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Energy Efficiency in Smart Grid: Using Automatic Relay on Energy Management Systems

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ABSTRACT : The current state of development in demand response (DR) programs in smart grid systems, there have been great demands for automated energy scheduling for residential customers. Recently, energy scheduling in smart grids have focused on the minimization of electricity bills, the reduction of the peak demand, and the maximization of user convenience. Thus, a user convenience model is proposed under the consideration of user waiting times, which is a non-convex problem. Therefore, the non-convex is reformulated as convex to guarantee optimal solutions. Moreover, mathematical formulations for DR optimization are derived based on the reformulated convex problem. In addition, two types of pricing policies for electricity bills are designed in the mathematical formulations, i.e., real- time pricing policy and progressive policy. In real-time pricing policy, convexity is guaranteed whereas progressive policy can not guaranteed.To reduce energy demand with solar energy to the grid during peak load.The reduction of the peak demand and the maximization of user convenience.using Advanced metering with automated relay in power distribution.

KEYWORDS : Smart Grid, Management, Cloud Computing, Energy, Efficiency ,Relay

I. INTRODUCTION

In the last few decades, global electricity consumption has dramatically increased and fluctuated in uncertain ways, causing blackouts. Due to the unexpected peak electricity demands, a significant electricity supply is required. One promising solution to this problem is the use of smart grid systems envisioned as a future power system. The smart grid systems are capable to reduce the electricity peak and induce effective electricity consumption through various price policies, demand response (DR) control methodologies, and state-of-the-art smart equipment in order to optimize electricity resource usage in an efficient way .The current state of development in smart grid systems, Improves the automated scheduling schemes on the consumer side.

The current scenario of residential smart grid systems.composes of a retailer, advanced metering infrastructure (AMI), load controller, scheduling manager, database, and a number of appliances. DR is one of the key technologies for smart grid systems and there are two types of DR in the literature, i.e., incentive-based programs and price-based programs. The incentive-based DR program is designed to induce smaller amount of electricity use at times of high market price or when grid reliability is "jeopardized". On the other hand, a price-based DR program is defined as a tariff or program established to motivate changes in the price of electricity to reduce energy demand with solar energy to the grid during peak load.

The reduction of the peak demand and the maximization of user convenience.Advanced metering with automated relay in power distribution. Nowadays, wireless technology has given a big impact in term of security and privacy of users. Secure and efficient communication between human being and managed devices is critical for Smart Grid System. The main point is to resolve the peak problem by enabling real-time communications between the customer and the utility. The 74 degrees Celsius, which has caused a variety of environmental problems, such as climate change and rising sea levels. Furthermore, fossil fuel is being exhausted because of a sharp increase in the consumption of energy after the Industrial Revolution. Some environmental experts expect that fossil fuel will run out

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completely in the near future. For this reason, recently, smart grid technology used for sustainable growth is emerging and a lot of related works have been done by various researchers around the world.

Electrical power is one of the most important infrastructure inputs necessary for the rapid economic development of a country. The rapid economic development is in turn causing huge stresses in the existing generation, transmission and distribution systems as they are not able to keep pace with the increasing demand. Installation and incorporation of a large number of electrical power generation units with increased capacities to deal with the surging demand has an adverse impact of the environment therefore efficient energy management is imperative. Conventional instrumentation has proven inadequate for the purpose of managing the extensive and complex power systems.

Intelligent systems driven by microprocessors and computers need to be employed for online monitoring and control of modern large-scale power systems, in generation, transmission and distribution to overcome the complexities and drawbacks of the conventional instrumentation schemes. These intelligent systems form the basis of the smart grid. The smart grid (generation, transmission and distribution) by itself does not completely solve the problem of the existing demand-supply mismatch. The smart grid needs to be complemented with smart (programmable) appliances at the customer sites to efficiently re-distribute the demand to provide the benefits of lower costs for customers and operational efficiencies for suppliers. Smart Energy Information Management System need to integrate with Smart grid & Smart Appliances to analyze end to end complex power system data which leads to the reduce power consumption and increase smart grid reliability.

1. Smart Grid Technologies

The term Smart Grid means more than a single technology or even a clear set of individual technologies. Is an “umbrella” term under which various technologies of electric power systems are considered, both in hardware and software? For some people, Smart Grid is characterized primarily as the addition of an information and communication technology (ICT), superimposed in a way on existing infrastructure. For others, Smart Grid represents the installation of new transmission lines, meters, and renewable energy generation [7].

However, in order for both conditions to comply, first it is necessary to understand the legacy electric systems worldwide. The current dominant infrastructure of electric power systems involves four basic elements:

- Generation: Electric power is generated in large-scale power plants;
- Transmission: High-voltage electrical energy is transported from the plant to substations closer to consumers;
- Distribution: Low voltage energy is distributed from substations to residences and commercial buildings;
- Consumer: Electricity used for consumer devices such as refrigerators, computers, lights, pumps and other devices used by residential, commercial, and industrial devices.

The main mechanism in power generation by current systems depends on the heat produced by burning fossil fuels, division of atoms in nuclear energy, or from the hydroelectric stations water movement. Except for solar cells, almost all other forms of power generation, including the burning of fossil fuels, nuclear, biomass, hydro, wind, concentrated solar, cogeneration, and need driving a turbine to produce electricity [7] [8].

The generation usually produces electricity with relatively low voltages ranging from 2 to 30 kilovolts (kV), depending on the size of the unit. Since electricity is generated, its tension is amplified before transmission. A critical step between the generation of electricity and long-distance transmission involves a transformer to increase the voltage. Often, the generation of electric energy occurs far from the places where the electricity is needed, making the long distances of high voltage transmission lines, a crucial part of the electrical system. The long-distance transmission voltage varies from 115 to 120 kilovolts (KV), so the transformer plays a crucial role in increasing the voltage for transmission [7] [8].

The high-voltage transmission lines carry electricity from generating plants to local substations, where the energy is “left over” for a lower voltage and then sent through electric energy distribution networks for local users, including the industrial, commercial, and residential consumers. From the substation, the electrical energy is distributed locally within a community to individual buildings and houses. The voltage is usually reduced at the point of use, to the standard voltage of that region, which varies in different countries (with most consumers receiving 110 - 120 V in the United States and 220 - 240 V in Europe) and with the requirements of electric power use [7] [8].

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II. MAIN TECHNOLOGIES

The term Smart Grid represents the integration of digital technologies, sensors, and ICTs to empower and make the management on the use of electricity more reliable and efficient. Smart Grid includes technologies for the consumer (with which consumers interact) and the grid (transmission and distribution that are less visible to consumers). The Smart Grid technologies also include hardware and software [7] [8].

One of the definitions of the term Smart Grid is the integration of various technologies, products and services, from the generation, transmission, and distribution; using advanced communication and control technologies. **Figure 1** illustrates this concept.

2. Energy Management Systems in Smart Grid

The vast majority of the energy management systems just consider the monitoring and data statistics of energy consumption of consumer electronics. For these systems, manual actuation is necessary in each device to reduce energy consumption. However, the Smart Grid technologies require management systems to be smarter and able to respond to demands related to the charge control, energy management, and timing systems with micro grids
[9].

Some architectural solutions for energy management systems are being integrated into a concept of Smart Grid; these are presented blow. Chang-Sci Choi develops an architecture using AMI solutions for an energy management system entitled EMM (Energy Monitoring and Management), interoperating this system with the Smart Grid. Among the

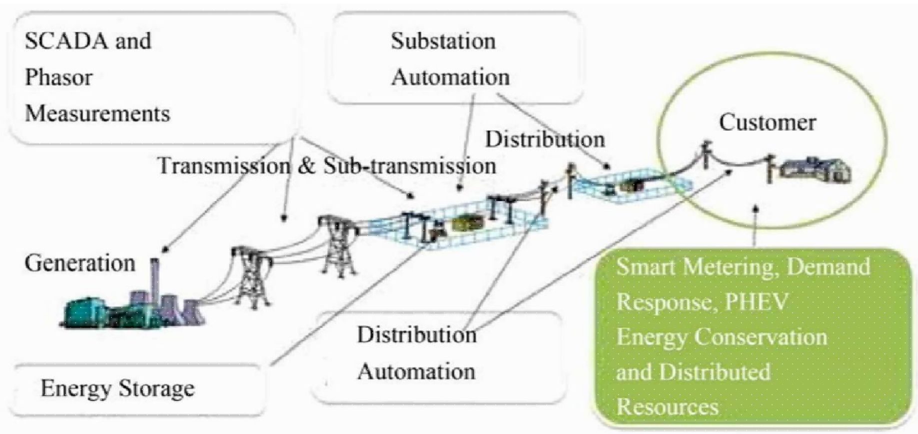

Figure 1. Concept for control and communication systems in Smart [9].

Assumptions adopted, the most important is the division of the stream of operation and settings of residences and buildings [9].

The sizing system EMM first considered complex apartments and residential environments popular in South Korea, with advanced infrastructure of home networks and several features, such as: electricity, gas, water, and cogeneration. **Figure 2** shows the architecture that is installed via the internet providing accessibility, mobility, and interoperation with other systems. Each EMM installed performs communication with smart watches “Smart Meters”, and interface with networked home appliances. To report the current status of the house, the energy measurement system sends data in real time via the Internet [9].

For commercial buildings and industrial plants, the author proposes the BEMS (*Building Energy Management System*). However, these systems and its communication protocols depend on the market and corporate strategies at the time of construction, and its concepts of energy efficiency and energy management, which adopt generic and growing open communication standards and protocols, such as: BACnet, LonWorks, Modbus, KNX, WLAN, Zigbee, SNMP, IEC61850, DNP3, etc. To overcome these constraints, the author proposes the development of 2 CCL (*Common*

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Communication Layer) protocols. The first one is called BAS CCL, and the other one, EMM CCL. **Figure 3** illustrates the configuration of EMM for heterogeneous integration BEMS in each building [9].

In both systems, the server data is analyzed by software, providing information about weather and conditions of operation of the entire plant. This information can be broadly used and incorporated into a maintenance planning, among other applications [9] [10].

Levels of data analyzed by the software can be broadly classified as:

- Level 1, Management: Supervision of computers, servers and services data management servers;
- Level 2, Automation: Smart G/W (gateway);
- Level 3, Installation: Sensors, actuators and controllers.

The software operates considering a data group, composed of service server and data management that are installed on the building control center, as illustrated in **Figure 4**. The Smart Gateway is installed inside the building, collecting the data of the electric power consumption through intelligent devices such as meters, sensors and actuators, etc., that are engaged in the construction of an operating system, including electricity control systems, HVAC/HVDC, lighting systems, etc. [10].

This architecture allows the system to provide multiple functions for energy saving control, such as: control of maximum demand of energy, weather-based light and dimming control by means of sensors. The information generated by the system makes it possible to provide the function of energy efficiency through predictive analysis of the trend of energy consumption, comparing with the data in real time, through a comparative analysis with similar facilities. Another option is the provision of services, such as load shifting adapting to pricing/rates through Smart Grid function; connection with renewable energy sources; and energy exchange function. In addition, it allows a selection of ideal tariff systems appropriate to the construction standard and energy consumption of the installation [10].

3. Analysis of the Condition of Demand Response

To meet peak demand, high-cost generating stations are required. Adding more generation was the strategy used in

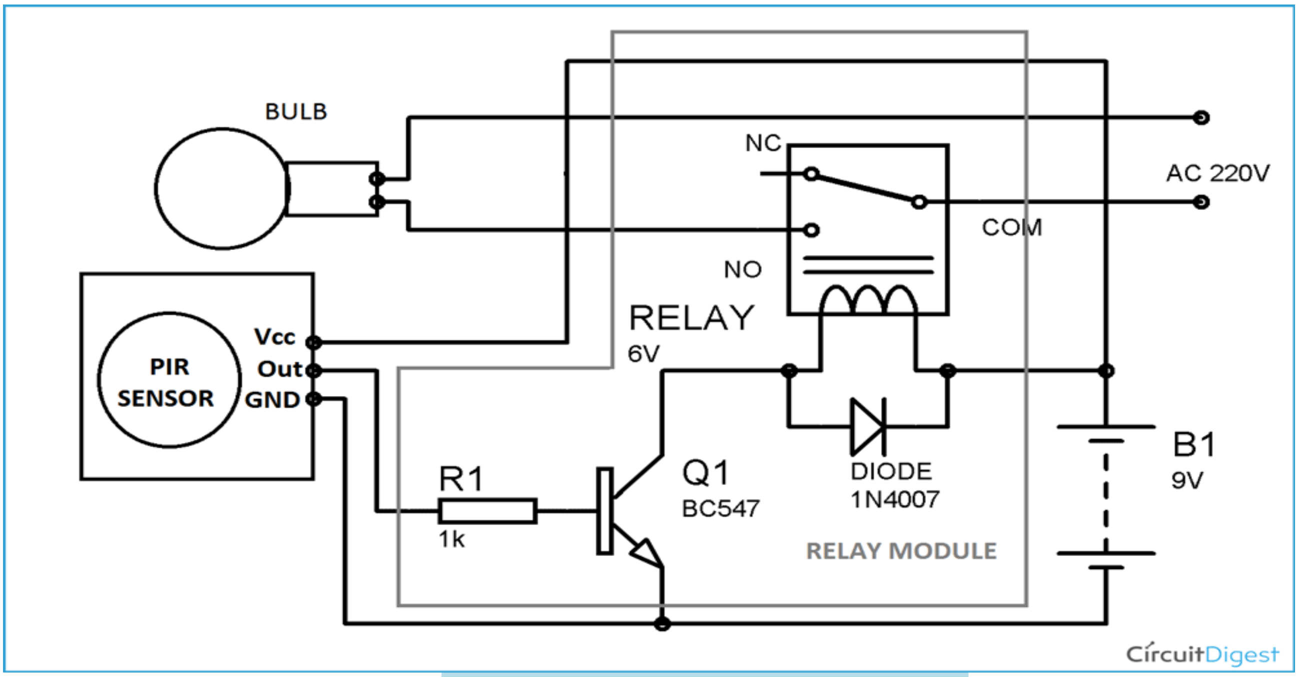

Figure 2(B) Systems configuration of EMM for residence [9].

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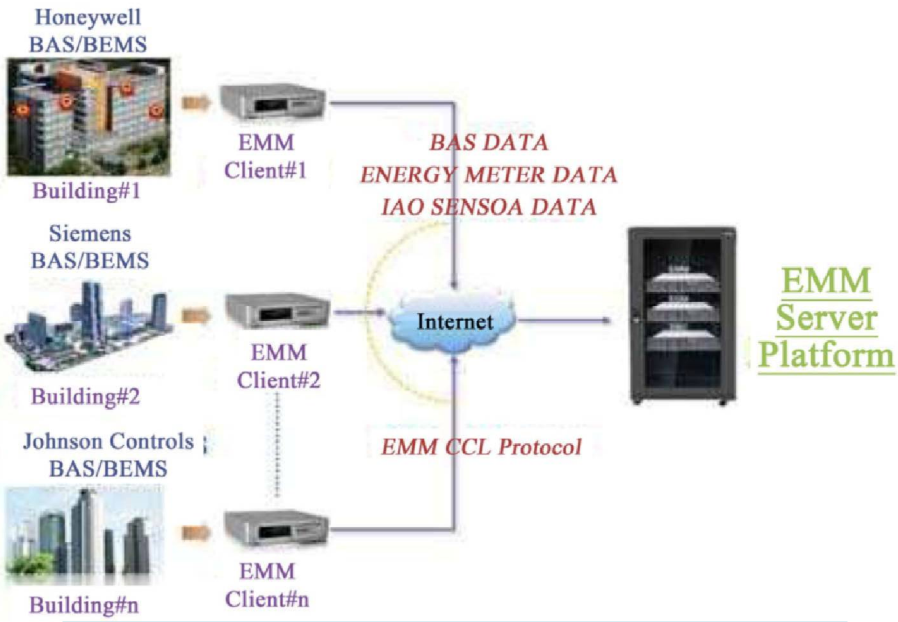

Figure 3. Systems configuration of EMM for integration with BEMS [9].

The past to meet the demand of electricity. Currently, the energy utilities have given more attention to demand management in order to reduce peak demand. Using the Smart Grid concept means more than a single technology or even a clear set of individual technologies for this [2].

Demand response (DR) is a key concept in energy demand management, which helps to reduce peak demand in critical situations. DR is defined as the changes in the use of electricity, for end consumers, of their normal consumption patterns in response to changes in the price of electrical energy over time, or the incentive payments intended to induce a better use of electricity at peak hours [11].

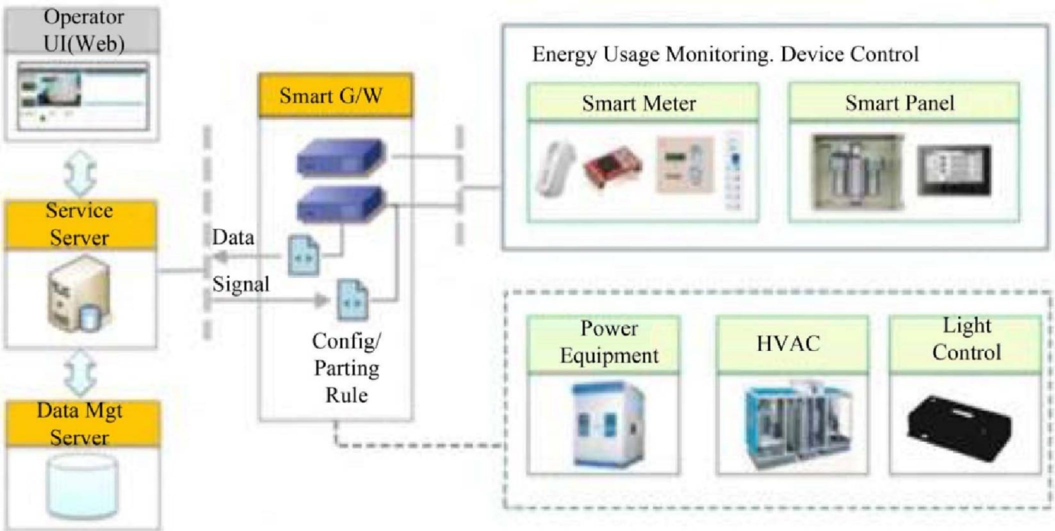

Figure 4. Performance software architecture [10].

Load management is defined as a set of objectives which aim to control directly or indirectly and/or modify patterns of electricity consumption of various consumers, aiming to reduce peak demand. This control and modification enable the supply system to meet the demand, making better use of its available generation and transmission capacity [12].

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For leveling the peaks of demand, three common strategies for load management are used: "*Peak Clipping*", "*Load Shifting*" and "*Valley Filling*", as illustrated in **Figure 5**.

"Peak Clipping": Load reduction for short peaks and periods of use, usually performed by the direct load control. In this method, the energy utilities disconnect the consumer when there is a critical situation. This direct control can be used to reduce capacity requirements, operational costs and dependence on fossil fuel generation [12].

"Valley filling": Creation of loads during the peak period. This helps to reduce the average price of electricity. One of the methods used in industrial production, which uses the loads generated by fossil fuels [12].

"Load Shifting": Moves the peak loads for other periods of time without necessarily changing the global consumption. This method combines the benefit of "Peak Clipping" and "Valley Filling" moving existing loads during off-peak hours [12].

In programs of DR, electricity consumers play an important role in the reduction of peak demand during peak hours. Consumers can move their loads and thus help the energy utilities to prevent failures and blackouts in the electrical system, reducing the probability of stress conditions of the system. Improve energy security through the DR increases productivity and customer satisfaction. The DR also eliminates the need for high-cost generators and eventually reduces the cost of electricity [2].

In order to inform consumers with real-time data, there must be a communication link between the energy utilities and consumers. Consumers must be able to measure their electrical energy demand, in real time, in order to act for demand response events. Advanced metering infrastructure implementations (AMI) and other technologies allows the user to measure the real-time energy demand and further enhance the use of resources of DR in daily operation [13].

Therefore, it is evident that there is a need for an automatic energy management system in DR programs, which will provide more flexibility consumers.

III. SIMULATION RESULT

The term cloud computing has many definitions; in scenarios as Smart Grid, it is defined as a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. The characteristics of cloud computing include on-demand service,

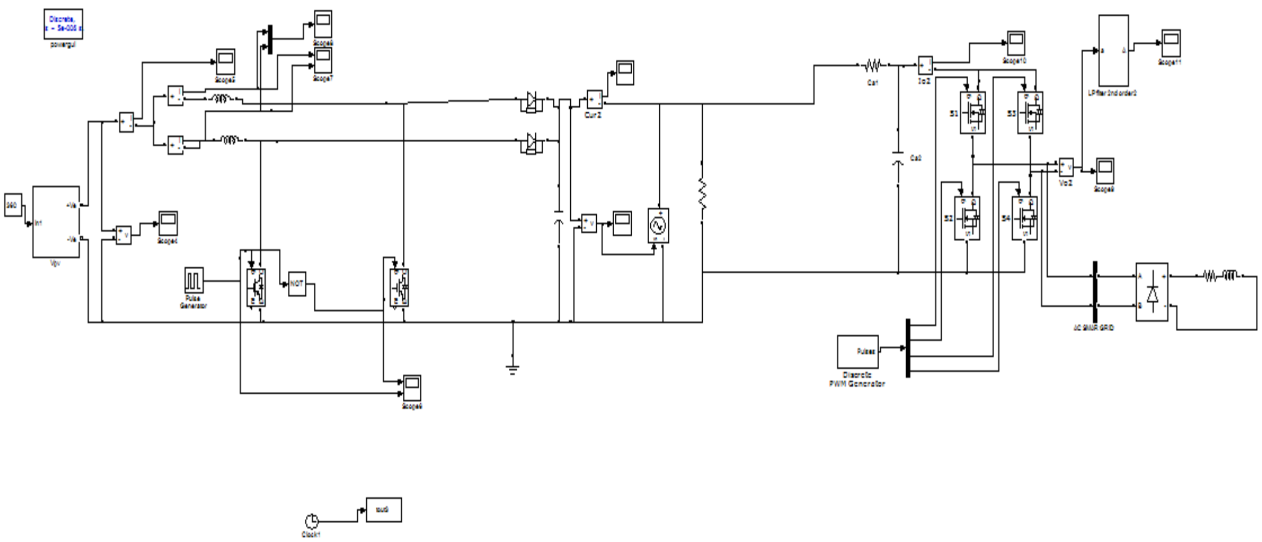

Figure 5. Strategies for load management [12].

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Output result

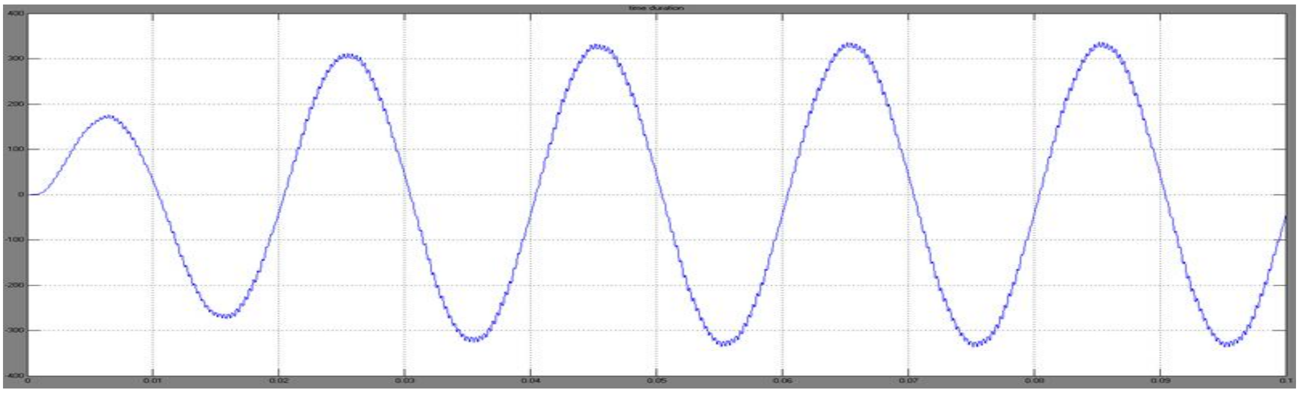

Figure: 6 Wave Form For LP Filter Output

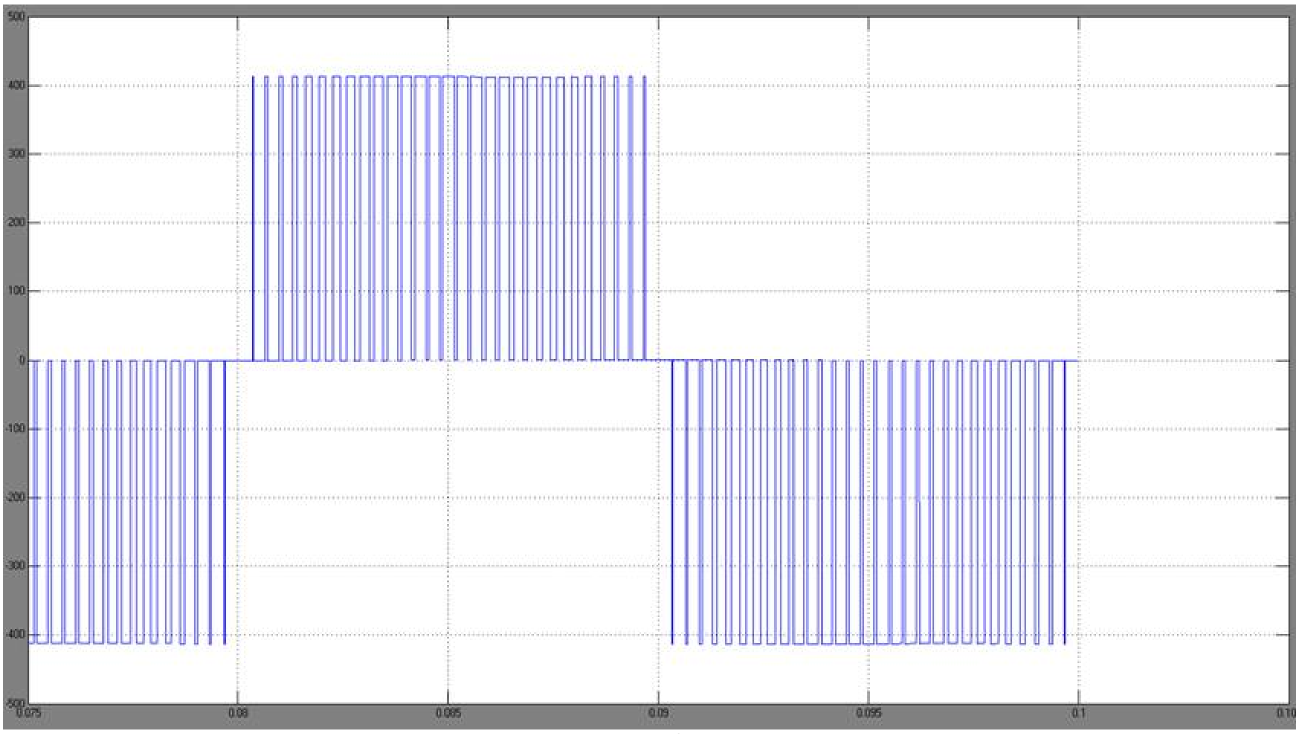

Figure: 7 Wave Form for PWM Output

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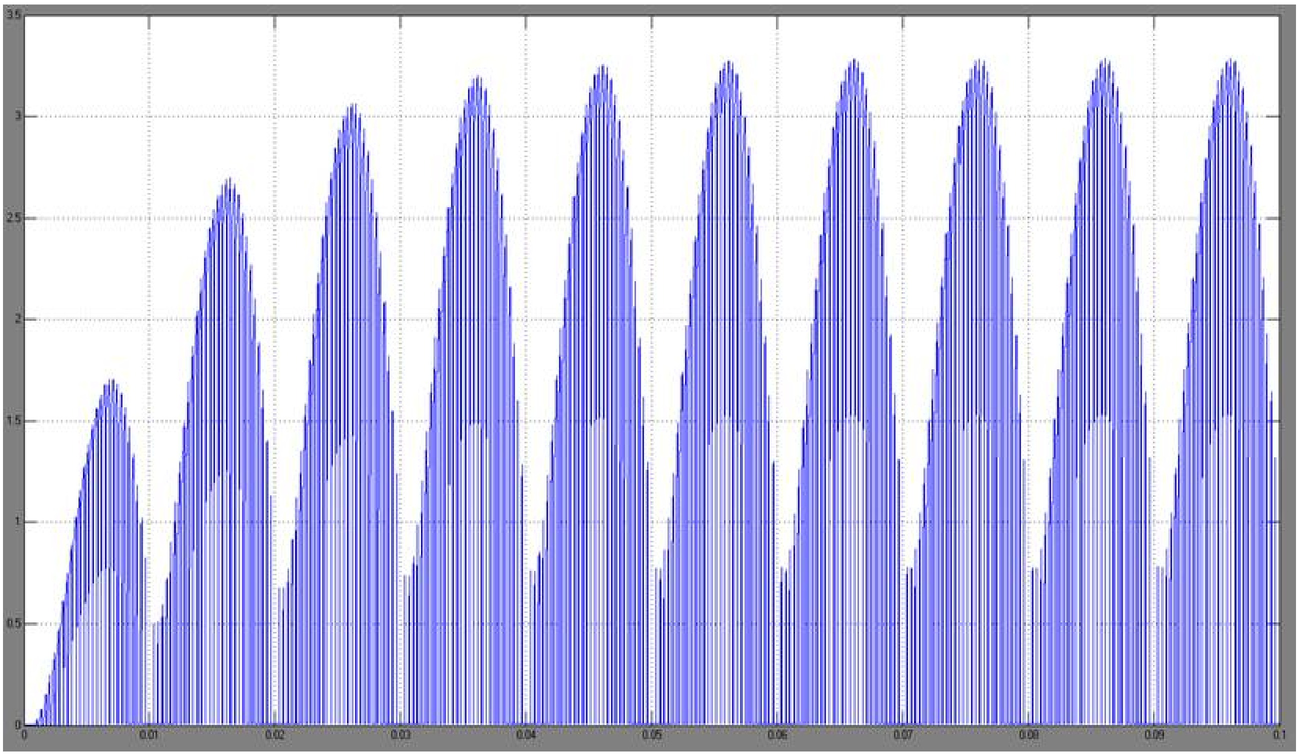

Figure: 8 Wave Form for Control Voltage source Output

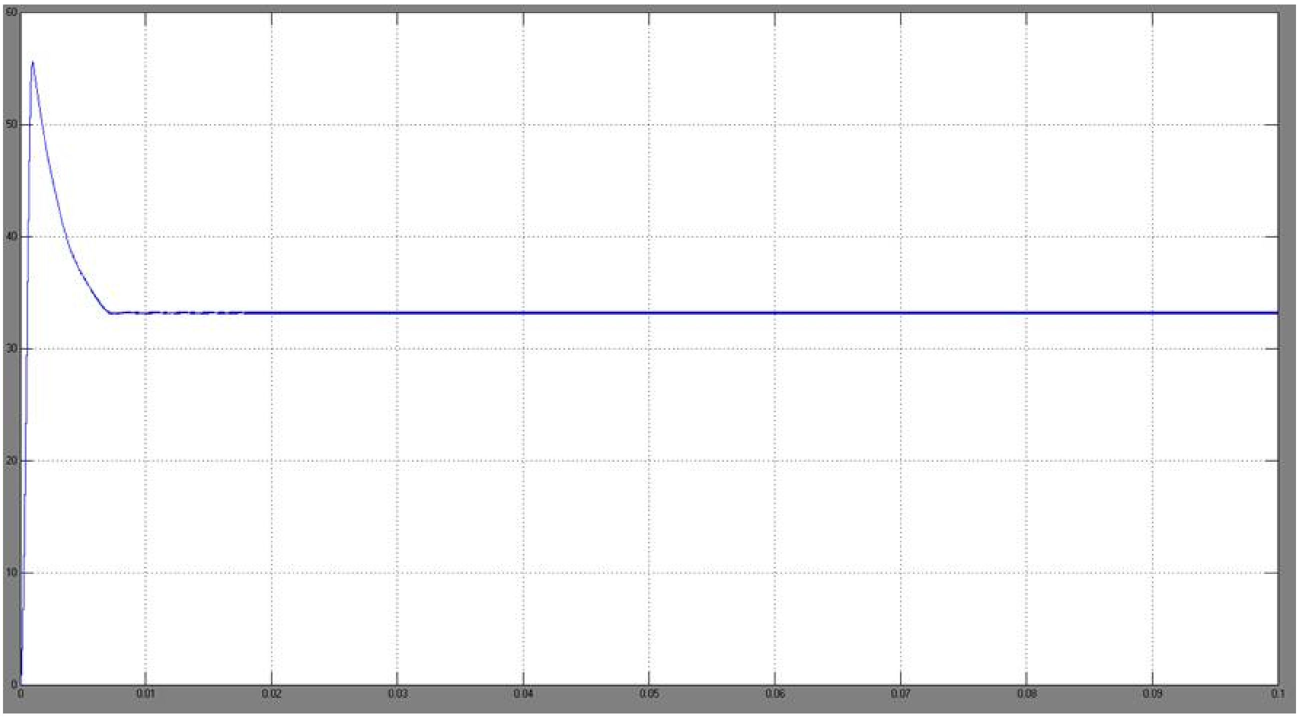

Figure: 9 Wave Form for Current Measurement

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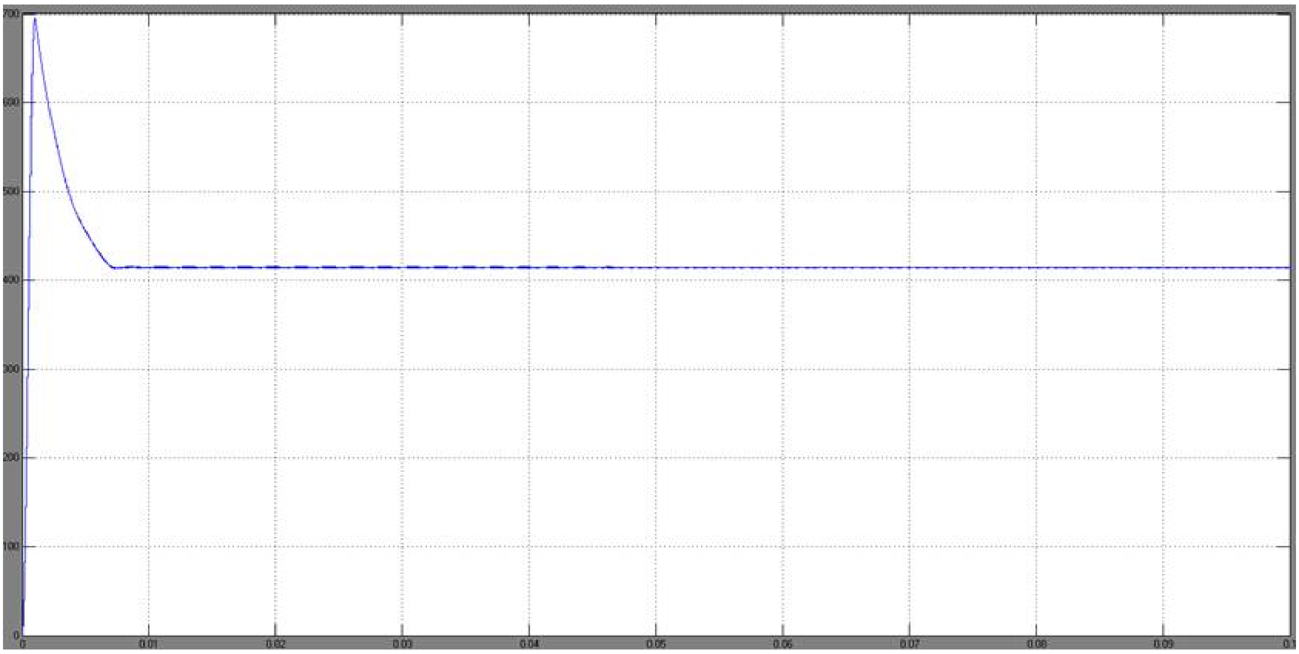

Figure: 10 Wave Form for Voltage Measurement

7.2.6 SOLAR OUTPUT WAVE FORM

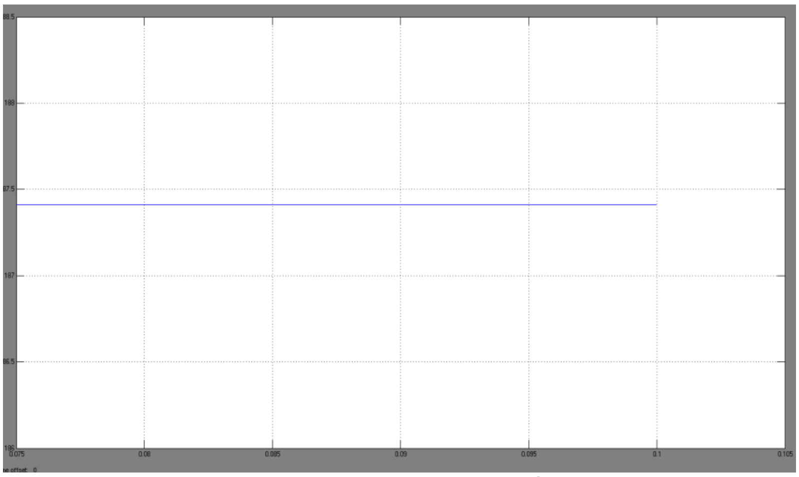

Figure 7.7 Solar output wave form

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7.2.7 SYNCHRONISING WAVE FORM FOR SOLAR TO GRID

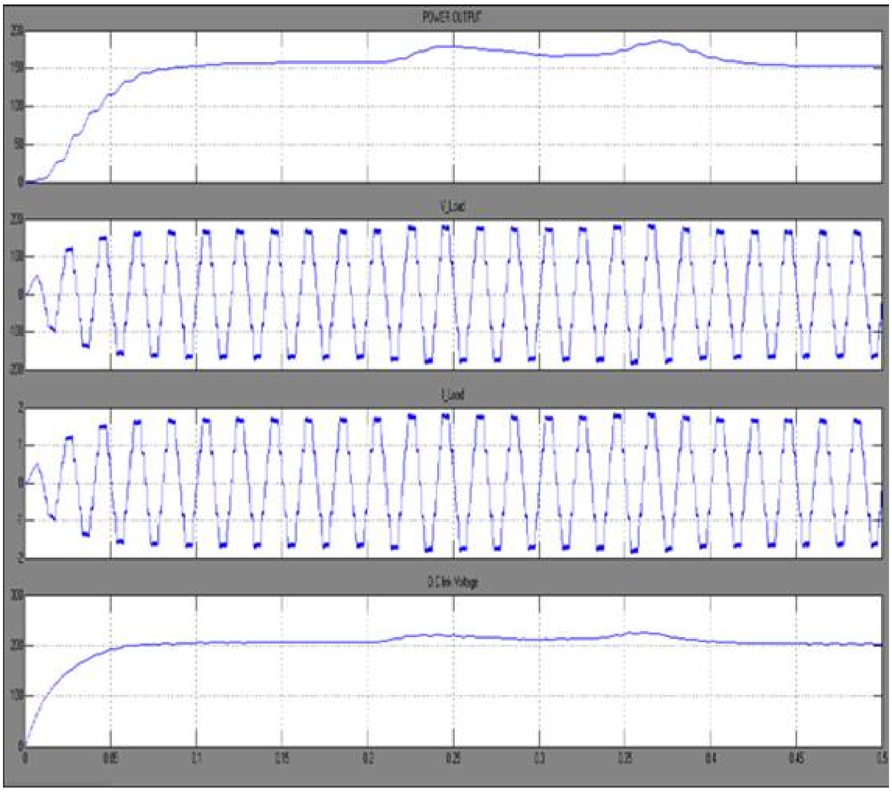

Figure 7.8Synchronising wave form for solar to grid

IV. CONCLUSION

Cloud computing is not a universal solution. It has strengths and weaknesses, and understanding them is the key to making a decision about whether it is right for a particular application. The main advantages of cloud computing are: Economy of scale: sharing of computing resources between different customers; Pay per use: customers pay for the service instead of buying software licenses and hardware; On-demand usage/flexibility: cloud services can be used almost instantly and can easily be scaled up and down; External data storage: customers' data is stored externally at the location of the cloud computing provider; Highly reliable services: clouds manage themselves in case of failures or the performance degradation

Among the main Smart Grid technologies, the most important and that directly impacts the design of an energy management system are the solutions on cloud computing. Cloud computing has established itself as an adequate means to provide resources to customers, primarily in energy management systems, with access to a large amount of information and computer storage. With cloud computing, customers do not have to manage and maintain their own information technology (IT), and are not bound to its local resources which often are limited. However, for customers and energy utilities, making sure that your cloud services are usable, an appropriate level of guarantees of Quality of Service (QoS) is needed.

In recent years, the creation of solutions in Data Center Networks (DCNS) came with rapid growth in scale and complexity, making possible hosting large applications, known as cloud hosting. This growth imposes enormous challenges to update the current datacenter infrastructure, especially considering a scenario of Smart Grid with cloud computing solutions, broadly used in energy management systems.

The proliferation of the adoption of cloud computing solutions in recent years is driven by the potential for obtaining benefits such as reduced costs, greater agility, and better use of resources. However, there are many challenges to ensure the success of these cloud-based services, and these need to be understood and managed before the major use in concepts such as Smart Grid.

However, the major current infrastructures are owned by a large number of Internet Service Providers (ISPs); and it is difficult to adopt new architectures without the agreement of all parties concerned. This includes the standardization of communication protocols and creating regulations for wide use of cloud computing solutions.

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