GRID INTELLIGENT SOLAR

Switching perception about utility scale solar and unlocking new business models

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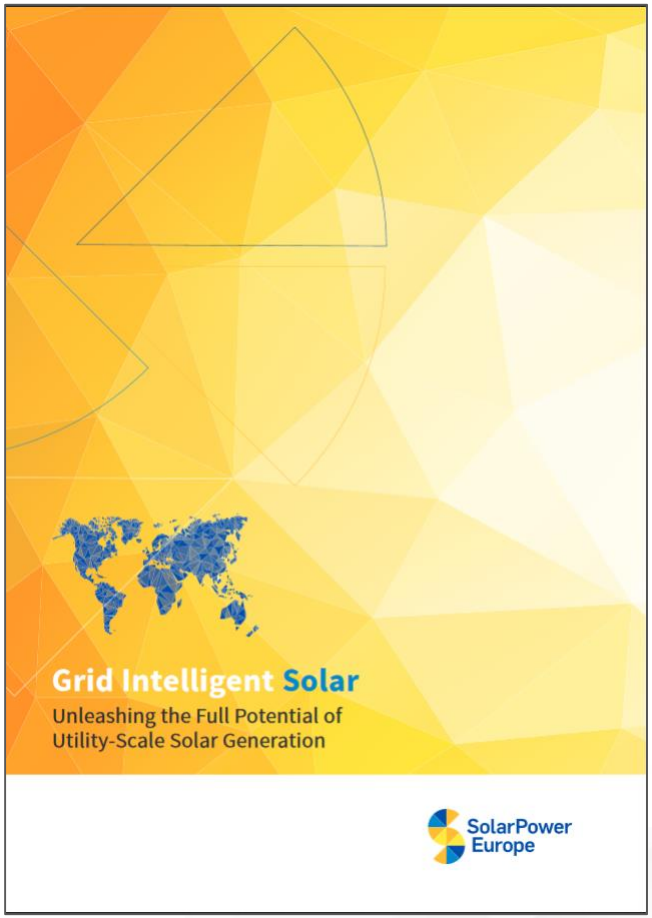
GRID INTELLIGENT SOLAR – PROBLEM STATEMENT

- The **continued penetration of Europe's transmission and distribution grids with RE imposes several challenges to the grid itself**
- Until today, **curtailment of RE generation** is the main measure in Europe taken by grid operators to ensure grid stability in case of overload
- On the way to Solar 3.0, we must **change the perception, that Solar PV is not manageable and imposing a significant threat to the grid**
- Examples from other global regions demonstrate, that **utility-scale Solar PV has a lot to offer to integrate itself well into the grid** and can help reduce the necessary investments of grid owners and operators on our way to a sustainable energy future



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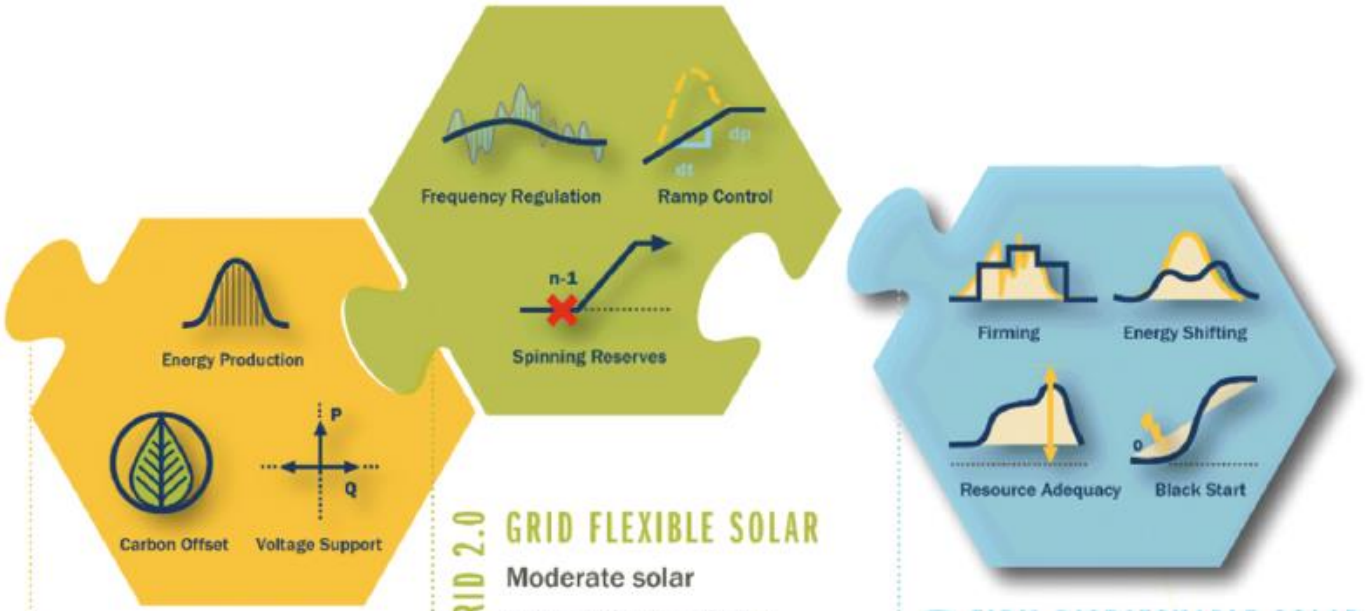
FROM SOLAR 1.0 TO SOLAR 3.0

FIGURE 4 THREE GRID PHASES OF SOLAR POWER PLANT EVOLUTION – BASIC SOLAR, GRID FLEXIBLE SOLAR, FIRM DISPATCHABLE SOLAR



GRID 1.0 **BASIC SOLAR**
Low solar penetration markets; maximizes energy production

GRID 2.0 **GRID FLEXIBLE SOLAR**
Moderate solar penetration markets; solar controlled to provide flexibility & grid reliability services

GRID 3.0 **FIRM DISPATCHABLE SOLAR**
High solar penetration markets; addition of storage provides firm dispatchable capacity

Source: First Solar.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Demonstration of Essential Reliability Services by a 300-MW Solar PV Power Plant

California ISO

First Solar®

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energ

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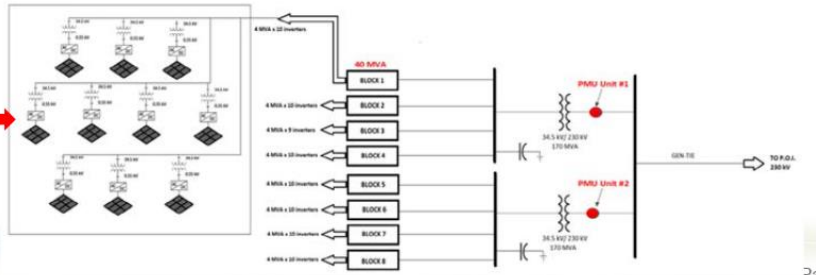
The capabilities of solar PV are there

Can variable energy resources provide essential reliability services to reliably operate the grid?

- NERC identified three essential reliability services to reliably integrate higher levels of renewable resources
  1. Frequency Control
  2. Voltage Control
  3. Ramping capability or Flexible Capacity

- Test results demonstrated utility-scale PV plant has the capability to provide these essential reliability services
- Advancement in smart controls technology allows these plants to provide services similar to conventional resources
- VERs (Variable Energy Resources) with the right operating characteristics are necessary to decarbonize the grid



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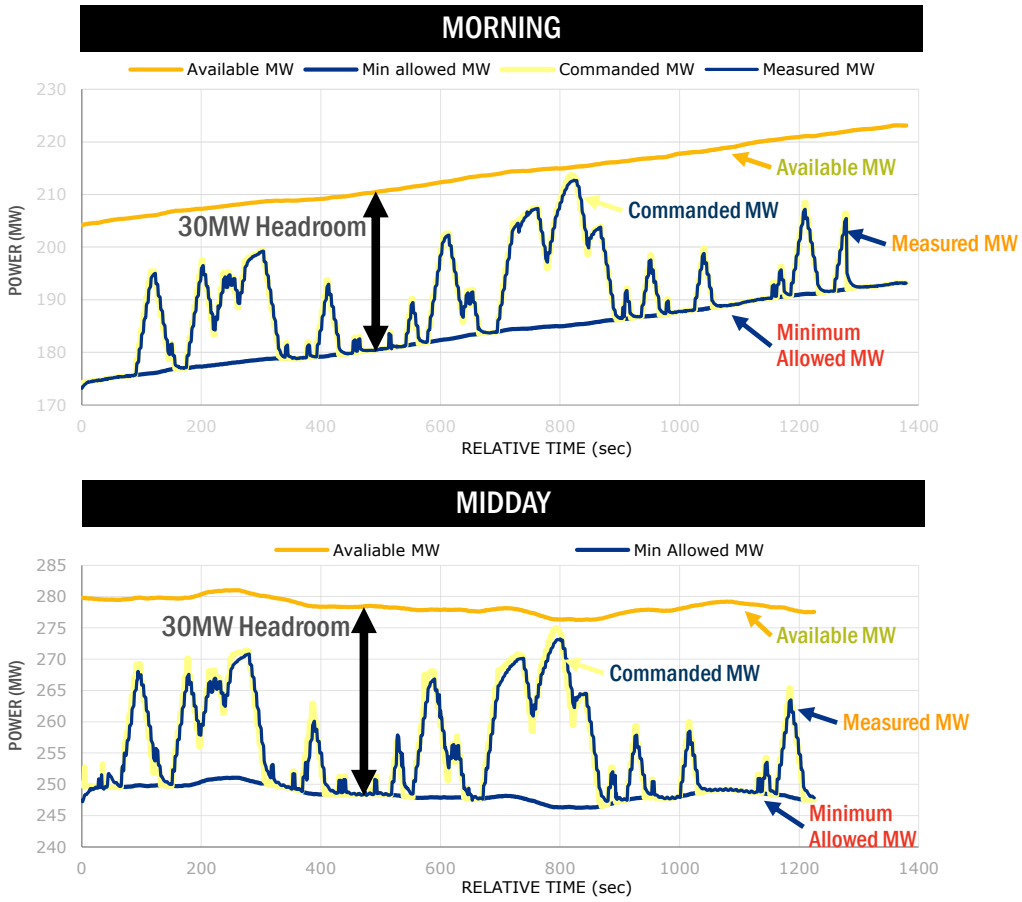
AGC Participation Tests: 300 MW Utility-Scale PV Plant



- 30MW headroom
- 4-sec AGC signal provided to Plant Controller
- Tests were conducted for
  - Sunrise
  - Middle of the day
  - Sunset

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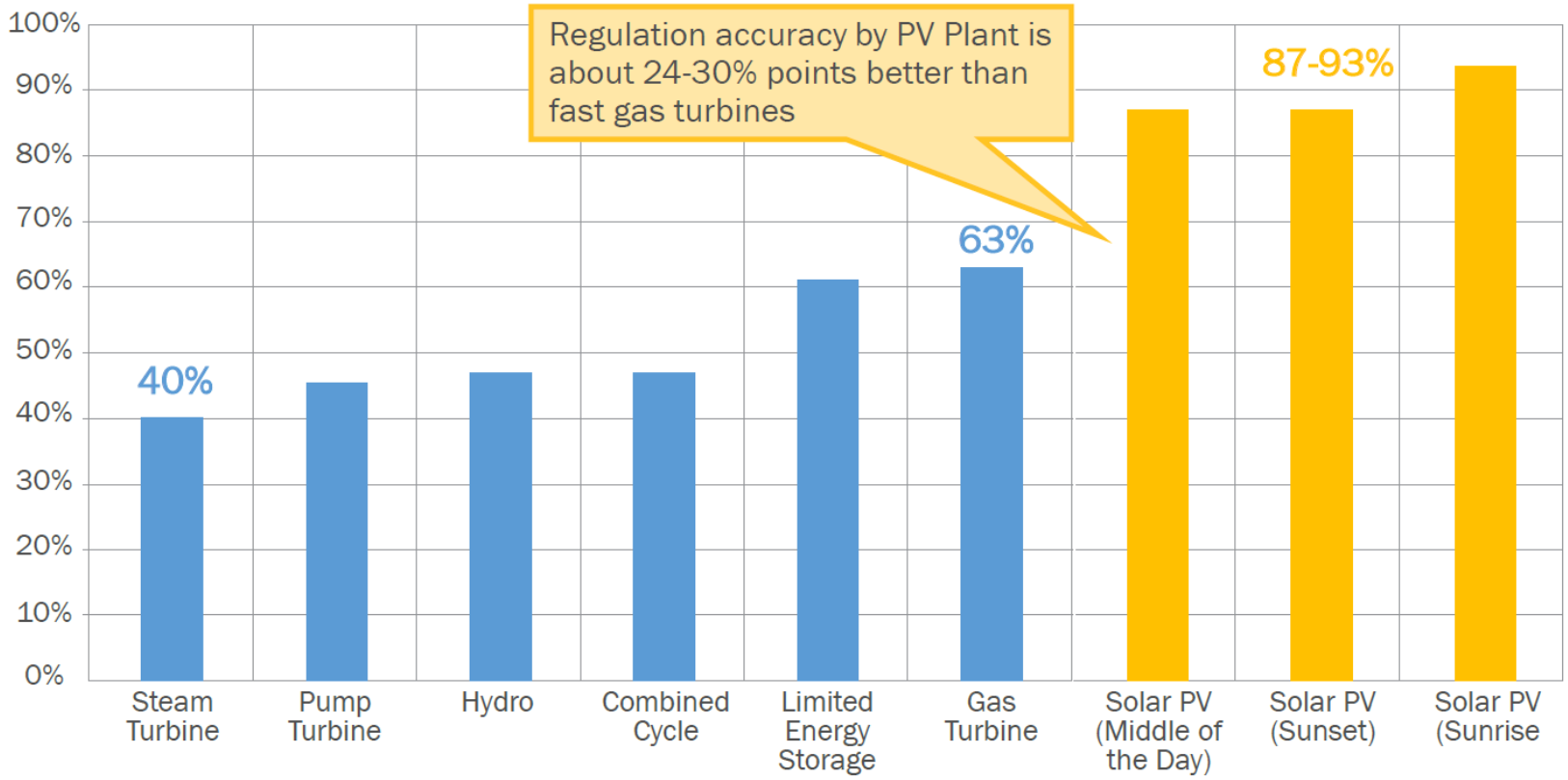
PV Plants Outperform Conventional Resources in Frequency Regulation



California ISO

Blue bars taken from the ISO's informational submittal to FERC on the performance of resources providing regulation services between January 1, 2015 and March 31, 2016

http://www.caiso.com/Documents/TestsShowRenewablePlantsCanBalanceLow-CarbonGrid.pdf

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CAISO/NREL Conclusions

- Advancements in **smart inverters** technology combined with **advanced plant controls** allow solar PV plants to provide power regulation, voltage support, and frequency response during various modes of operations.
- Solar PV resources with these **advanced grid-friendly capabilities** can enhance system reliability by providing:
  - Essential reliability services during periods of oversupply
  - Fast frequency response (inertia response time frame)
  - Frequency response for low as well as high frequency events.
  - Voltage support when the plant's output is near zero
- Variable energy resources with the right operating characteristics are **necessary to decarbonize the grid**

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KEY TAKEWAYS

- ✓ Through **intelligent plan control paired with solution-oriented plan sizing**, solar can create cost-effective flexible capacity supporting supply/demand adjustment
- ✓ Utility-scale solar Pv can provide features such as **ramping capability, voltage support, frequency regulation** and other services more accurately than conventional power plants
- ✓ Even **without storage, solar can achieve significant penetration on the grid economically**, and cost-effectively dispatched like conventional plants

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KEY RECOMMENDATIONS

RECOMMENDATIONS	STAKEHOLDERS INVOLVED
Ancillary Services markets should prioritize the dispatch of electricity generation units that are most cost effective and efficient and provide better regulation service capabilities.	
The availability of reliable data and more precise generation forecast information should be leveraged to increase the granularity of bids and scheduling of day ahead markets and dispatches to better match loads and resources.	
Planning, procurement, and contracting processes and procedures should be modified to more properly value flexibility in all resources.	
Variable renewable energy resources should be modeled as dispatchable in Integrated Resource Planning process of grid operators and utilities.	
Tender requirements for new renewable generations should value more flexible dispatch capabilities and the provision of grid services as well as plant controls and communications systems quality (e.g. as currently drafted in the German Innovation Tender program).	
Procurement of electricity by grid operators should incentivize the dispatch of plants in the most cost-efficient, grid-efficient and flexible manner.	
Utility-scale PV power plants need better access to ancillary services to reduce conventional "must run" capacity and allowing PV plants to generate income from such grid services.	

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