Renewable Energy Development;Application of Discrete Power Converter for Sustainable Development in Nigeria.

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Renewable Energy Development; Application of Discrete Power Converter for Sustainable Development in Nigeria

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Abstract: The development of Africa (especially Nigeria) has been hampered generally by inadequate sustainable technology development and application. According to world energy council, about 50% of Nigerians have no access to electricity and this is limiting the development of the country. Mechanization of small scale farming will also boost the agricultural production of this country at large. "Discrete Power Converter (DPC) also known as Kornich machine is a symmetrical compound machine based on particular combination in vertical plane and two rocking levers with two mechanical feedbacks, which is driven by gravity force of free-flowing mass oscillating mode and is able to transfer energy in the forms of reciprocating motion in vertical and horizontal planes." In this study, DPC will be discussed in details and the application of this technology to enhance sustainable development in Nigeria. Renewable energy potential and challenges in Nigeria will also be highlighted.

Keywords: *Discrete Power Converter, Renewable Energy, Solar, Wind*

A. Introduction

Renewable energy's contribution to global energy consumption is still below 20% (REN 21, 2017). Although in recent years, attentions have shifted towards the importance of energy access in developing countries for accomplishing the Millennium Development Goals (MDGs), Only 58% of Nigeria population has access to electricity (WEC, 2018). Nigeria is currently ranked 110th in the world energy ranking according to World Energy Council.

	2015	2016	2017	2017 Trend	2017 Score
Index Rank	101	104	110	▶	CDC
Energy Security	5	8	67	▶	C
Energy Equity	107	108	113	▶	D
Environmental Sustainability	102	101	98	▶	C

Figure 1: Nigeria Energy Index Ranking Chart (WEC, 2017)

Nigeria's energy security ranking has dropped in recent years and the priority for Nigeria should be energy source diversification. According to world energy council "Nigeria has one of the lowest shares of electrification, however is showing signs of progress, climbing from 48% of people having access in 2010 to 58% in 2014". Nevertheless, about 93 million Nigerians have no access to electricity (fig. 2).

Developing and improving transmission and distribution networks will continue to feature as priorities for the country's energy agenda (WEC, 2017). One of the factors that affect a country's energy sector is the per capital GDP. Germany which is one of the world leaders in solar photovoltaic installation capacity has a stronger GDP than all sub-saharan African countries combined (fig. 3).

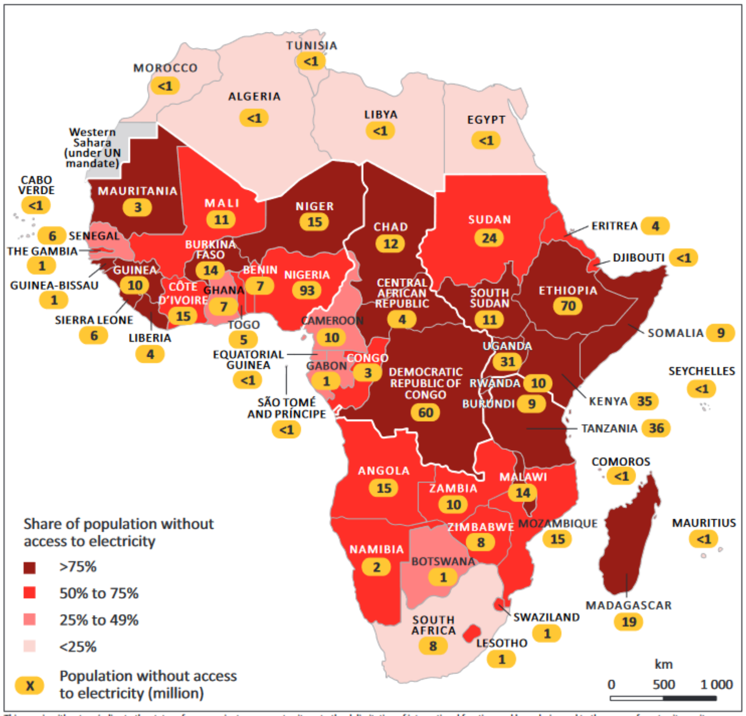

Figure 2: Number and share of people without access to electricity by country, 2012. (WEO2014_AfricaEnergyOutlook,)

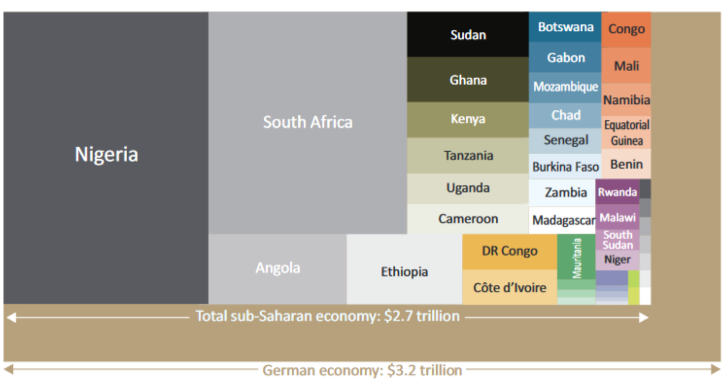

Figure 3: GDP of sub-saharan Africa and Germany in 2013. (WEO2014_AfricaEnergyOutlook,)

On the international stage, several agencies have stepped up their commitment in partnership with protocols from developing countries to address energy access issues focusing on sustainable development. Fortunately, energy has climbed the international policy agenda, impelled by concerns about the oil and gas prices, energy security, and connections to climate change. With the current pace of development, it's improbable that there will be significant change in existing grim energy access statistics (1.6 billion people in developing countries without access to electricity and 2.5 billion still using traditional biomass fuel for cooking) by 2030 (PAC, 2008). While these data are justifiably often quoted and act as drivers for energy access advocacy and policy, they fail to reflect the full extent of the energy access gap. Specifically, they do not amply manifest the need for energy in productive uses and basic processing in several different rural livelihood activities, undertaken everywhere in enterprises, farms, forests, mines, wells, workshops, river crossings and so on. The crucial point however, is that the energy end-use vector in all these cases is mechanical power, derived from whatever energy source is available. With this recognition, the contribution of mechanical power becomes apparent, and examples of its role in many applications can start to be mapped, along with their impacts, development outcomes and associated interventions.

Mechanical power is defined as 'the effective outcome of transforming different forms of energy sources (e.g. wind, hydro, fossil fuels etc) to kinetic energy (to cause motion)'. Mechanical power can further be broken down from an energy source perspective into that created by electrical and non-electrical power; the latter sources include human power, animal power, renewable/natural power or fossil energy without intermediate conversion to electricity. The local and global environmental impacts of mechanical power installations are linked mainly to the use impacts of the energy and the type of energy source being converted, with renewable sources clearly being less carbon intensive than fossil fuels for example. Of great concern is that, even though mechanical power is one of the oldest and most widespread forms of energy, there is often limited improvement in relation to technology or form of use apparent in impoverished regions of the world today. In this study, discrete power converter (DPC) which is based on a foundational principle is presented. The possible application of this technology to renewable energy development in Nigeria is also discussed. This work is divided into four sections. While section I introduces the subject in detail, section II reviews Nigeria's electrification access and renewable energy potential briefly. Section III focuses on DPC and the final section discusses the possible application of this technology.

B. Nigeria Electrification Access and Renewable Potential

Power generation in Nigeria is fixated on two major sources which are hydropower and natural gas. Electricity generation capacity of about 8,644 MW is estimated to have been installed, while an approximately 3,200 MW is said to be the available capacity. An estimate of 20,000 MW is potentially technically exploitable, so the hydropower potential of Nigeria is high and about 32 per cent of the total installed commercial electrical power capacity is credited to hydropower (BPE, 2012).

Although 40 per cent of the population utilize only about 109 kWh as annual electricity consumption per capita because of frequent power interruptions, load shedding and poor electricity infrastructure. The irregularities in electricity system of the country is pointed as a major factor responsible for poor economic growth, low creativity span, poor health services and slow technology advancement (IEA, 2005 and Federal Ministry of Power, 2006).

Only 10 percent of power connected to the national grid in 2009 managed to get to the rural inhabitants who make up 50 percent of the total population while electrification access stands at 50.6 percent (Obadote, 2009). Llugbo (2012) noted that theft and vandalism of cables and other essential equipments are wanted, in addition to inadvertent destruction of distribution lines and illegal connections, which often lead to over-loading of the distribution lines, unpredicted load shedding, protracted and intermittent outages. Various industrial outfits have accordingly resorted to private off-grid electricity generating sets (Olanrewaju, 2012).

Nigeria's renewable energy potential enormous. The country is endowed with some natural falls and large rivers which are responsible for the high hydro energy potential (Udochukwu et al., 2017). The total exploitable large-scale and small-scale hydropower potential are 11,250 MW and 3,500 MW (Table. 2). A summary of hydropower projects in Nigeria is given in Table. 1. The potential of small hydropower in Nigeria has been marred by inconsistent information. However, based on reports from the UNIDO Regional Centre on Small Hydropower, the potential for small hydropower gross for plants up to 10 MW is about 720 MW while the technically feasible potential is set at 605 MW and 498.4 MW is the economically feasible potential (Esan, 2011). 278 yet undeveloped sites for small hydropower production were listed in a study from 2006 and were said to have a total of 734.2 MW (with a definition of up to 30 MW) (Sambo et al., 2005).

Table 1: Hydropower Projects in Nigeria (https://www.africa-eu-renewables.org/market-information/nigeria/renewable-energy-potential/)

Power Station	**Capacity (MW)**	**Status**
Zungera Project	700	Financing Secured
Mambilla Project	3050	Under Development
Guarara II Project	360	Under Development
Guarara I Project	30	Under Development
Itisi Project	40	Under Development
Kashimbilla Project	40	Under Development

Nigeria is located within a high sunshine region and the country's solar radiation is well distributed. Solar radiation varies between 4.0 $kWh/m^2/day$ and 6.5 $kWh/m^2/day$ (Table 2) with annual average from 12.6 MJ/m^2-day to 25.2 MJ/m^2-day (Udochukwu et al., 2017).

Traditional biomass remains the most utilized renewable source of energy with about 43.4 million tonnes/yr of fuel wood used for cooking. Wind being a natural phenomenon is averagely distributed also in Nigeria. Table 2. Summarizes the renewable energy potential in Nigeria.

Table 2: Summary of Nigeria Renewable Energy Potential (https://www.africa-eu-renewables.org/market-information/nigeria/renewable-energy-potential/)

Resource	**Potential**	**Comments**
Large Hydropower	11,250 MW	1,900MW exploited
Small Hydropower	3,500 MW	64.2MW exploited
Solar	4.0 $kWh/m^2/day$ – 6.5 $kWh/m^2/day$	Significant potential for solar infrastructure; both for on-grid and off-grid use
Wind	Average of 2-4m/s @ 10m hub height	Moderate wind potentials in the country.
Biomass	Municipal Waste	18.5 million tonnes produced in 2005 and now estimated at 0.5kg/capita/day
	Fuel Wood	43.4 million tonnes/yr of fuel wood consumption
	Agricultural Residue	91.4 million tonnes/yr. produced
	Energy Crops	28.2 million hectares of arable land; 8.5% cultivated

A National Renewable Energy Policy was approved and launched in 2003; in addition to a National Energy Master Plan and a Renewable Energy Master Plan in final draft (Agbonaye et al., 2012). Much attention is geared towards stronger participation of the private sector linked with the expansion of electricity supply to 75 per cent of the population by 2025. This project also anticipates the promotion of renewable energies and their incorporation in the national energy mix (GATC, 2010). 18 per cent and 20 per cent of electricity from renewable energies by 2025 and 2030 respectively were the set goals, with broad objectives as follows (IREA, 2012):

- To raise energy security in the nation by diversifying the energy supply mix;
- To increase energy access especially in the rural and semi-urban areas;
- To alleviate employment creation and empowerment;
- To extenuate climate change and to protect the environment.

C. Discrete Power Converter

"Discrete Power Converter (DPC) also known as Kornich machine is a symmetrical compound machine based on particular combination in vertical plane and two rocking levers with two mechanical feedbacks and two capacities, which is driven by gravity force of free-flowing mass oscillating mode and is able to transfer energy in the forms of reciprocating motion in vertical and horizontal planes." An unprecedented mechanical compound machine patented for converting the energy of the falling under gravity force flow of water (or another free-flowing mass) directly in the energy of reciprocating motion (simultaneously in vertical and horizontal plane) of the linkage of machine. The kinematic scheme of this machine is based on specific combination of two rocking levers which are provided with periodical working strokes. The machine is capable to accumulate periodically the working mass into levering up capacities and to multiply (as mechanical advantage) the gravity force (as effort) during each discrete stroke in conformity with the law of the lever. Because of mechanical feedbacks, the mechanism is interchanging between lower and higher position as sequence of distinct actions, so that it functions in free-running mode (as oscillator) under gravity force. The Schematic diagram of DPC is shown in fig. 4.

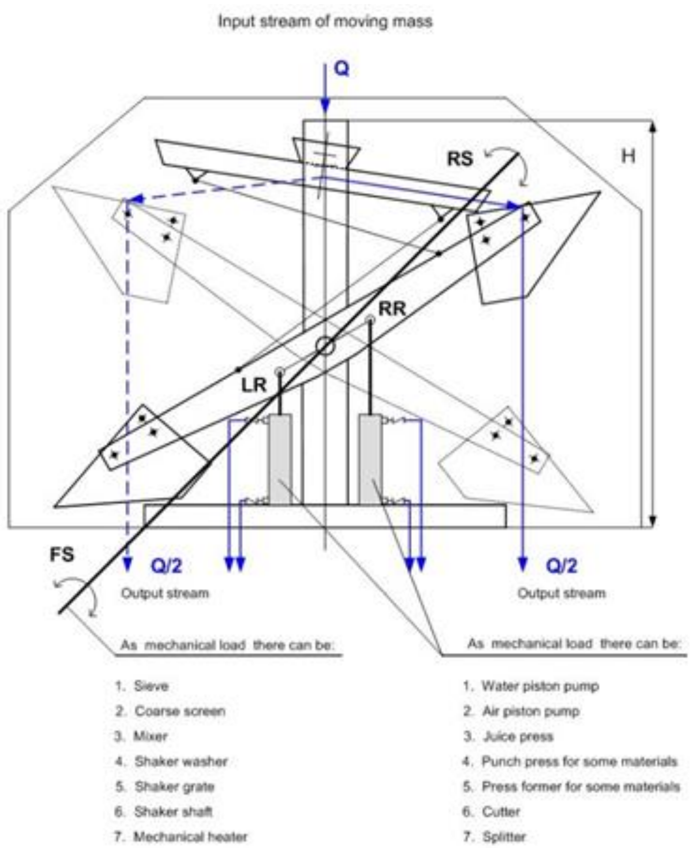

Figure 4: Schematic Diagram of DPC

Kornich machine can be connected easily (without some intermediate mechanisms) with mechanical loads of reciprocal nature (piston pumps, for example). Thus, the total efficiency and reliability of the system will be increased while complexity and cost price will be decreased. DPC utilization in practical applications allows expanding the possibilities of gravity force as prime mover in addition to water wheel as simple machine. Besides the transformation of mechanical energy, the DPC can split the input stream of free-flowing mass on two equal output streams, separated in space depending on the geometry of the converter.

D. Application

DPC primary concept is to construct a new mechanical prime mover (power converter) operating under gravity force (like a water wheel, but in a unique mode – reciprocating motion). Withal, clarity set in that DPC is as well a completely adequate mechanical model of the familiar electronic relaxation oscillator – a stable multivibrator (AMV). Thus, hydro analogy (as educational methodology particularly) was enriched by new additional tool which allows to visualize for students the similar processes caused by potential fields of different nature (gravitational and electrical accordingly). The cognitive value of DPC as the base for Educational Kit (small working model & CD) can be considered for further development.

DPC is applicable to several purposes where it can be attached directly to various useful loads of mechanical nature because both of output motions of machine (as prime mover) can be used at the same time: reciprocal in the vertical plane (by rocking beam), and the reverse rotation in the horizontal plane (by main shaft). Some examples of application of DPC machine with various mechanical loads are as follows:

Water powered piston pumps (air or water): In this configuration DPC is combined with two piston pumps which are connected symmetrically to the rocking beam of machine. DPC uses (as prime mover) reciprocating motion of arms of the beam which is like the motion of pistons (as load); thus, linkage is very simple, without any intermediate mechanisms (avoid extra losses). The input water flow (as working medium) can be taken from some natural sources (lake, water fall, creek, spring, and river). This application has been recommended for irrigation purposes on mountain landscapes in the rural area.

Filtering and desalination of brackish water: On the base of combination of DPC (as water powered mechanical driver) and water filter and desalination devices and equipment which already exist (Katadyn, for example) the small-scale brackish water desalination system (for households and farms) can be designed and manufactured in developing countries.

Hydropower: With the enormous hydropower potential in Nigeria and with the power supply problem in the country, application of DPC technology will be very good. This machine can provide electricity and maximize the hydro potential available. Also, this technology is applicable to the agricultural sector, it is highly efficient for farm irrigation and other related processes.

The feasibility of these technology is not discussed in this study as the technology is still at laboratory stage. The main goal of DPC currently is to build replicate the model and test in different application.

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