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Analysis of Smart Grid Interoperability

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ABSTRACT

The energy grid is currently undergoing a historical change of state from the traditional structure where a utility owns the generation, transmission and distribution services into an integrated smart grid in a monopolistic market which introduce consumers as active players in managing and controlling the power. This report provides an analysis of the methods applicable to smart grid interoperability tests. A systematic approach for developing smart grid interoperability tests was adopted by analyzing a house and an industries looking at the analysis of their active power. This analysis of active power gives the exact idea to know the range of maximum permissible loads that can be connected to their relevant bus bars. This paper presents the change in the value of Active Power with varying load angle in context with small signal analysis using wind, solar and generator (grid). The result obtained showed that, consumers can then choose the cheapest energy to be consumed.

KEYWORDS: *Smart grids; Smart meter; Photovoltaic systems; Wind energy, Load schedule, Load curve*

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INTRODUCTION

Electric energy is essential to increase productivity and ensure a high quality of life. Therefore, the relationship between electric power and economic growth is crucial. However, the consequence of the current worldwide economic growth and electricity demand is the depletion of energy resources. The essential and effective way to prevent the depletion of resources and promote economic growth at the same time is the application of the concept of energy efficiency through energy management systems. This is being the basic principle of the Smart Grid (Loschi, H.J., Leon, J., Iano, Y., Filho, E.R., Conte, F.D., Lustosa, T.C. and Freitas, P.O., 2015).

The transition from the traditional vertically integrated hierarchy of the energy companies into this form of "smart, intelligent grid" or "energy grid with brain" is no doubt a game change that will not be possible without the effective participation of the information and communication technologies to enable an instantaneous, all time, and safe two-way passage of information among the linked parties. It requires a systematic integration of the most advanced capabilities in the communication, data sensing and measurement and information technology to successfully transform the current scene from hundreds of centralized power sources, which supply receiving-end consumers with energy flowing in a one way direction only, into what potentially could be tens of millions of plug-in electric cars, thousands of distributed sources, demand response control and management programs, and other consumer-owned assets that constitute the concept of a smart grid (Tawfiq, 2019).

The concept of Smart Grid combines a number of technologies, customer solutions and addresses several policy and regulatory drivers. Smart Grid does not have any single obvious definition. The European Technology Platform defines the Smart Grid as: A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it (figure 1) generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies (EARPA, 2022).

Interoperability refers to the ability of two or more devices from the same vendor, or different vendors, to exchange information and use that information for correct cooperation. The ability of two or more networks, systems, devices, applications, or components to interwork, to exchange and use information in order to perform required functions. In addition, Interoperability between systems in a smart grid must be considered and well specified in use cases, in order to develop interoperable Smart Grid systems by design. Use cases provide a basis for the specification of functional requirements, non-functional requirements, test cases and test profiles (Papaioannou, I., Tarantola, S., Lucas. A., Kotsakis, E., Marinopoulos, A., Ginocchi, M., Olariaga G. M., Masera M. 2018).

Luca, A., Giuseppe, P., Giuseppe, M., and Maurizio, M., (2013) reviewed Smart Grid Technologies in Europe. Luca *et al,* analysed the state-of-the-art of smart grids, in their technical, management, security, and optimization aspects. Provision was made for a brief overview of the regulatory aspects involved in the development of a smart grid, mainly from the viewpoint of the European Union.

It is obvious that smart grid technology is the best when compared to the traditional power sector. However many countries have not embraced this and because of this, such countries like Nigeria is having a lot of challenges with power supply.

Smart grid interoperability technologies has large initial cost of set up but at long run, it is cheaper, more convenient at both consumers and the distributor's end. There will be what we call check and balances with less stress or no stress at all. With this technology generation will be distributed and not centralized like it use to be, that means flow of information will be two way. More advantages of smart grid technology will be detailed in table 1.

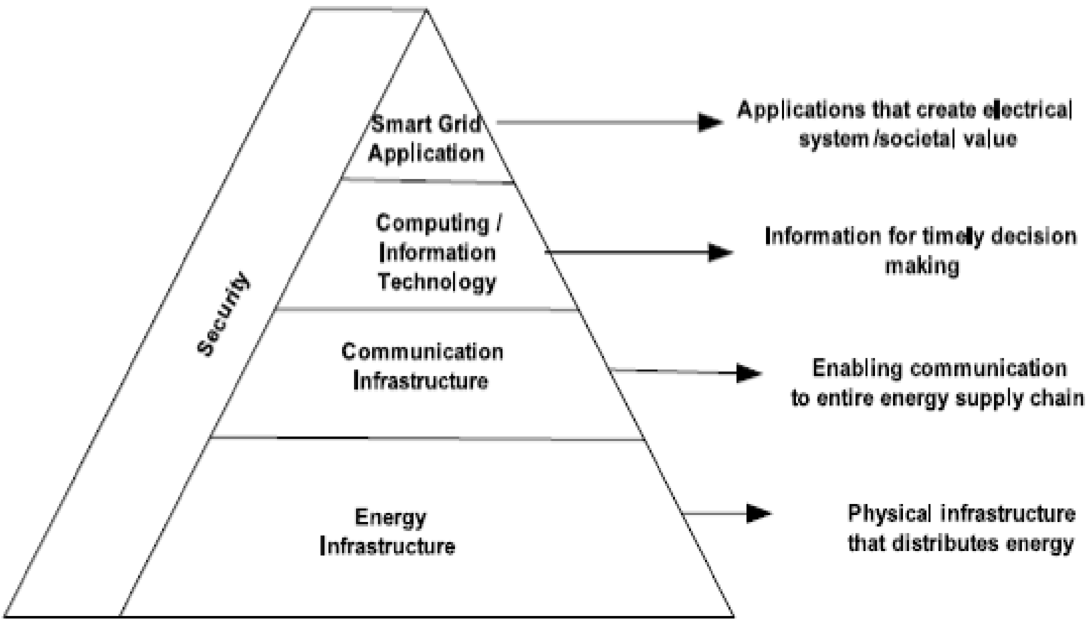

Figure 1: Description of Smart Grid

SMART GRID AND THE TRADITIONAL POWER GRID

Table 1 shows the differences between Smart Grid and the traditional power grid (Amuta, E., Wara, S., Agbetuyi F., and Matthew, S., 2018).

Table 1: Difference between Traditional Power Grid and Smart Grid

S/N	Characteristics	Traditional Power grid	Smart Grid
1	Customer interaction	Limited	Extensive
2	Metering	Mainly electromechanical	Digital (enabling real-time pricing and net-metering)
3	Restoration following Disturbance	Manual	Self-healing
4	Power flow control	Limited	Comprehensive, automated
5	Reliability	Prone to failures and cascading outages; essentially reactive	Automated, pro-active protection; prevents outages before they start
6	Transmission/Distribution Line Losses	Above ten percent (10%) loss of the total power in the transmission/distribution lines.	About two percent (2%) loss of the total power in the Transmission/distribution lines.
7	Flow of information	One-way	Two-ways

8	Generation of electricity	Central	Distributed
9	Pollution of the environment	Very high	Low
10	Efficiency of the overall grid	Poor	Excessive
11	Ability to monitor	Blind	Self- monitoring
12	Topology of the grid	Spiral	Networked

PROPOSED NETWORK

The major mechanism of a Smart Grid (Figure 2) are electric power generators, electric power substations, transmission and distribution lines, controllers, smart meters, collector nodes, and distribution and transmission control centers. Power generators and electric power substations use electronic controllers to control the generation and the flow of electric power. All of the subsection is explained as follows:

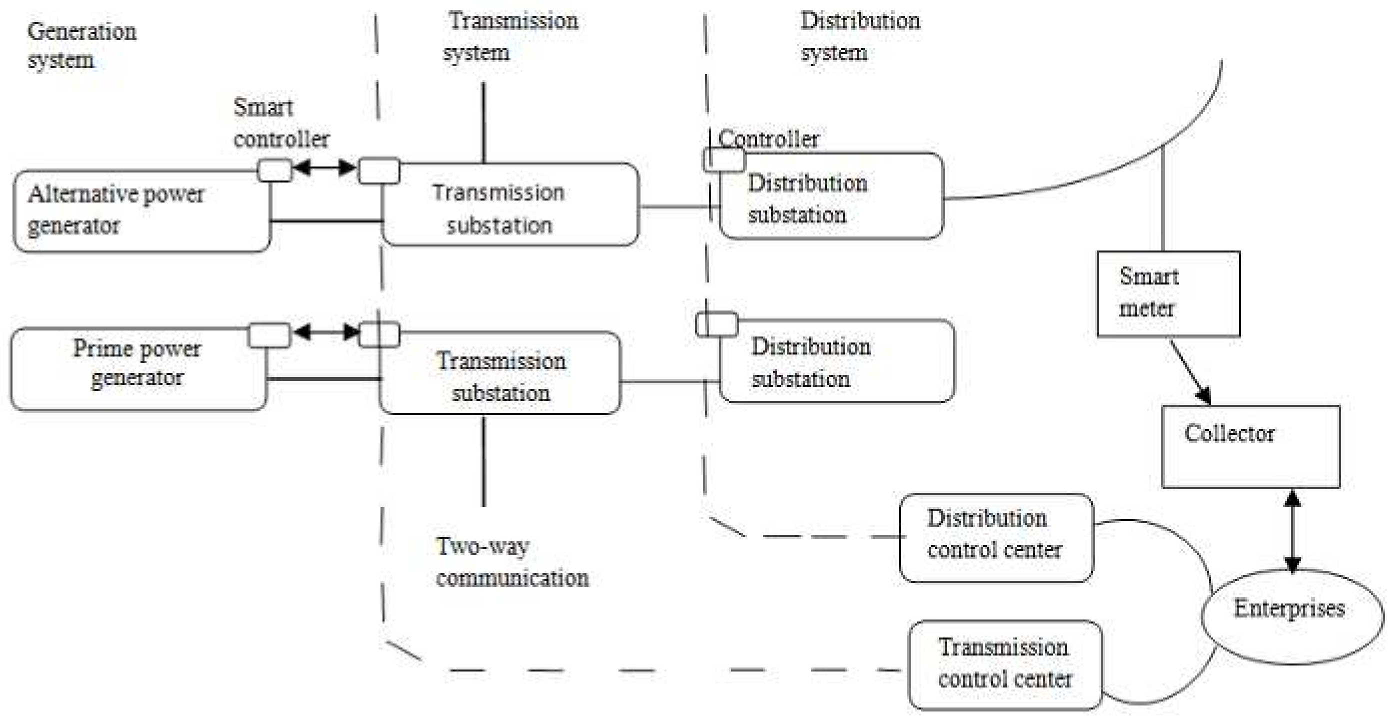

Figure 2: Block diagram of typical smart grid components and connections (Anastasia, 2012).

Alternative power generator

Alternative power generators produce electricity from renewable energy sources. Renewable energy is energy that is collected from renewable resources which are naturally replenished on a human timescale. Such as: Wind, Solar, Hydropower and so on.

Smart Controller

The intelligent controller involves the collection of simulation objects operating as controllers using actual internet communication and running in real time. The intelligence of the controller involves running simulations of the distributed system or subsystem concurrently with the control of the generation and the flow of electric power.

Prime power generator

Prime power generators are commonly used as a site's primary source of continual power which serves as the source of operation. They can also be used for on-grid applications. It is designed to work long term. Most often, the prime generator is designed to offer a variable power load that is drawn over time.

Transmission substation

A transmission substation connects two or more transmission lines. The simplest case is where all transmission lines have the same voltage. In such cases, substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. This transmission substation can range from simple to complex.

Distribution substation

A distribution substation transfers power from the transmission system to the distribution system of an area. It is uneconomical to directly connect electricity consumers to the main transmission network, unless they use large amounts of power, so the distribution station reduces voltage to a level suitable for local distribution.

Controller

A controller is an individual who has responsibility for all accounting-related activities, including high-level accounting, managerial accounting, and finance activities, within a company. A financial controller typically reports to a firm's chief financial officer (CFO), although these two positions may be combined in smaller businesses.

Smart meter

Smart meter is an advanced energy meter that measures electrical energy consumption and provides additional information as compared to a conventional energy meter. It aims to improve the reliability, quality and security of supply. Smart meters allow utilities to determine how much energy you pull from the grid at any point in time.

Distribution control center

These features include the capability to generate the proper electrical signals and simulate large distribution systems with diversity of devices, distributed sources and load models among others aspects related with the functional operation in control centers. Today's power distribution control center manages the day-to-day operation of distribution network to ensure uninterrupted power supplies to the end customers.

Transmission control center

The transmission control centre is the real heart of every utility's power system operations. Transmission system control centers serve a critical function in today's power systems as the nerve center which integrates numerous automation and control technologies and as the command center from which system operators monitor and control remote system assets. Typical transmission control centre's have three main desks – the generation, transmission and scheduling desk.

Collector

A collector is a device that is primarily used to active solar heating and allow for the heating of water for personal use. A collector is the center point between the substation and the smart meters.

LOAD ANALYSIS

In order to analyze home and industrial loads, the following table was used: Table 2 showing all the loads consumed at various time and how the grid switches in automatically without any human intervention on like the traditional grid. While table 3 showed the industrial load as they were been consumed and how much energy was needed at each time. The analyzed results are plotted in figure 3 and 4 respectively.

Table 2: House load schedule

Time (hrs)	Pgrid (KW)	Psolar (KW)	Phouse (KW)	Pwind (KW)
0	0	0	1	5
1	0	0	1	5
2	0	0	1	5
3	0	0	1	5
4	0	0	1	5
5	0	0	1	5
6	0	0	1	5
7	7	0	1	5
8	7	0	1	5
9	7	0	1	5
10	7	0	1	5
11	7	0	1	5
12	7	0	1	5
13	7	0	1	5
14	7	0	1	5
15	7	0	1	5
16	7	0	1	5

17	7	0	1	5
18	7	0	1	5
19	7	3	6	5
20	7	3	6	5
21	7	3	6	5
22	7	3	6	5
23	7	3	6	5
24	7	3	6	5

Table 3: Industrial load schedule

Time (hrs)	Pgrid (KW)	Psolar (KW)	PIndustry (KW)	Pwind (KW)
0	15	0	13	10
1	15	0	13	10
2	15	0	13	10
3	15	0	13	10
4	15	0	13	10
5	15	0	13	10
6	15	0	13	10
7	15	0	13	10
8	15	10	9	10
9	15	10	9	10
10	15	10	7	10
11	15	10	7	10
12	15	10	7	10
13	15	10	7	10
14	15	10	7	10
15	15	10	7	10
16	15	8	6	10
17	15	4	4	10
18	15	4	4	10
19	15	4	4	10
20	15	0	4	10
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22	15	0	4	10
23	15	0	4	10
24	15	0	4	10

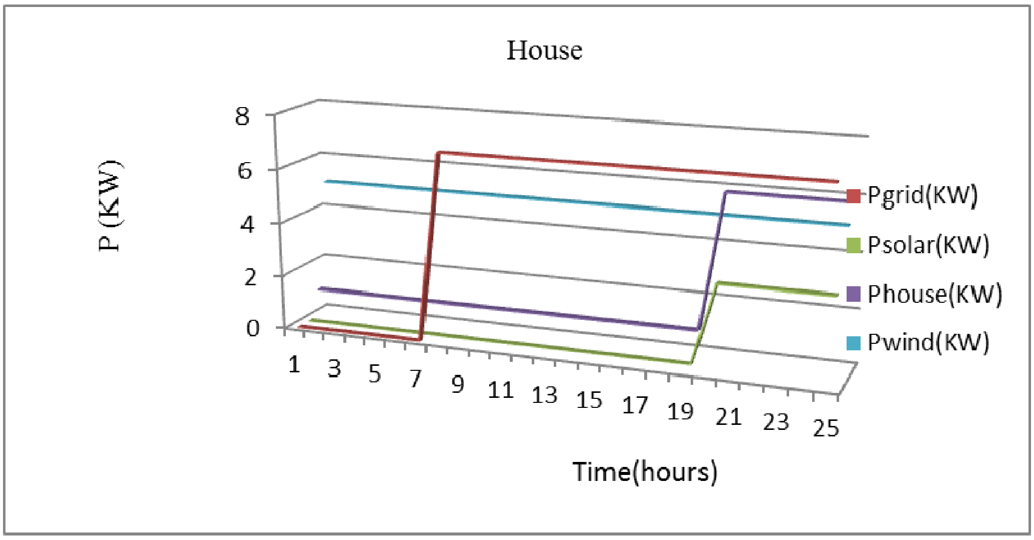

Figure 3: The house analysis results

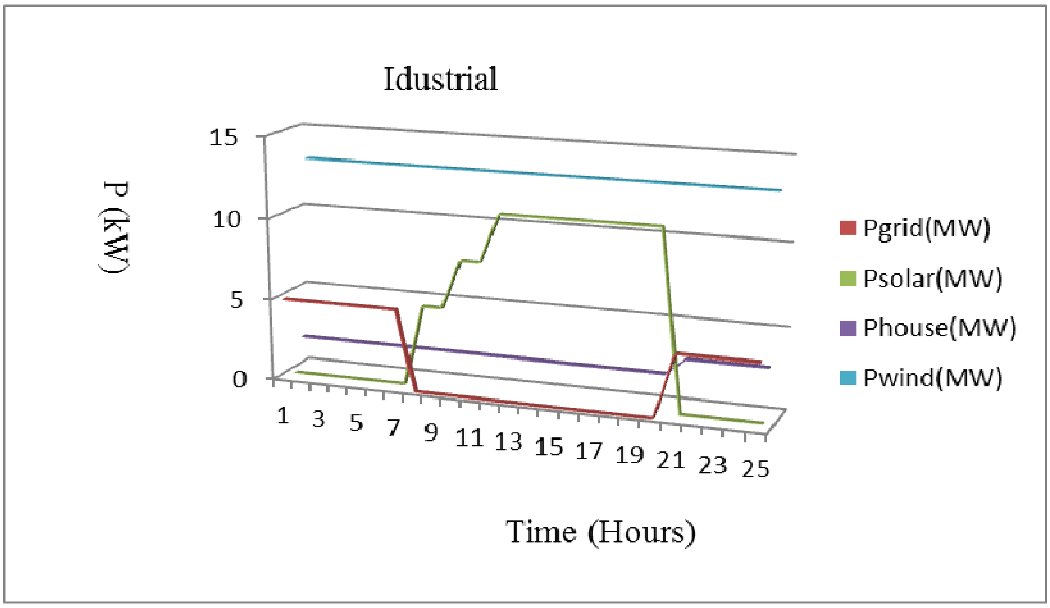

Figure 4: The Industrial analysis results

RESULTS AND DISCUSSION

Here analysis of a house and an industry was looked into, with the analysis of their active powers. After the analysis, the following results were obtained.

The house, shown in Figure 3, was powered by two energies, wind energy of 5KW and the grid. Its load curve is described by the following program: from 0:00 to 7:00am, the house consumes a constant electric power of 1KW supplied by the wind turbine. At 7:00 am, there was a peak of load reaching a value of 5KW, also supplied by the wind turbine. As a result, the house remains isolated from the generator until 7.00 pm where a second peak of 7KW of power was observed and must last until 23.00. During this period the grid intervenes to fill the gap.

Unlike the house, the industry has important pools of production and consumption. The industry, shown in Figure 4, contains a solar park with a capacity of 10MW and was connected to the grid, so it is powered by both energy sources. Its load curve is described by the following distribution: from 00h00 to 6h00 it consumes a constant power of 13MW provided by the grid. With the arrival of the workers and the start-up of the machines of the industry, a peak of 9MW power is observed and only the grid takes care of it. At 8:00 am where the solar energy appears and begins to provide energy, both energy are operational but solar energy cannot satisfy this demand alone, and the peak will last until 10:00. Following a reduction in power of 7MW, the grid is released and only the solar park feeds the plant. A second peak of 6MW was observed at 15h00 and continues until 16h00, which again involves the grid. At 5 pm, with the closure of the industry, consumption was reduced to 4MW. The latter is provided by the solar park until 19:00 with the sunset, the grid was used again until the end of the day.

CONCLUSION

The anticipated model involves both types of solar and wind energy under normal operating conditions and this explains the energy swap between consumers and grid. The cost of electricity was not taken into reflection, but the different consumers can choose the cheapest energy. The industry consumes more between 8am and 3pm as the demand increases and decreases between 10MW to 13MW and then 9MW and it was maintained at 7MW. While for the home, the peak load starts from 7pm till dawn.

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