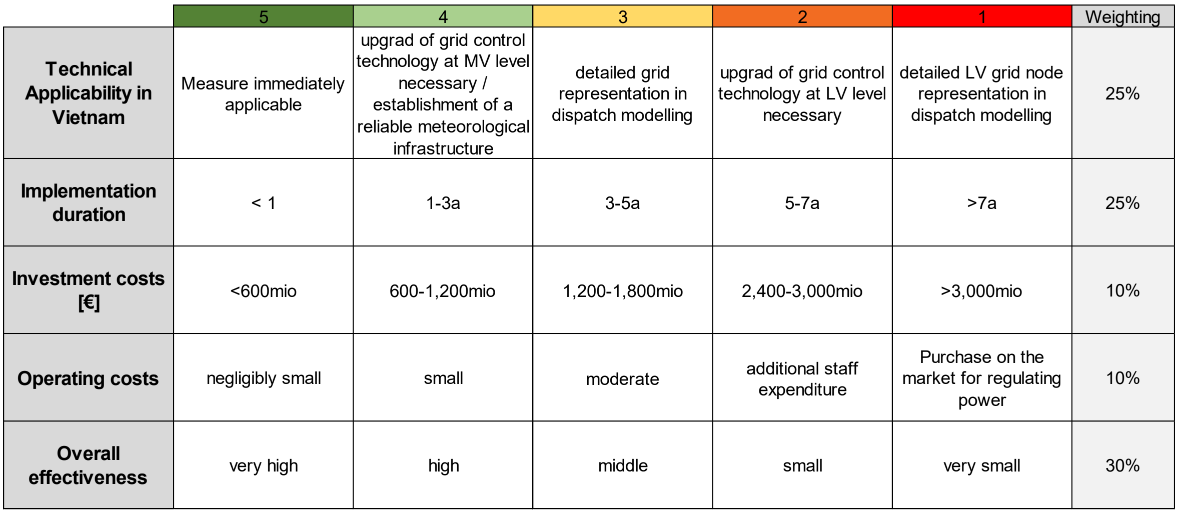
In the past, the RESs were excluded from the redispatch and were subject to a special regulation within the framework of feed-in management. Now, the general feed-in priority of RE and CHP plants is to be further taken into account through the minimum factors.

This approach, which is used in Germany, enables congestion to be resolved more cost-effectively through the targeted curtailment and inclusion of RESs.

7.2 Task 2.2

In the following chapter, the recommended GMMs are prioritised on the basis of five selected criteria. The prioritisation based on the evaluation criteria results in an order that shows which measures can be used to upgrade grid management in Vietnam as effectively and quickly as possible. As shown in chapter 6.3, the prioritisation includes both planning and operational GMMs.

Each gap in Vietnam's grid management was assigned to a challenge area identified from the analysis. Each of these individual measures is now prioritised in this part of the report by the technical applicability in Vietnam, the implementation duration, the extent of the investment costs, the level of operational costs for the transmission system operator when implementing the measure and the effectiveness. Figure 41 gives an overview of the evaluation options and the necessary characteristics of the respective measures for the evaluation level.



	5	4	3	2	1	Weighting
Technical Applicability in Vietnam	Measure immediately applicable	upgrad of grid control technology at MV level necessary / establishment of a reliable meteorological infrastructure	detailed grid representation in dispatch modelling	upgrad of grid control technology at LV level necessary	detailed LV grid node representation in dispatch modelling	25%
Implementation duration	< 1	1-3a	3-5a	5-7a	>7a	25%
Investment costs [€]	<600mio	600-1,200mio	1,200-1,800mio	2,400-3,000mio	>3,000mio	10%
Operating costs	negligibly small	small	moderate	additional staff expenditure	Purchase on the market for regulating power	10%
Overall effectiveness	very high	high	middle	small	very small	30%

Figure 41: Evaluation levels and weightings of the five prioritisation criteria

As can be seen in the figure, an evaluation range of 1 to 5 was chosen with 5 being the best grade. Each evaluation level is well defined and is only reached by a measure if the definition for the measure applies. The weighting is chosen so that the effectiveness of the individual measures is weighted highest. Through assessments with experts, a three times higher weighting was chosen for effectiveness compared to investment and operational costs. Technical availability and implementation time were chosen as two important characteristics, as against the backdrop of a fast growing economy, solutions are needed quickly in Vietnam in order to be able to continue to guarantee the energy supply.

Technical availability in Vietnam indicates whether the measure can be implemented immediately in Vietnam without upgrading the infrastructure, such as grid control technology. The respective evaluation level indicates how much have to be invested in the infrastructure to create the basic precondition for the applicability of the measure. The implementation duration indicates how long the implementation of the measure will take if the technical availability in Vietnam for this measure is guaranteed. The investment costs refer to the investment sum incurred by the transmission system operator if the respective GMM is to be implemented in Vietnam. Here, only the investment costs of the specific measure are considered and not the upgrading of the infrastructure, which was already considered in the first criterion. The operating costs then refer to the costs incurred by the transmission system operator when the respective measure is used within the framework of grid management. The final criterion is the effectiveness of the measures on the congestion analysed in chapter 6.2. Here, the effects of the measures on the congestion arising in the different challenge areas are evaluated.

7.2.1 Technical applicability

The first evaluation criterion is the technical applicability of the measure in Vietnam. In this area, HVDC and PST technology does not require any further upgrades to the current state of the Vietnamese transmission grid and can therefore be implemented immediately. The introduction of a DTLR requires the provision of reliable meteorological data. Therefore, it is necessary to upgrade the meteorological infrastructure along the overhead lines and to ensure that the information is provided to the transmission system operator at a high quality level. From the international experience in Germany, chapter 7.1.6, it can be concluded that a higher quality of the meteorological data can be ensured through cooperation with the distribution system operators and the meteorological services of the country. Therefore, a rating of 4 in the area of technical applicability was chosen for the DTLR.

The situation is somewhat different for the other presented measures. The BESS at the transmission grid level could also be immediately implemented because the transmission grid level in Vietnam has been digitalised and is operated 100% by the SCADA system. For BESS systems at the distribution grid level, further expansion of grid control technology of local grid stations at MV level is required in order to make use of peak shaving and voltage conservation benefits. DSM requires an expansion of the grid control technology down to the LV level in order to be able to control the consumers remotely and to be able to tap the benefits of curtailment at all. However, the current electricity grid in Vietnam only provides digital infrastructure at the transmission grid level (see chapter 6.2).

The situation is no different for the applicability of feed-in adjustment of small decentralised RES (e.g. roof-top solar PV). Many of these small generators are connected to the LV level, which is why this must be made observable and remotely switchable so that the DSO can intervene in the event of congestion.

In the area of regulatory framework conditions, no additional technical conditions need to be fulfilled by the Vietnamese grid regarding a load-dependent feed-in tariff. In the area of market zone structuring, granularity is the most important factor. When a country is divided into bidding zones, the grid capacities across the bidding zones must be available at all times in order to be able to include the respective restrictions in the auction on the market. A detailed MV grid representation in the dispatch modelling is therefore necessary. When it comes to nodal pricing, the granularity becomes higher and the available grid capacities must be available at the respective grid nodes. Here, a detailed grid node representation in the dispatch modelling, even up to the LV level, becomes important.

7.2.2 Implementation duration

In the implementation duration evaluation, the HVDC link from north to south Vietnam is evaluated with an estimated duration of 5-7 years. In Germany, this process would prob-ably take much longer due to a lot of authorisation work. Given the political conditions in Vietnam and the duration of the PDP (power development plan) of nine years, the construction can be expected to take between 5-7 years. PSTs are classified with an implementation period of 1-3 years. The first step is to locate the right site for the technology and to commission the size of the PST. However, the technology is then installed very quickly at a transmission substation. If the required meteorological infrastructure for the application of the DTLR is available, all safety restrictions of the overhead line sections must also be checked and integrated into the software. Such safety restrictions can be, for example, the minimum distance of the lines to the ground or to surrounding structures, which could otherwise be affected by the high currents. Therefore, an implementation period of 1-3 years was chosen after consultation with internal experts.

For BESS at the transmission level, international projects show that the measure can be integrated into the grid within a year. However, in order to be able to store the entire surplus generation at low load times, a storage capacity of 2.6 GWh is required. An investment on this scale can be implemented within 1-3 years. Smaller BESS for the distribution grid level are mostly already prefabricated and therefore require less time. Thus, this measure is placed with a very short implementation duration. When the infrastructure or the technical applicability of the DSM is given, consumers can offer their load reduction on the market. This can happen in a time horizon of less than one year. However, the establishment and expansion of the DSM market will take at least 1-3 years until a greater benefit for the grid operator can be recognised.

The integration of small RE power plants into the redispatch is to be evaluated here with a duration of 1-3 years, if the technical applicability in the Vietnamese grid is guaranteed. The main reason for this is not only to ensure technical availability, but also to recruit new staff and ensure better cooperation between DSO and TSO.

The load-dependent feed-in tariff is classified with an implementation duration of less than one year. This regulatory measure is immediately valid and applicable after the decision. The situation is slightly different with the regulatory measures for structuring market zones. Here, too, trained personnel must be deployed in addition to the technical applicability in order to enable a precise grid modelling. The expected implementation period for training staff and creating new positions is 1-3 years.

7.2.3 Investment costs

In the area of investment costs, the costs for the HVDC line between Hanoi and Ho Chi Minh City are calculated as follows: The AC high-voltage transmission extends over a distance of 1,500 km from north Vietnam (Hanoi) to south Vietnam (Ho Chi Minh City). For the imputed costs of the lines and converters, a brief report by FfE is used [93]. The available transmission capacity is set at 2GW, as transmission capacities of up to 1800MW are already being achieved on the 500kV AC connection between central and south Vietnam. In total, the investment costs amounted to more than 3 billion euros. The HVDC link is therefore clearly the most expensive measure to implement. The PST is much cheaper in investment cost in relation to the HVDC technology. In this case, it is assumed that a PST with a capacity of 1GW would be implemented, which would result in costs of around 20 million euros. The investment costs for the DTLR depend on the current meteorological infrastructure in Vietnam. Unfortunately, information on this could not be found. However, after consultation with internal experts, a classification in the recommended measures could be made. According to estimations, it can be assumed that the DTLR is in the range of the PST in terms of investment costs. For this reason, the measure was also given a rating of 5.

In the area of BESS, there are two ways of approaching the issue. If the measures are counted as market-related measures, as is the case in Germany, then only operational grid management costs arise for the grid operator, as the control reserve provided by the BESS owner must be purchased on the market. If the BESSs are installed by the grid operator itself, they can be used as grid-related measures as the grid operator has direct access to them. In this case, investment costs of over 600 million euros would arise in Vietnam in order to be able to store the reduced RE output of 1.3GW in the low-load hours of 11-13 o'clock and feed it back in during the evening hours when solar PV generation falls. For energy storage at the distribution grid level for peak shaving or smoothing, smaller energy storage systems are required, which on the one hand are more expensive per MWh capacity than the large BESS at the transmission grid level, but do not require such large storage capacities. For this reason, the investment costs for this technology were estimated to be far below €600m.
All other measures also have significantly lower investment costs than the HVDC technology.

7.2.4 Operating costs

In the area of operating costs, it should be noted that grid-related measures only cause negligibly small costs for the grid operator when they are applied. Therefore, the measures HVDC, PST, DTLR, Transmission BESS and Distribution BESS are received with very low operating costs for the system operator.

Through access to the DSM and also the availability of feed-in from small RES at the distribution grid level, the grid operator incurs costs per kW of de-energised power or load. Payment is usually made via a balancing power market, on which the grid operator can purchase balancing power. These costs are particularly expensive for RESs due to the promised feed-in tariff.

The determination of new regulatory framework conditions, such as the introduction of a load-dependent feed-in tariff, also causes operational congestion. The load-dependent feed-in tariff, for example, causes high electricity prices for the grid operator in order to create an incentive for investors. The division of the electricity market into smaller units causes operating costs in the form of new personnel costs.

7.2.5 Overall effectiveness

The general effectiveness of each individual measure is determined in consultation with experts from the energy industry, as well as experiences from workshops with Vietnamese officials, and is not based on grid calculations.

In addition to low-loss transmission of electricity over long distances, HVDC technology offers many other grid-supporting properties that have been explained in chapter 7.1.1. Due to this multitude of advantages for the grid operator, this measure receives a very high effectiveness rating. PSTs offer fewer advantages in the action area of grid management on the high-voltage grid connection between north and south Vietnam compared to HVDC due to a smaller area of effect. Therefore, after consultation with experts, a score of 2 was given to the PST solution.

Similar to the PST, the DTLR also tries to make better use of the existing electricity grid. However, the DTLR pursues a completely different approach. By exploiting suitable weather conditions along the overhead lines, a higher transmission capacity of the lines is to be made possible. The example project from Germany shows that there is great potential in this measure. However, it has already been analysed that a variable of the DTLR, the ambient temperature, covers a much smaller range in Vietnam than in Germany. In summary, this means that the DTLR in Vietnam offers less potential than in Germany due to the low fluctuations in seasonal outdoor temperature. It needs to be examined in what way the wind speeds along the lines can offset this lower potential. Based on these considerations and the support of the company's internal experts, a score of 3 was assigned to the DTLR in the area of effectiveness.

BESS at the transmission grid level address the challenge area of efficient integration of a high share of VRE units at VRE-Hotspot areas to a very high degree. BESS at the distribution grid level also have a great advantage for voltage stability at the distribution grid level. However, compared to the large peak-shifting storage facilities and HVDC, they are less effective for the overall grid management. Furthermore, the use of BESS at the transmission level must be distinguished from that of BESS at the distribution grid level in the area of the overall effectiveness. The reason for this is that the BESS at the distribution grid level are usually much smaller than the large storage facilities at the transmission grid level. Another reason is that the BESS at the distribution grid level only generate a high level of effectiveness in a local area. If the energy stored in the BESS at the distribution grid level is needed at a more distant location, it must first be transformed down and up again via the transformers. This results in losses and the effectiveness decreases.

The DSM measure is well suited for use in the load centres. Nevertheless, the measure is highly dependent on the participation of communities and/or individual households. The example project in South Korea has shown that the participation of a few consumers only brings a small benefit. The benefit from load reduction for the grid operator is therefore classified as medium (3).

The inclusion of RES in redispatch will help the efficient integration of RE by reducing the total amount of curtailed RE power.

The load-dependent feed-in tariff, on the other hand, has a very high general effectiveness. The incentive can encourage investors to invest in BESS themselves and thus charge their storage systems with solar PV power at low load times. This would result in a smoothing of the residual load curve. The structuring of the market into bidding zones prevents the occurrence of congestion on lines between bidding zones due to restrictions on the market. In addition, the measure sets important market signals by distinguishing between different market prices in the respective bidding zones. This effect enables growing companies to become grid-oriented early on, as there is a financial incentive for them to do so. This is particularly important in view of the continuing strong growth of the Vietnamese economy. Nodal pricing generates even stronger market signals than bidding zone subdivision due to a finer granularity of market prices. Against the backdrop of the rapidly growing economy and the associated strong growth in electricity consumption, the two measures receive high and very high ratings in the area of the overall effectiveness.

7.2.6 Scoring

In summary, the points shown in Table 12 were awarded for the measures. The sum of the total number of points is then calculated by multiplying the respective points achieved with the weighting of the individual criterion.

Measures **Criteria**	*HVDC*	*PST*	*DTLR*	*Transmission BESS (Grid-related)*	*Distribution BESS (Grid-related)*	*DSM*	*Inclusion of small RE power plants in Redispatch*	*Load dependent FIT*	*Bidding zone*	*Nodal pricing*
Adressed challenging area	North-South transmission link	North-South transmission link	North-South transmission link	VRE-Hotspots (Ninh Thuan, Binh Thuan)	VRE-Hotspots (Ninh Thuan, Binh Thuan)	Load centres (Hanoi, Ho Chi minh city)	VRE-Hotspots (Ninh Thuan, Binh Thuan)	VRE-Hotspots (Ninh Thuan, Binh Thuan)	North-South transmission link	All
Technical applicability in Vietnam	**5**	**5**	**4**	**5**	**4**	**2**	**2**	**5**	**3**	**1**
Implementation duration	**2**	**4**	**4**	**4**	**5**	**4**	**4**	**5**	**4**	**3**
Investment costs	**1**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**5**	**5**
Operating costs	**5**	**5**	**5**	**5**	**5**	**1**	**1**	**3**	**2**	**2**
Overall effectiveness **(challenging area impact)**	**5**	**2**	**3**	**5**	**3**	**3**	**4**	**5**	**4**	**5**
Sum	**3.85**	**3.85**	**3.9**	**4.65**	**4.15**	**3**	**3.3**	**4.8**	**3.65**	**3.2**

Table 12: Evaluation table

8 Results and Outlook

Vietnam is an emerging country in south east Asia. Through the Power Development Plan VII of 2016, the government decided to expand the share of RESs in the country to further secure a sustainable power supply for its rapidly growing economy. To this end, feed-in tariffs were introduced for solar PV and wind generation, which led to a grade expansion of the technologies in a short period of time.

In order to facilitate measures for the efficient integration of VRE systems, this report first analysed the current electricity system in Vietnam. Foure challenging areas for the country's grid management were identified. These areas include the:

- 500kV transmission line between the two load centres Hanoi in the north of the country and Ho Chi Minh City in the south
- VRE-Hotspots Ninh Thuan, Binh Thuan in the south
- Two load centres Hanoi and Ho Chi Minh in the north and south of the country
- Expansion of VRE limited to a few provinces in the south of Vietnam

The 500kV transmission line between north and south Vietnam is undergoing increasing strain due to the country's rapidly increasing energy consumption. In addition, seasonal and temporal generation changes of hydropower in the north and solar PV plants in the south of Vietnam are increasing power flow changes.

The VRE-Hotspot regions of Ninh Thuan and Binh Thuan are strongly affected by the expansion of solar PV technology due to particularly good conditions for solar PV installations. As these two provinces do not consume a particularly large amount of electricity, the extreme expansion has resulted in an energy balance with a surplus of 7,825 MW. This leads to congestion at the transmission and distribution grid substations since electricity must be transported from the VRE-Hotspots to the load centres. Furthermore, it was found that a further expansion of rooftop solar systems is to be expected, as the owners of the system are granted increasingly more liberty in trade.

There is also congestion at the distribution grid level in the load centres. The primary challenge here is the strong increase in electricity demand, which leads to overloading of the transformers.

Through the country selection, an assessment of the current grid management in Vietnam could then be made in further research. The assessment provides an overview of the GMMs that are not yet applied in Vietnam. By including the previously selected countries, these gaps in the Vietnamese grid management fleet could be interpreted and experts for the gaps can be identified. The gaps to be improved resulted from

- HVDC technology
- PST technology
- DTLR
- the energy storage options
- the DSM, the load-dependent FIT
- the structuring of market zones

- the adaptation of the RE feed-in
- the creation of a digital infrastructure through digitalisation and automation as a foundation

In further studies, exemplary best practices of each gap could be presented by the selected countries. Through the specific characteristics and advantages of the individual measures, it became clear that each measure could be assigned to an action or challenging area in Vietnam from the analysis.

In a final step, the proposed measures were prioritised. By prioritising the measures in the areas of

- technical applicability in Vietnam
- implementation duration
- investment costs
- operating costs
- the overall effectiveness for the respective challenge area and beyond

the recommendation are further specified. For each criterion of this prioritisation, a weighting is determined, which is adjusted on the basis of the requirements of Vietnam that emerge from the analysis. The weighting is chosen so that the effectiveness of the individual measures is weighted highest. Technical availability and implementation time were chosen as two important characteristics, as against the backdrop of a fast growing economy, solutions are needed quickly in Vietnam in order to be able to continue to guarantee the energy supply. By evaluating the individual measures in the respective criteria, a prioritisation order results that best addresses vietnam's requirements.

The following order of measures is the most beneficial in terms of Vietnam's current requirements:

1. Load dependent FIT
2. Large scale BESS at transmission level
3. BESS at distribution level
4. DTLR
5. HVDC and PST
6. Market structuring in bidding zones
7. Inclusion of small RE power plants in Redispatch
8. Market structuring with nodal pricing
9. DSM

These measures best address the challenges and requirements of the Vietnamese power system for integrating a high proportion of VRE. In order to get a better overview of the prioritisation, the following table summarises the findings of the individual areas.

Area	Existing Vietnam´s regulation/ Actions in Vietnam	International best practices	Suggestion for Vietnam (Overall ranking)	Justification on reason for those suggestion
Regulatory framework	**Currently no structuring of market zones**	**Bidding zones**	**Bidding zones (6)** **Nodal pricing (8)**	The market structuring of a country into bidding zones or nodal pricing makes it possible to eliminate structural congestion in the electricity supply grid. This advantage arises from the fact that the transmission capacities of the bidding or cross-nodal zones are included in the electricity trade on the market. This allows the electricity market to better reflect the local electricity price from the local supply and demand ratio. A detailed description can be found in chapter 6.3.1.1. The outside effect of the measures is that the different electricity prices in the zones create a further incentive for investors and companies to invest in storage options and to behave in a grid-serving manner. Companies now have the opportunity to benefit from the different electricity prices, for example by adjusting their electricity purchases to the electricity market prices. The prioritisation that was carried out in the course of this report prioritised the bidding zones over nodal pricing. One reason for this is in any case the additional expansion of the digital infrastructure that is necessary for nodal pricing.
		Nodal pricing		
	Constant feed-in tariff (FIT)	**Load dependent FIT**	**Load dependent FIT (1)**	A load-dependent feed-in tariff enables the interests of the grid operator and the VRE system owner to be aligned. The international experience of the United States shows that the problem of the duck curve (Figure 34) can be mitigated. In addition, incentives are set for investors to invest in battery storage systems, which enable the overproduction of solar PV systems at midday to be used in the evening. In this way, the grid integration of VRE is additionally supported.
	Mobilisation and curtailment via power plant grouping	**Redispatch 2.0**	**Adaptation of the redispatch 2.0 variant to Vietnam (7)**	The Redisptach 2.0 approach from Germany offers the possibility of integrating renewable energies into the curtailment order in such a way that congestion can be eliminated more quickly and efficiently. By using minimum factors, a prioritisation of the renewable energy plants can still be ensured. In this way, curtailment costs are minimised.
Digitalisation /Automation	**Integration of the transmission grid level into the national scada system**	**Collection of Consumer Data at the distribution level by a Smart Meter Rollout**	**Integration of the distribution grid level into the national scada system and provision of fibre optic lines for increased data collection**	The need for data collection is increasing due to the expansion of solar PV systems at the distribution grid level. The digitalisation and connection of the substations at the distribution grid level with the national SCADA system in Vietnam is therefore essential to ensure the continued safe operation of the grid (see chapter 6.3.1.2). The expansion of decentralised VRE results in a higher data demand and therefore a high data flow. In order to be able to transmit this large amount of data safely and quickly, it is important to select the right communication medium. Fibre optic connections are especially important for particularly fast transmissions, which can both save costs and increase supply security in the event of impending congestion.

Area	Existing Vietnam´s regulation/ Actions in Vietnam	International best practices	Suggestion for Vietnam (Overall ranking)	Justification on reason for those suggestion
Grid-related measures	**Vietnam is currently in the process of increasing its transmission capacity through the expansion and construction of new AC transmission lines**	**HVDC**	**DTLR (4)** **HVDC and PST (5)**	DTLR and PST technology enable more efficient use of existing transmission capacity. In a direct comparison of these two measures, DTLR performed better in terms of prioritisation. The reason for this is that the effectiveness of DTLR at the transmission grid level in Vietnam is higher than that of PST technology. HVDC transmission has been identified to support the current North-South transmission link in Vietnam. The technology offers the advantages of low-loss transmission over long distances. In addition, grid stabilisation effects can be provided at the converter stations. These stabilisation effects could support the grid in the metropolitan areas around Hanoi and Ho Chi Minh City and in this way reduce congestion risks.
		PST		
		DTLR		
Market-related measures	**Introduction of an wholesale electricity market in Vietnam**	**Transmission BESS**	**Transmission BESS (2)** **Distribution BESS (3)** **DSM (9)**	BESS at the transmission and distribution grid level offers a good opportunity to store the overproduction of the solar PV systems at midday and to use it efficiently later, in the evening hours, when the electricity generation from the solar PV systems decreases significantly. Similar to the load-dependent feed-in tariff, the problem of the duck curve (Figure 34) can thus be mitigated. In the area of Prioritisation, the BESS at the transmission grid level have received a higher rating than the BESS at the distribution grid level. The reason for this is that the balancing energy from the BESS at the distribution grid level must undergo several voltage transformations if the balancing energy is not required locally. This results in additional losses and an additional stress on the substations, which reduces the effectiveness. The DSM offers a good opportunity to control the rapidly increasing electricity consumption in the urban areas of Ho Chi Minh City and Hanoi. However, this measure requires a high degree of digitalisation. Therefore, the measure scored the lowest overall number of points in the evaluation.
		Distribution BESS		
		DSM		

Table 13: Final overview of recommended measures in the different areas

Against the background of a further expansion of rooftop solar PV systems, further measures for the effective integration of solar PV generation at the distribution grid level need to be investigated. In 2020, as a result of the changes in the decision on the feed-in tariff for rooftop solar systems, the share of this technology has already increased to 4.2% and includes a capacity of 2.6 GW. The distribution grid level in Vietnam needs to be investigated and upgraded in this area in order to precisely identify the challenges of this level and to recommend specific solutions. For example, in the long term, a quota system should be introduced in which the instructions to reduce and mobilise resources are shared. In addition, a high degree of automation should be targeted in the long term for faster access to VRE systems.

Chapter

09

Adaptation of the work plan

9 Adaptation of the work plan

According to the TOR, a physical kick-off workshop was planned after signing the contract at the beginning of May 2020 with the necessary stakeholders given in Table 14. Due to the COV19 situation and the given restrictions, it is not possible to execute a physical workshop in Vietnam at the planned time. Furthermore, a resilient postponement in 2020 is not possible.

Table 14: Identified stakeholders

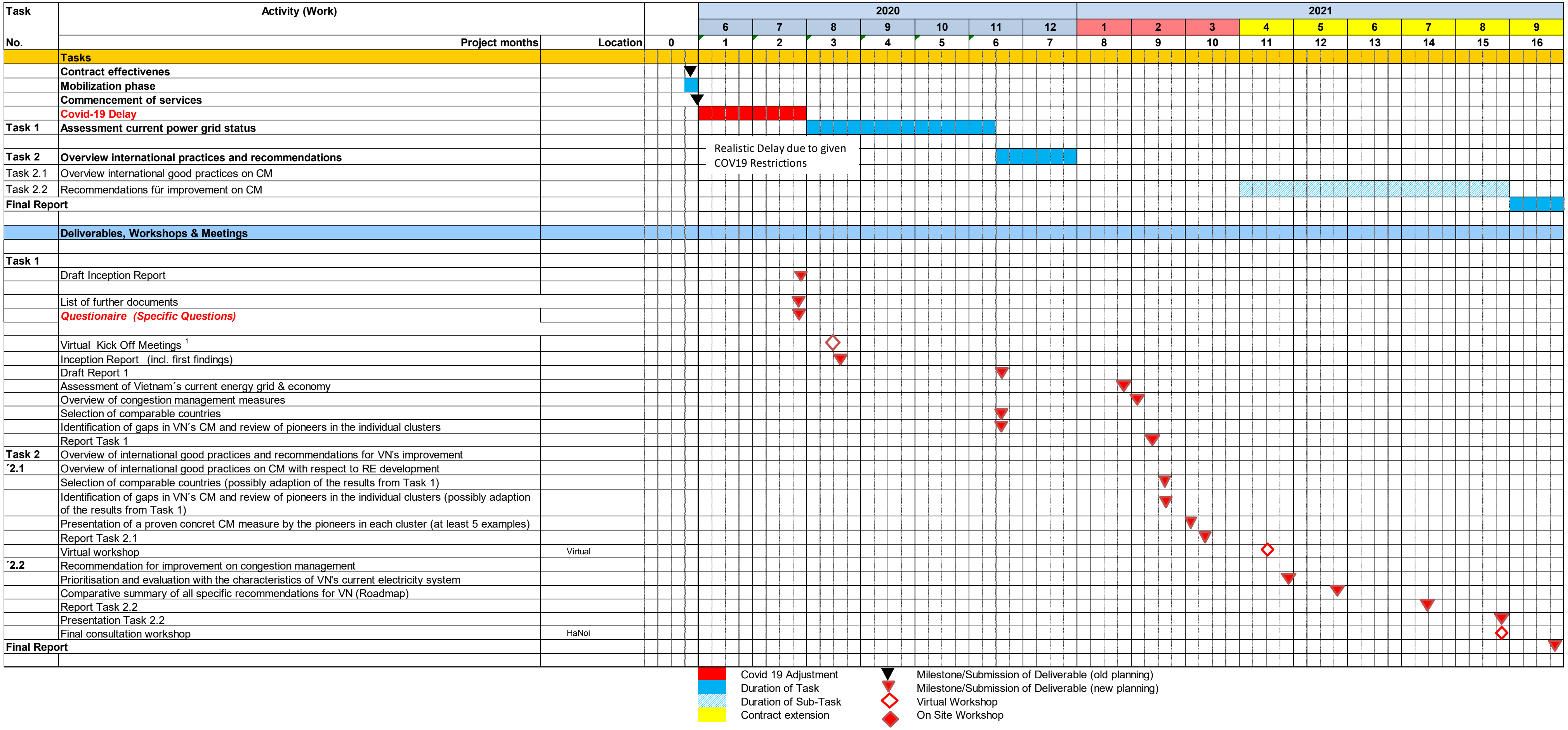
	Stakeholder	City
GIZ Vietnam	Greeting and Kick-off call: Grid management solutions	Ha Noi
ERAV	Electricity Regulatory Authority of Vietnam	Ha Noi
EREA	Electricity and Renew able Energy Authority	Ha Noi
EVN	Vietnam Electricity	Ha Noi
NLDC-A0	National Load Dispatch Center, System/Market Operator	Ha Noi
EVN NPT	National Power Transmission - EVN	Ha Noi
EPTC	Electric Power Trading Company -EVN	Ha Noi
IE	Institute of Energy, Vietnam	Ha Noi
EVN CPC	Central Power Corporation	Da Nang City
EVN CRLDC-A3	Central Regional Load Dispatching Center A3	Da Nang City
EVN SPC	Southern Power Cooperation	Ho Chi Minh City
EVN SRLDC-A2	Southern Load Dispatching Center	Ho Chi Minh City
EVN GENCONS	EVN Owned Generation Companies	To be determined
IPP	Independent Power Plants	To be determined

Therefore, we propose an approach that takes into account the restrictions regarding COV19 and the stakeholder situation, and in our opinion can also increase the efficiency of the project. The revised project plan as well as a preliminary schedule for a site visit mission is given in the following.

9.1 Revised project schedule

Due to the COV19 restrictions and the discussion in the inception call on 24th of June 2020, GIZ and ERAV suggested to hold all workshops virtually until COV19 is settled down and international flights are opened again without quarantine requirement. The new virtual kick-off workshop is scheduled (planned) on the beginning of August 2020 (Figure 42). Perspectively – if it is possible due to COV19 restrictions – the Final Consultation Worshop should be on site.

Figure 42: Revised project schedule



Task No.	Activity (Work) Project months	Location
	Tasks	
	Contract effectivenes	
	Mobilization phase	
	Commencement of services	
	Covid-19 Delay	
Task 1	**Assessment current power grid status**	
Task 2	**Overview international practices and recommendations**	
Task 2.1	Overview international good practices on CM	
Task 2.2	Recommendations für improvement on CM	
Final Report		
	Deliverables, Workshops & Meetings	
Task 1		
	Draft Inception Report	
	List of further documents	
	Questionaire (Specific Questions)	
	Virtual Kick Off Meetings [1]	
	Inception Report (incl. first findings)	
	Draft Report 1	
	Assessment of Vietnam´s current energy grid & economy	
	Overview of congestion management measures	
	Selection of comparable countries	
	Identification of gaps in VN´s CM and review of pioneers in the individual clusters	
	Report Task 1	
Task 2	Overview of international good practices and recommendations for VN's improvement	
´2.1	Overview of international good practices on CM with respect to RE development	
	Selection of comparable countries (possibly adaption of the results from Task 1)	
	Identification of gaps in VN´s CM and review of pioneers in the individual clusters (possibly adaption of the results from Task 1)	
	Presentation of a proven concret CM measure by the pioneers in each cluster (at least 5 examples)	
	Report Task 2.1	
	Virtual workshop	Virtual
´2.2	Recommendation for improvement on congestion management	
	Prioritisation and evaluation with the characteristics of VN's current electricity system	
	Comparative summary of all specific recommendations for VN (Roadmap)	
	Report Task 2.2	
	Presentation Task 2.2	
	Final consultation workshop	HaNoi
Final Report		

[1] EREA, ERAV, IE, EVN, EVN NLDC A0, EVN NPT, EVNSPC, EVNCPC, EVN CRLDC A3, EVN SRLDC A2, GIZ, RCEE-NIRAS

9.2 Organisation of the virtual kick off workshop

After a first analyses of the stakeholder situation by RCEE NIRAS and Fichtner, a virtual kick off workshop with the following stakeholders are proposed:

- EVN (Vietnam Electricity)
- NLDC-A0 (National Load Dispatch Center, System/Market Operator)
- EVN SRLDC-A1 (Northern Regional Load Dispatch Center)
- EVN SRLDC-A2 (Southern Regional Load Dispatch Center)
- EVN CRLDC-A3 (Central Regional Load Dispatching Center A3)
- EVN CPC (Central Power Corporation)
- EVN SPC (Southern Power Cooperation)

Chapter

10

Findings from the first review of the documents

10 Findings from the first review of the documents

The findings of the first review were all discussed with the respective stakeholders in the kick-off-meeting. The minutes for the mentioned meeting can be found in 11.1.

ANNEXES

11 Annexes

11.1 Minutes

Greeting Call 26th of May 2020

20200526 Mintues
SGREEE Greeting Ca

Inception Call 24th of June 2020

SGREEE_Minutes_In
ception Virtual meet

KickOff Meeting Call 12th/13th/17th August

SGREEE_Minutes_Ki
ck_Off_Virtual meeti

Task 1 Presentation 21th December

SGREEE_Minutes_
1st Task report_Virtu

Intermediate Consultation Workshop: Grid management 20th April 2021

SGREEE_Minutes_A
A1_Congestion Mgr

11.2 Bibliography

Following Documents are already shared:

General

- Decision No. 1670/QD-TTg on the Development of Smart Grids in Viet Nam (in short: Smart Grid Road Map, SGRM)
- Grid Situation in Vietnam_September 2019
- Introduction presentation of Viet Nam's current power system
- General map of Viet Nam's RE projects
- EVN Annual Report 2018
- IEVN power sector and RE

Solar + Wind Incentive Incentive Mechanism + PPAs

- Decision 11/2017/QD-TTg of PM on Solar FIT
- Decision 02/2019/QĐ-TTg of Prime Minister amending Decision No.11/2017/QĐ-TTg on Promoting solar power development projects in Viet Nam
- Circular 16/2017/TT-BCT of MOIT on Project Development and Standardized Power Purchasing Agreement for Solar Power Projects
- Decision 13/2020/QD-TTg on New Solar FIT (Solar FIT 2)
- Decision 37/2011/QD-TTg on Wind FIT
- Decision 39/2018/QD-TTg on New Wind FIT (Wind FIT 2)
- Circular 02/2019/TT-BCT of MOIT on Project Development and Standardized Power Purchase Agreement for Wind Power

Power Market regulations + PPAs of other Power Plants

- Overview on methods of determining generation cost
- Circular 56/2014/TT-BCT of MOIT on the Method of Determination of Electricity Generation Costs, Sequence of Inspection of the Power Purchase Agreement (PPA)
- Circular 45/2018/TT-BCT dated 15th November 2018 promulgating operation of Viet Nam wholesale electricity market (VWEM) and amendment and supplements some articles to Circular 56/2014/TT-BCT provision on methods of determining generation prices and order to check electricity purchase contract.
- Overview of Viet Nam WholeSale Electricity Market
- Decision 8266/QD-BCT dated 10th August 2015 on Detailed Design of the Wholesale Electricity Market of Vietnam
- Decision 6463/QD-TTg dated July 22, 2014 on Conceptual design of the VWEM
- Circular 21/2015/TT-BCT (Ancillary Service contract regualtion)
- Circular 46/2018/TT-BCT (Ancillary Service contract regualtion)
- Decision_2093_QD-BCT_EN (Viet Nam Retail Market)

Electricity tariff regulations

- Decision 28/QD-TTg dated 7th April 2014 on Electricity tariff's structure

Dispatching regulations

- Circular 40/2014/TT-BCT dated 05th November 2014 stipulating the procedure for dispatching of national power system
- Circular 31/2019/TT-BCT dated 18th Nov 2019 supplement some Articles to Circular 40/2014/TT-BCT dated 5th Nov 2014.
- Circular 30-2019-TT-BCT of MOIT on amending and supplementing a number of articles of the Circular No. 25/2016/TT-BCT dated November 30, 2016 of the Minister of Industry and Trade regulating electricity transmission system and the Circular No. 39/2015/TT-BCT dated November 18, 2015 of the Minister of Industry and Trade regulating the electricity distribution system
- Circular No. 25/2016/TT-BCT dated November 30, 2016 of the Minister of Industry and Trade regulating electricity transmission system
- Circular No. 39/2015/TT-BCT dated November 18, 2015 of the Minister of Industry and Trade regulating the electricity distribution system

Planning regulations + upcoming RE projects

- Resolution 55-NQ/TW of Politburo on the Orientation of the Viet Nam's National Energy Development Strategy to 2030 and outlook to 2045
- Decree 37/2019/NĐ-CP of GoV on Elaboration of the Planning Law
- Decision 329/QĐ-BCT of MOIT on the Principle and Order of Priority for Adjustment and Addition of Power Projects into Power Plans
- Documnent 2491-BCT-DL on the Request and Proposal for Extending the Feed-in-Tarriffs for Wind Power in Decision 39
- Document 1931/BCT-DL dated 19th March 2020 request PM for supplementing the planning on wind power project
- Document 3299/BCT-DL dated 8th May 2020 request PM for supplementing the planning on wind power project (second time)
- Document 2199/BCT-DL dated 27 March 2020 of MOIT request PR for supplementing transmision projects to Power Development plan

RE-related hurdles (Congestion + Curtailment)

- Summary-of-Power-release-of-RE-in-Viet-Nam
- Operation of RE sources in Binh Thuan and Ninh Thuan province 2019-2020
- Congestion Articles
- Ability to release wind power capacity in the period of 2020-2021
- Documents 1791/DDQG-TTD dated 28th May 2019 on dispatching principle of RE sources
- Documents 5378/BCT-DTDL dated 29th July 2019 on dispatching principle of RE sources
- GRID CAPACITY ASSESSMENT
- Reports of Grid Status at some hot-spots regions (EVN, ERAV, EREA, MOIT)
- Presentation of current Viet Nam Power system with major challenges
- EVN NLDC, "Updates on solar and wind power development in Vietnam," 2019
- EVN NPT, "Grid analysis for injection of renewable energy in central and southern region of Vietnam," Hanoi, 2018
- Other studies and technical assistance programs exisiting to improve grid management with respect to RE development in Vietnam

Previous Studies + Other Supporting Documents

- SGREEE_DeskStudy_Renewable Curtailment in Germany

- Final Report: Technology Assessment of Smart Grids for Renewable Energy and Energy Efficiency
- Final Report: Gap analysis & review of the regulatory framework for smart grid development that enables integration of Renewable Energy and Energy Efficiency
- "Initiatives or ouputs of activities under the bilateral cooperation project Smart Grids for Renewable Energy and Energy Efficiency (SGREEE)"
- Other Legislative documents
- EREA & DEA, "Detailed grid modelling of the Vietnamese power system. Background to the Vietnam Energy Outlook Report 2019," 2019.
- EOR 19 - Vietnam Energy Outlook Report 2019 (DEA & EREA)
- Intergartion of Renewable Energy targets into Viet Nam's Power system (World Bank)
- Grid absorb capacity (Phase I + II)
- Assessment of grid-capacity in the Mekong Region for Wind and Solar (RE integration phase 1): Calculate grid absorb capacity up to 2021: evaluated grid absorb capacity for 2000 MW (already approved in power plans) and grid absorb capacity in 5 provinces (Ca Mau, Soc Trang, Bac Lieu, Tra Vinh, Ben Tre); Develop grid extension plan to absorb 6.300 MW RE up to 2021 (with several grid projects in 500, 220 and 110 kV); Recommendation for 20-30 grid improvement project – estimate investment less than 100 million $
- Assessment of grid-capacity in southern region for Wind and Solar (RE integration phase 2): Assess grid absorb capacity and grid development plan in southern region plus Binh Thuan, Ninh Thuan up to 2030; RE development plan will be used base on C2 scenarios of EOR 2019, in which up to 2030, solar power is 27 GW, wind offshore 4 GW, wind onshore 10GW and no coal fired after 2025 (compare with several provincial RE development plans); Grid development consider only 500 and 220 KV and 110 kV to connect and collect RE power with power flow model; Grid development consider only 500 and 220 KV and 110 kV to connect and collect RE power with power flow model
- REPORT IN PDP8 WORKSHOP PRIMARY ENERGY INPUT PARAMETERS AND RESULTS POWER SOURCE DEVELOPMENT PROGRAM
- OFFSHORE WIND ROADMAP FOR VIETNAM - WB (GWEC-conference-Jun-2020)
- Prepareation for the operation of solar energy power plants in Viet Nam (EN)

Additional background documents

- Summary of Grid's congestion - related issues from NLDC operation report 2019 (BCTK 2019 A0)
- AGC - Curtailment principle (A0, NLDC)
- SG road map-2019 report and 2020 tentative plan_EN
- Bao cao tong ket LDTM 2019_final
- HVDC for PDP 8_PECC2_EN
- 2020-Operational Practices and Future Challenges for Renewable Energy as a Major Power Source in Japan
- CV gửi A0 cac PC ve thu tu huy dong
- Flexibility in 21 st Century Power Systems
- Interview_Strompreis_NguyenDucNinh
- RE update from ERAV Mr Hung
- TCBC ve DMTMN da len toi 9296 MWp

11.3 Questionnaires

20200608 Draft
Questionnaire 1 SGF

11.4 List of the additional documents provided

Grid development plan:

- https://www.netzentwicklungsplan.de/de
- 01_NEP_2035_V2021_2_Entwurf_Teil1
- 02_NEP_2035_V2021_2_Entwurf_Teil2
- 03_Punktmassnahmen_NEP_2035_V2021_2_Entwurf
- 04_Beitrag_Stromsektor_Dekarbonisierung_NEP_2035_V2021_2_Entwurf
- 05_NEP_2035_V2021_2_Entwurf_Systemstabilitaet

Redispatch 2.0

- 00_Regulatory_Framework
    - 00_NABEG_2.0_bgbl119s0706_77494
- 01_Core_Papers
    - 01_20181128_Diskussionspapier_Netzbetrieb_2.0
    - 02_Awh_2020-05-RD_2.0_Branchenlösung_Kerndokument
    - 03_Awh_2020-05_RD_2.0_LF_Ausfallarbeit
- 02_Description_Papers
    - 04_Bilanzieller_Ausgleich
        - BK6-20-059_Anlage1_vom_06_11_2020
        - BK6-20-059_Anlage2_vom_6_11_2020_ba
        - BK6-20-059_Anlage3_vom_06_11_2020
        - BK6-20-059_Beschluss_vom_06_11_2020
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