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R-SGEMS: A Novel Green Energy Management System for Renewable Energy Utility

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Abstract
Renewable energy has received universal acceptance as the energy of the future. Review of literature highlighted several research efforts geared towards the optimization of the availability and usage of this energy alternative. However, literature has failed to highlight any research efforts focused on the aspect of monitoring and management procedures that would facilitate avoidance of energy wastage from end user perspective. This paper articulates existing works on green energy management systems, their architectural operation, and their merits and demerits. The work then proposed a Robust Smart Green Energy Management System (R-SGEMS) with an integrated energy monitoring and management platform that leverages on cloud computing datacenter. For the SGEMS, Demand Side Management (DSM) was implemented using Oracle JAVA Netbeans and MySQL. This was embedded in the Enterprise Energy Analytic Tracking Cloud Portal platform (EETACP) of SGEMS. A deployment context was mapped out and was satisfactorily tested on a simulated Distributed Cloud Computing Network (DCCN) using Riverbed Modeller version 17.5. The advantages of this new initiative were discussed while outlining its implementation strategy.

1. Introduction

Unlike the conventional energy utility, renewable energy utilities have not commenced DSM which will help to promote efficiency and cost savings for both the utility vendors and the end users. Energy demand management, also known as DSM, is the modification of consumer demand for energy through various methods such as financial incentives [1], education and techonology. Usually, the goal of Demand Side Management (DSM) is to encourage the consumer to use less energy during peak hours, or to move the time of energy use to off-peak times such as nighttime and weekends [2]. An example is the use of energy storage battery banks to store energy during off-peak hours and discharge them during peak hours [3]. Now, the aim of energy management is to lower energy costs and bring Return on Investments (ROI) to an organization or an enterprise. It involves the use of a structured application with a range of management techniques that enables an organization to identify and implement measures for reducing energy consumption and costs. The related activities usually include: Energy purchasing, metering and billing, performance measurement, Energy policy development, energy surveying and auditing, awareness-raising, training and education, capital investment management including equipment procurement [4].

Essentially, the demand for renewable energy power supply can be modified by actions of market players and government. Hence, energy demand management implies actions that influence demand for energy. Reducing energy demand is counter-productive, hence with economies of scale and technology, DSM can effectively promote energy usage from cheaper energy sources. By employing energy demand measures in renewable energy plants, this will increase the efficiency of energy consumption. These programs, generally known as Demand Side Management (DSM). This is aimed at either reducing consumption or shifting consumption.

Little research has been carried out in DSM programs intended to shape users' energy consumption profiles with respect to existing green energy systems. Such programs allow the available generation capacity to be employed more efficiently. Besides, with DSM in place, monitoring, and control of the entire energy utility becomes efficient and reliable. This can act as a decision support system that can assist an end user in decision making. This will consequently, improve the reliability and quality of service in terms of reducing outages, minimizing outage time, maintaining acceptable consumption pattern.

1.1. Research Contribution

The main goal of this work is to implement DSM in SGEMS particularly in EETACP. This will facilitate charging energy consumers based on the true price of the utilities at that time. If consumers could be charged less for using electricity during off-peak hours, and more during peak hours, then supply and demand would theoretically encourage the consumer to use less electricity during peak hours, thus achieving the main goal of DSM in SGEMS. Besides, users can literally view the consumption pattern and take informed decision on their energy usage trends. Energy billing for R-SGEMS remains a vital aspect of this proposal left for future work.

1.2. Theoretical Concepts

DSM measures can be put in place by utilities or energy end users. But utilities try to encourage energy users to alter their demand profile through positive tariff incentives allowing customers to schedule demand activities at a time that will reduce their energy costs. This in turn helps the utilities by moving the demand away from the peak period. In most cases, negative incentives or penalties are charged for the continued operation of inefficient equipment with unnecessarily high loads. This is intended to encourage customers to upgrade equipment and thereby reduce energy demand. The main types of DSM activities may be classified into these categories [4]:

i. Energy Reduction Programmes: This involves reducing demand through more efficient processes, building or equipments. These also include all forms of energy saving tips/procedures in both domestic and industrial settings.

ii. Load Management Programmes: This involves changing the load pattern and encouraging less demand at peak times and peak rates. The types of load management techniques are:

- Load levelling: The load levelling helps to optimize the current generating base-load without the need for reserve capacity to meet the periods of high demand.
- Load Control: This is where loads (eg. heating, cooling, ventilation and lighting) can be switched on or off, often remotely, by the utility. In this case, the customers may have back-up generators or energy storage capability and generally have an interruptible agreement with the utility in return for a special rate. The energy distribution industry may use rolling blackouts to reduce demand when the demand surpasses the capacity. Rolling blackouts are the systematic switching off of supply to areas within a supplied region such that each area takes turns to lose supply.
- Tariff incentives and Penalties: Utilities encourage a certain pattern of use by tariff incentives where customers use energy at certain times to achieve a better-priced rate for their energy use. These include:
- Time-of-use-rates: Here, utilities have different charges for power use during different periods. Higher peak time charges would encourage a user to run high load activities in an off-peak period when the rates are lower.
- Power Factor Charges: In this case, users are penalized for having power factors below a fixed threshold, usually 0.90 or 0.95 or 0.8 at worst case condition.
- Real-Time Pricing: In case, the rate varies based on the utilities load (continuously or by the hour).

iii. Load growth and conversion Programmes: These are implemented with the intention of improving customer productivity and environmental compliance while increasing the sale of KW for the utilities. This increases the market share of the utility and enables an ability to increase peaks. They can divert unsustainable energy practices to better and more efficient practices such as the reduction of the use of fossil fuels and raw materials.

iv. Energy Efficiency: This involves using less power to perform the same tasks in domestic or industrial settings.

v. Demand Response: This involves any reactive or preventative method to reduce, flatten or shift peak demand. Demand Response includes all intentional modifications to consumption patterns of electricity of end user customers that are intended to alter the timing, level of instantaneous demand, or the total electricity consumption [5]. Demand Response refers to a wide range of actions which can be taken at the customer side of the electricity meter in response to particular conditions within the electricity system (such as peak period network congestion or high prices) [6].

vi. Dynamic Demand: The concept is that by monitoring the power factor of the power grid, as well as their own control parameters, individual, intermittent loads would switch on or off at optimal moments to balance the overall system load with generation, reducing critical power mismatches. As this switching would only advance or delay the appliance operating cycle by a few seconds, it would be unnoticeable to the end user.

With the above concepts, EETACP will be developed taking cognizance of a renewable Cloud Energy Metering System (CEMS) which facilitates DSM in context.

The rest of this paper is organized as follows: Section II presents related works on energy management systems and their draw backs, Section III detailed the proposed system architecture as well as the software implementation framework. Section IV presents the implementation strategy (R-SGEMS Subsystem). Section V presents the implementation results and analysis. Conclusion, recommendation and future directions are discussed in Section VI.

2. Related Works

2.1. Green Energy Management Systems (GEMS)

The works in [7],[8],[9],[10],[11],[12], and [13], proposed a power plant model known as Solar Chimney Power plant, SCPP. The system consists of a solar hot air collector, a solar chimney and a turbine with generator. This system have been conventionally used in agriculture for air replenishment in barns, silos, greenhouses, etc. as well as in drying of crops [14], grains, fruits or wood [15]. It is also used for natural passive ventilation in buildings [16], and for harvesting solar energy [7]. Fig 1a and 1b shows the full model of SCPP.

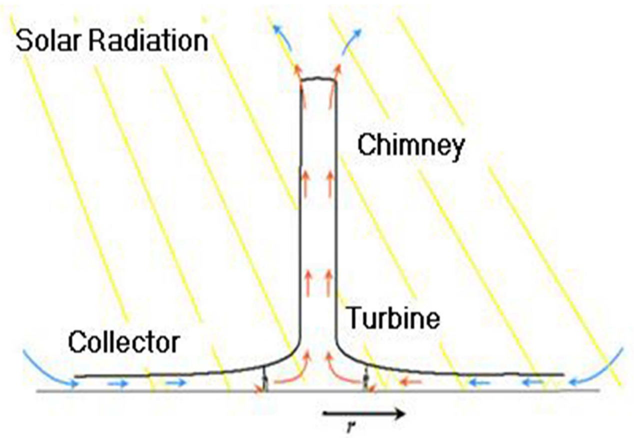

Fig 1a. *A schematic of SCPP [17],*

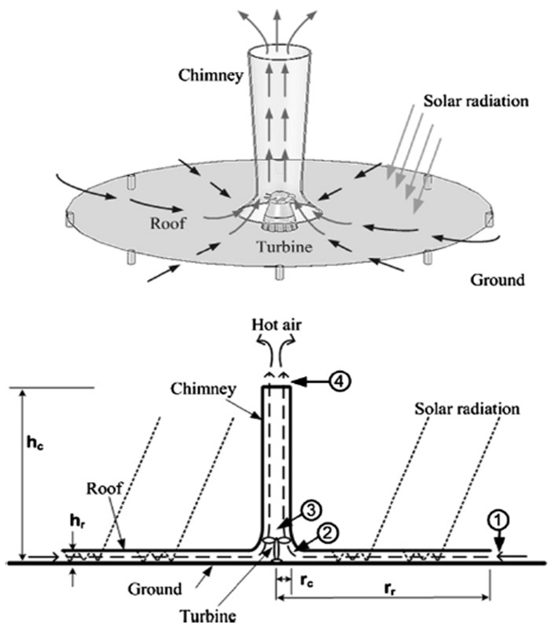

Fig 1b. *Analytical schematics for SCPP [18]*

For SCPP, little research have been carried out in the context of energy management, this forms a serious research gap.

The work in [19] discussed Parasol, a solar-powered micro-Data Center built as a research platform. In its physical infrastructure, the Parasol comprises a small custom container, a set of fixed solar photovoltaic (PV) panels, batteries and a grid-tie, a free cooling unit, and a direct-expansion air conditioner (HVAC). As shown in Fig 2a, 16 PV solar panels are mounted on top of the steel structure and shade the container from the sun most of the time. Each panel produces up to 235W DC power which is transformed into AC using two SMA Sunny Boy 2000HF-US inverters placed inside the container. The panels produce up to 3.2kW of AC power (after de-rating).The work established that through Green Switch, Parasol is the first green datacenter prototype to dynamically manage workload demands, multiple energy sources (renewable energy, batteries, and grid), and multiple energy stores (batteries and net metering), all at the same time. The Green Switch part of their system is used for scheduling workloads and selecting the source of energy to use (solar, battery, and/or grid) at each point in time. Fig 2b depicts the model representation of the greenswitch with the predictor, solve and configure that drives the parasol in Fig 2a.

Fig 2a. *Outside view of Parasol [19].*

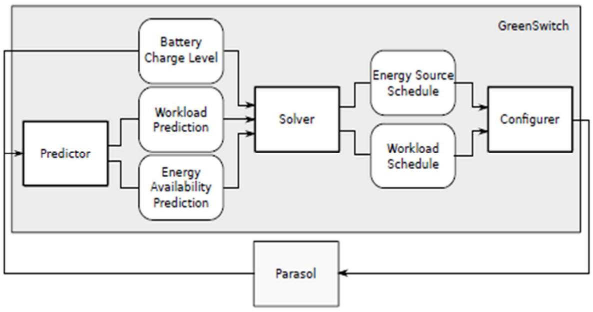

Fig 2b. *Green Switch architecture [19].*

The authors explained that Green Switch model can used to manage workloads and energy sources during electrical grid outages. The following are the identified research gaps in Parasol & Green Switch, viz:

i. The proposed research platform lacks adequate discussions on the metering infrastructure for its renewable energy availability prediction.
ii. The web based management application interface with the net metering system was not implemented and discussed.
iii. The network communication interface between the Parasol and Green Switch was not clearly defined as to how the system can reduce grid electricity cost and consumption.
iv. Details on how Green Switch can tackle the set of issues and tradeoffs one may face in managing energy sources and workloads in green datacenters of any size are lacking in their proposal.

The report in [20], and [21] proposed Solar Energy Grid Integration Systems (SEGIS) concept which seeks to achieve high penetration of photovoltaic (PV) systems into the utility grid. The SEGIS program proposes integrated power conversion topologies for distributed generators with new emphasis on energy management and grid integration. Fig 3c shows the topology of a typical net-metered PV system, in which power is supplied to the grid, when available, and the inverter monitors the grid as required by the IEEE 1547 standard. Here, no communication occurs between the system and the grid. The system has wide-scale deployment of solar and other distributed resources. The program objective is to develop the technologies for increasing the penetration of PV into the utility grid while maintaining or improving the power quality and the reliability of the utility grid. Highly integrated, innovative, advanced inverters and associated balance-of-system (BOS) elements for residential and commercial solar energy applications are the key critical components of the proposal. As shown in Fig 3, provision is made for control of the distributed energy system by the advanced distribution infrastructure via a portal associated with the smart metering system. All communication flows through this portal, including the ability to intentionally dispatch energy from the system or to request the system to operate independently of the grid. Two-way communication is also shown so that the SEGIS systems are able to report their status, including the availability of solar or stored energy, to the utility [21].

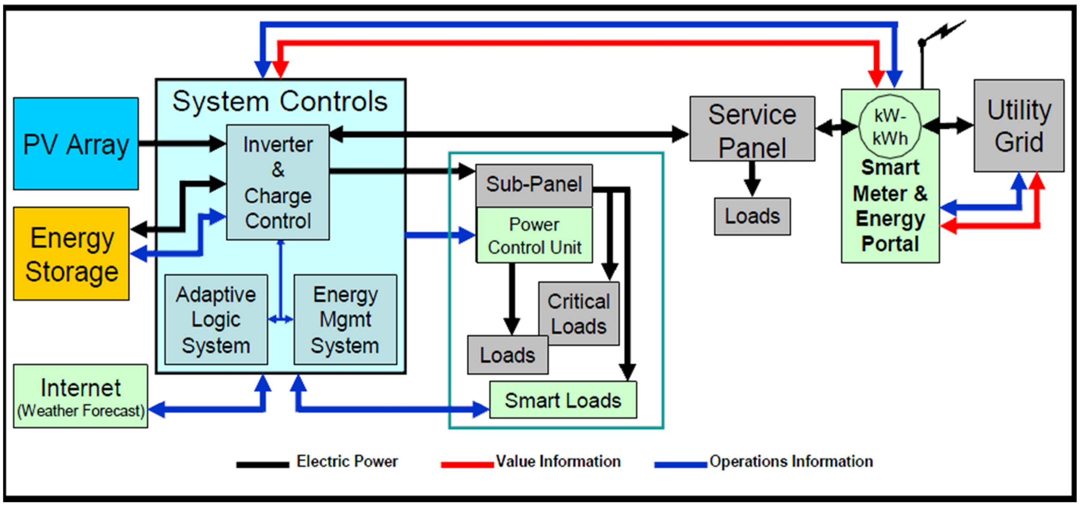

Fig 3. *SEGIS System for Advanced Distribution Infrastructure [21]*

This work observed that Energy Management Systems (EMS) have not been integrated with distributed generation. For residential and small commercial systems, it is possible that energy management functions may be incorporated in a novel way. This system is closely related the green energy management proposal in this thesis.

The only research gap in the SEGIS system is that its implementation is highly capital intensive. Also, the use of distributed cloud computing imitative is absolutely lacking in its program drafts, hence SEGIS is still novel in the energy industry today.

C. D. Dumituru, and A. Gligor [22] identified the main principles of energy management that was used for the design, implementation and testing of a Supervisory Control and Data Acquisition (SCADA) system. The work explained that the system can be applied to manage a small power generation system based on renewable energy sources which operates in isolation or interconnected with the public network.

Z. Vale et al [23] explained that future distribution systems will have to deal with an intensive penetration of distributed energy resources ensuring reliable and secure operation according to the smart grid paradigm. In their work, the SCADA model was used to support the energy resource management undertaken by a distribution network operator (DNO). Their resource management considers all the involved costs, power flows, and electricity prices, while allowing the use of network reconfiguration and load curtailment. The system applied Demand Response (DR) programs on a global and local basis.

According to A. Gligora et al [24], monitoring and control of technological process in many cases that spread out over small or large geographical areas, are achieved with supervisory control and data acquisition SCADA. Their work developed Service-Oriented Architecture (SOA) applicability conditions and recommendations on the design and implementation of monitoring and control systems in case of database-as-a-service DbaaS approach.

The report in [25] presented a renewable energy system known as EDIBON SCADA-NET system (ESN) developed for teaching students on renewable energy systems with laboratory exercises. This system integrates the classroom and the laboratory in only one place thereby enhancing the teacher and student learning environment. It supports electronic interfaces, data acquisition boards, soft wares and PLCs. Only thirty students can work on the ESN simultaneously. A related report in [26] presented a research innovation referred to as Computer Controlled Photovoltaic Solar Energy Unit (CCPSEU) which uses photo-conversion law for the direct conversion of solar radiation into electricity with EDIBOM SCADA integration as shown in Fig 4.The unit contains PV solar panels, solar simulator (which is contains solar lamps), ventilation system, DC load and battery charger regulator, auxiliary battery charger, battery, DC load modules, sensors (temperature, light radiation, DC current and DC voltage). The system is supplied with the EDIBOM computer control system (SCADA) and includes- a control interface box, a data acquisition board, computer control, management soft wares packages for controlling the processes and all the parameters involved in the processes.

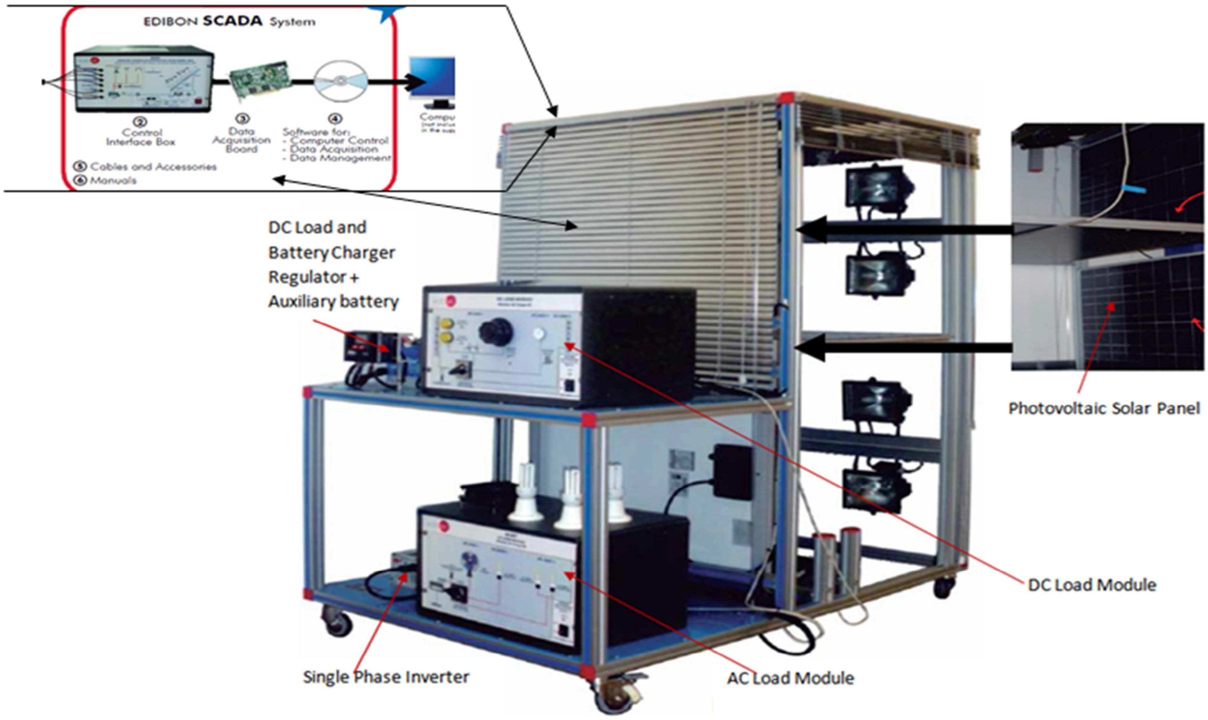

Fig 4. *CCPSEU renewable energy SCADA design with full integration for CCPSEU* [26]

The SCADA based systems are dedicated system that handles data monitoring and control with wired communication networks. These systems have smaller coverage distances. Also, in these systems, all the control actions are mostly automatically performed by the Remote Control or terminal unit or Programmable Logic Controllers. This lacks scalability, fault tolerance and efficient storage management of computed datasets.

I.Cvetkovic [27] proposed a Home Uninterruptible Renewable Energy System (HURES). In their proposal, the house can have a photovoltaic and/or small wind turbine interconnected into the Integrated Power Hub (IPH) - an integrated solution with all of the equipment enclosed in a single cabinet. The IPH have an internal single or three phase bus-bar for interconnection of available renewable sources, PHEV, power meter, synchronization contactor, circuit breakers and system controller. According to the author, the basic idea of introducing the IPH is to develop a system that can be easily installed in the house, without any substantial modifications and rewiring.

Though the system satisfies the requirements for a smart grid infrastructure, the system still lacks detailed implementation discussions on the web integration platform vis-à-vis load balancing. The model lacks system stability in case of over-subscription by end users. This remains a research gap in Nano-grid Renewable Energy System.

In [28], the authors proposed a Smart Energy Management System (SEMS) which functions as a control using a motion sensor and setting time of power usage to reduce power consumption. The SEMS not only supplies power just as the the common power strips do but also controls sockets of the SEMS using Zig Bee wireless communication.

The report in [29] discussed Energy management and control system (EMCS) technology from pneumatic and mechanical devices to direct digital controls (DDC) or computer based controllers and systems. The systems consist of electronic devices with microprocessors and communication capabilities and utilize widespread use of powerful, low cost microprocessors and standard cabling communication protocols.

The overall intent of EMCS is to provide a building operator, manager or engineer with basic background information and recommended functions, capabilities, and good/best practices that will enable the control systems to be fully utilized/optimized, resulting in improved and more reliable, energy efficient facilities.

Owing to inherent grid instability issues, hybrid power systems (HPS) was proposed in [30] to improve Energy storage systems as well as handle Power management strategies. This system does not address DSM and system metering at full load.

The work in [31] proposed a Home Energy Management System (HEMS) for Interconnecting and sensing of electric appliances using a set of intelligent interconnection network systems. The work offers dynamic identification of various household appliances with a unidirectional information display. The interconnection can measure the power consumption of household appliances through a current sensing device based on OSGi platform. The system also integrates household appliance control network services so as to control them according to users' power consumption plans or through mobile devices, thus realizing a bidirectional monitoring service. The system offers localized DSM, lacks cloud metering and lacks scalability for remote access of home energy data.

The paper in [32] presents a new design strategy for energy management of home appliances with the aim of reducing consumed power using a simple low cost bidirectional Power Line Communication (PLC) system. This was utilized to control and monitor the home appliances and sensors for maximum power saving.

Similarly, the paper in [33] proposed distributed generation system architecture with it control algorithm that can efficiently manage the renewable energy and storage. This is to minimize grid power costs at individual buildings. The work evaluated their control algorithm by simulation using a collection of real-world data sets primarily. The system architecture in Fig 5 depicts the localized integration which does not account for DSM in cost effective cloud domain.

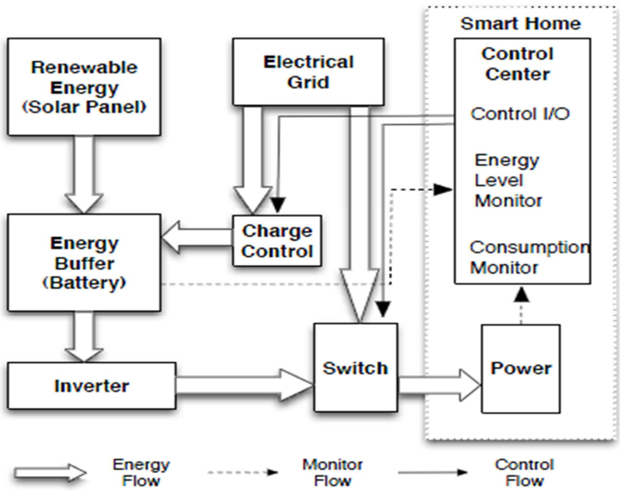

Fig 5. *Smart Home Renewable Energy System [33]*

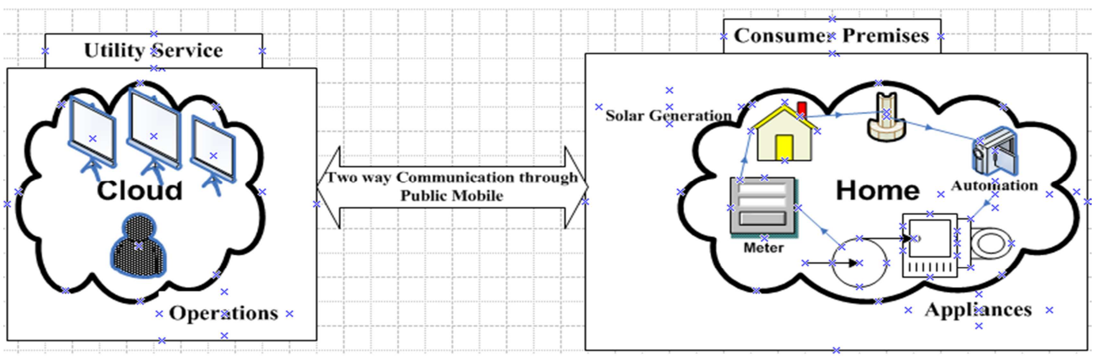

Fig 6. *SHREMS Conceptual Model [34].*

A closely related work to this research is the Smart home Renewable Energy Management System (SHREMS) found in [34] (See Fig 6). The work leverages the smart grid attributes to integrate renewable and storage energy resources at the consumption premises. The paper presented the design, implementation and testing of an embedded system that integrates solar and storage energy resources to a smart home. The proposed system provides and manages a smart home energy requirement by installing renewable energy; and scheduling and arranging the power flow during peak and off-peak period. Also, the work developed a two-way communication protocol to enable the home owner and the utility provider to better optimize the energy flow and the consumption efficiency. The work developed a prototype for the proposed system design while carrying out its implementation and testing using a controlled load bank.

The report in [35] presented an integrated energy management solution that is highly customized, and is fully integrated for end-to-end energy management. It provides industries specific functionalities for monitoring power quality, control and automation and cost allocation. The monitoring module captures voltage, current, power, energy and demand data from various field devices such as meters, relays and breaker trip units providing insight on the status of main power feeders, branch circuits and electrical equipment. Along with monitoring values, PMCS provides event and alarm management capabilities alerting operators though a multitude of channels for specific conditions and allowing them to acknowledge alarms remotely. PMCS also provides customized monitoring views to track and trend real-time energy consumption to give various users both at the enterprise and operator level perspectives for decision making. However, the concept of DSM was not implemented in the proposal.

2.2. Energy Management Systems Based on Smart Grid

The SGS represents a novel concept in energy generation, transmission, distribution and management with associated benefits. Smart grid is an electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviours of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity [36]. It is worthy to note that the concept of smart grid started with the notion of Advanced Metering Infrastructure (AMI) needed to improve demand-side management, energy efficiency, and a self-healing electrical grid to improve supply reliability and respond to natural disasters or malicious sabotage [70]. Demand response (DR), distributed generation (DG), and distributed energy storage (DES) are important ingredients of the emerging smart grid paradigm, and these resources collectively as distributed energy resources (DER) [37].Fig 7 shows a smart grid IT infrastructure in which the web is used as a platform for the incremental addition of new smart-grid applications and their integration with utility legacy systems and external systems.

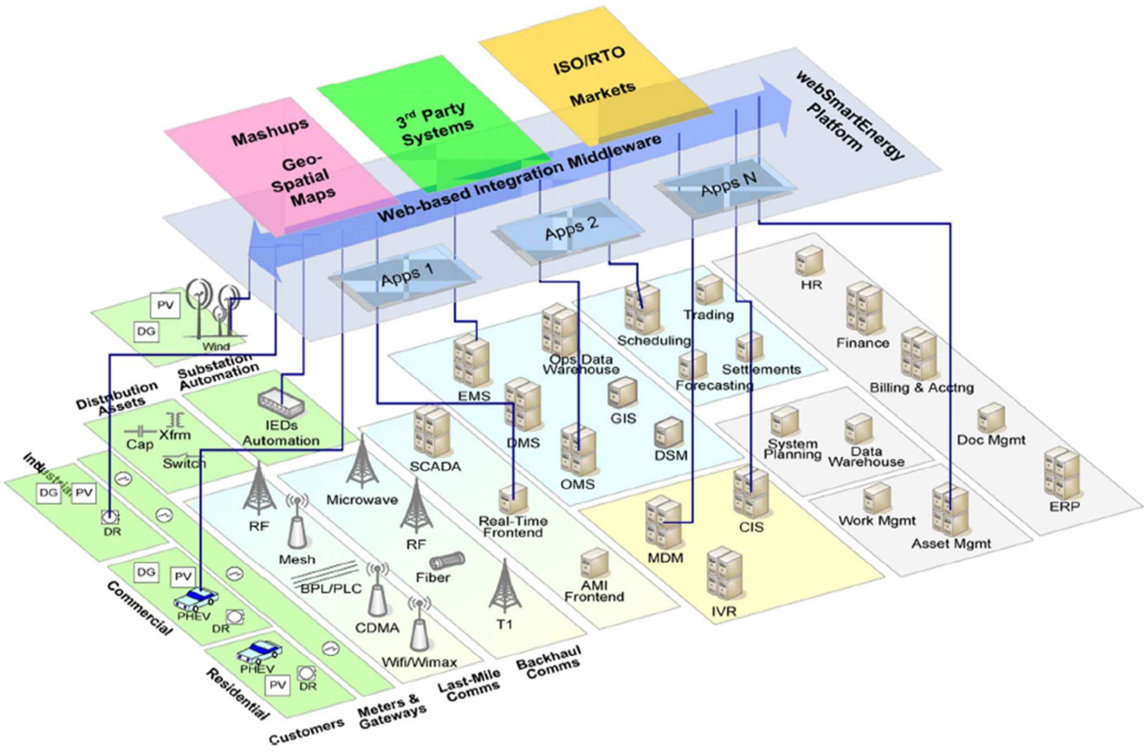

Fig 7. *A Conceptual model for Smart grid management system with DR/DER on top of legacy systems [37].*

Achieving enhanced connectivity and interoperability will require innovation, different applications, systems, and devices to operate seamlessly with one another. This will involve the combined use of open system architecture, as an integration platform, and commonly shared technical standards and protocols for communication and information systems [37].

To realize Smart Grid capabilities, deployments must integrate a vast number of smart devices and systems [37]. The following technology solutions are generally considered when a smart grid implementation plan is developed [38]: Advanced Metering Infrastructure (AMI), Customer Side Systems (CS), Demand Response (DR), Distribution Management System/Distribution Automation (DMS), Transmission Enhancement Applications (TA), Asset/System Optimization (AO), Distributed Energy Resources (DER), Information and Communications Integration (ICT). The work established that the deployment of these technologies is expected to create improvements in six key value areas viz: reliability, economics, efficiency, environmental, safety and security.

From the studied literature, smart grid could be an umbrella that appropriately combines concepts, thereby achieving a heterogeneous and intelligent energy system that delivers its expectations. In this case, most of the previous systems could form sub-networks of the smart grid. But the novelty of these systems is to introduce an efficient metering, demand side management with advanced computing and storage initiatives.

3. Proposed Smart Green Energy Management System (R-SGEMS)

3.1. Block Diagram Overview of SGEMS Global System Architecture

While Fig 8 shows the block diagram of the proposed Energy Management system framework. However, beside the literature reviews, the various contributions from our previous resulted in the summarized smart green system architecture shown in Fig 8. This architecture is shown to satisfy a smart grid solar micro-grid model for the Nigerian environment.

Based on the survey findings in [40], the proposed smart green energy management system (SGEMS) shown in Fig 8 represents the renewable energy utility with the distributed computer network architecture. This can be used by both end users and operators of electric utility grids to enforce DSM. The monitoring and control functions are said to be smart systems ie. the CEM, the cloud application and distributed cloud network. Hence, the terminology - SGEMS specifically refers to the collective suite of power generation, control, network and scheduling applications. The component parts of Again, Fig 8 includes the solar Satellite PV farm, current and voltage sensors, battery storage system, grid tie inverter, three phase switching controller, smart metering (CEM) and DCCN. From Fig 8, the scope of this work is limited to DSM via EETACP only.

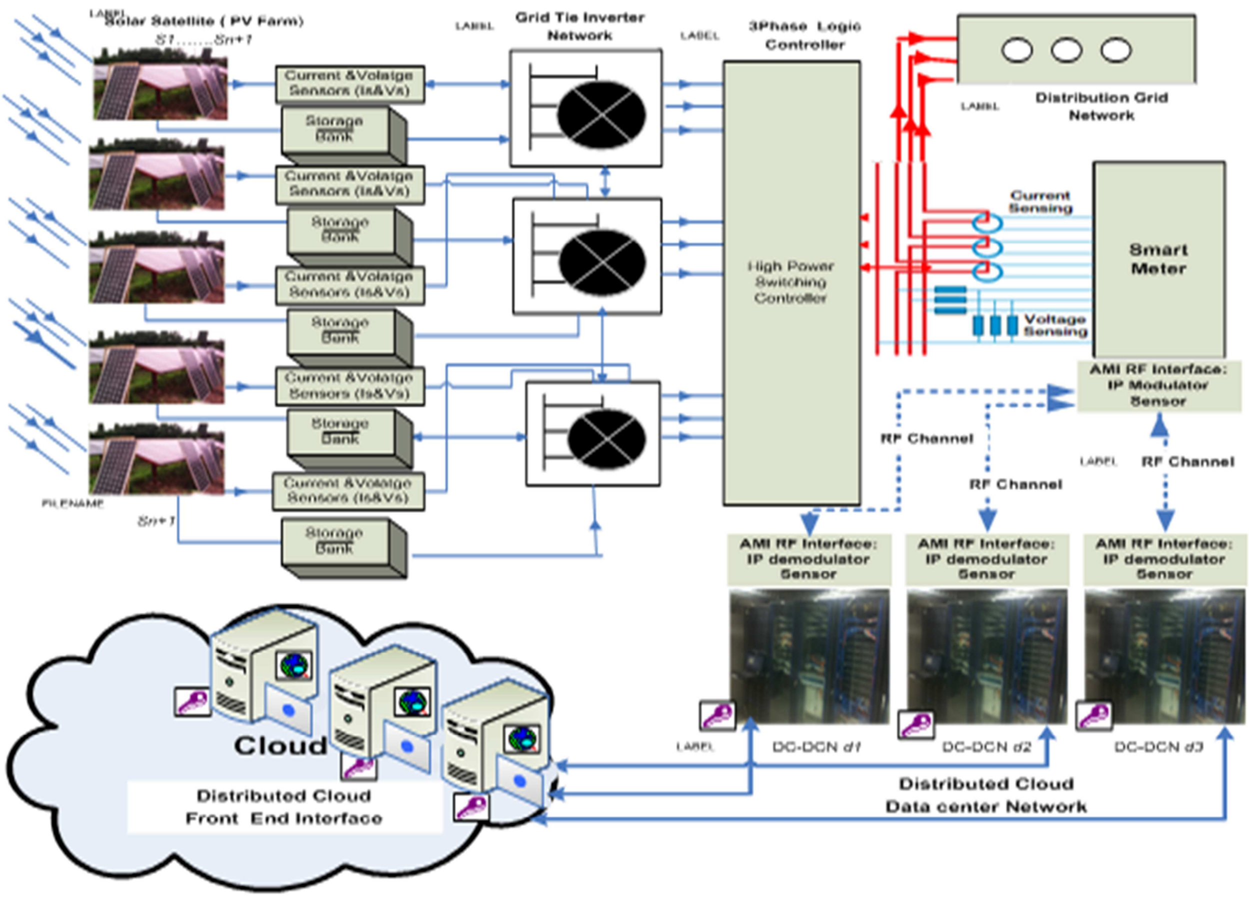

Fig 8. *Global system architecture for Smart Green Energy management System*

3.2. Advantages of the Proposed System

The advantages of the proposed SGEMS and its subsystems have been summarized below.

1. Cost Economy by Consolidation

Firstly, the SGEMS DCCN allows for network devices consolidation, VLAN scalability achievement via its switch, improves on-demand provision, and facilitates over system security. With the Integrated Service Open Flow Load Balancer (ISOLB) and server virtualization in the DCCN, the cost of deployment and management is very minimal. In this case, capital expenditure can be converted to operational expenditure.

2. Reliability and Agility

The smart green proposal makes use of technologies that improve fault detection and allow self-healing of the network without the intervention of technicians. This will ensure more reliable supply of electricity, and improve accountability in consumption. Again, for the DCCN, reliable operation is achieved since multiple redundant sites are used which can facilitate disaster recovery.

3. Flexibility in Network topology

The generation micro-grid distribution infrastructure effectively handles possible bidirectional energy flows, allowing for distributed generation such as from photovoltaic panels on building roofs.

4. Scalability and Elasticity

In the SGEMS DCCN, through dynamic on-demand provisioning of EEATCP, and other cloud resources on a fine-grained, self-service basis, users will have no difficulty in accessing their data even at peak loads.

5. Device and location independence

This enable users to access systems using a web browser regardless of their location or what device they are using (e.g., PC, mobile phone, etc).

6. Virtualization

This allows servers and storage devices to be shared. Resources and applications can be easily migrated from one physical server to another while running the EETACP.

7. Multi-tenancy

This enables sharing of resources and costs across a large pool of sever, thus allowing for:

- Centralization of infrastructure in locations with lower costs
- Peak-load capacity management at all levels

8. Efficiency

The model via its contributions improves the overall efficiency of energy infrastructure via its Demand-Side Management Scheme, eg. Shutting down meters at peak times, turning off air conditioners during short-term spikes in energy price. When applied in conventional utility, the overall effect is less redundancy in transmission and distribution lines, and greater utilisation of generators, leading to lower power prices.

9. Load adjustment and Performance monitoring

Using EEATCP platform, it is possible to predict energy consumption and effect demand response by ensuring optimal usage. In DCCN, its performance can be monitored using web services as the system interface.

10. Sustainability

The improved flexibility of the micro-grid permits greater penetration of highly variable renewable energy sources such as wind power, etc even without the addition of energy storage.

11. Security

Beside, the service consolidation, Open Flow VLAN, firewalling and other encryption schemes are used to facilitate the system security.

12. Improved interfaces and decision support for advanced and integrated EEATCP.

On the other hand, the SGEMS can be used in individual, and commercial entities to monitor, measure, and control their domestic loads on a distributed renewable energy source or even a utility grid. It can be used to remotely control consumption pattern from devices like HVAC units and lighting systems across multiple locations. A attempt was made to propose a generic architecture of the smart micro-grid that tends to converge the various proposed concepts. The proposed architecture appropriately accommodates the heterogeneous composition of the smart grid as well as provides flexibility, intelligence and autonomy at all level of the grid as required.

4. R-SGEMS EETACP Sub-System

4.1. Architectural Description

The R-SGEMS essentially comprises of the PV micro-grid, CEMS, EETACP running on DCCN as depicted in Fig 8. These subsystems are having been previously discussed in [40]. In this work, the DSM was achieved by using the Service Oriented Architecture (SOA) paradigm to achieve the modular blocks in Fig 9. The design objective in this case is to translate the logical architecture using a modular coding design approach into the envisaged EETACP DCCN sub-systems. It is worthy of note that the hosted software can be accessed using any browser from lower capacity systems.

Fig 9 represents the logical architecture of the cloud based application on the DCCN. Massive interaction on this platform could be done by customers, providers and third part policy makers. From the system, EETACP provides well defined user interface for registered customers. The output design shows how information is displayed to the user after a request is made by the user to the DCCN which hosts the EETACP. The user specifies what task is to be executed and based on that; the web browser displays the necessary information relating to the selected task. This means that the output web pages are displayed by the web browser after the server processing is completed. Every output is displayed on the web page. For any selected meter such as C007 id, the data capture from EETACP is displayed in a tabular rows and columns such as power, current, voltage, PF, location, date, etc as shown in Fig 11.

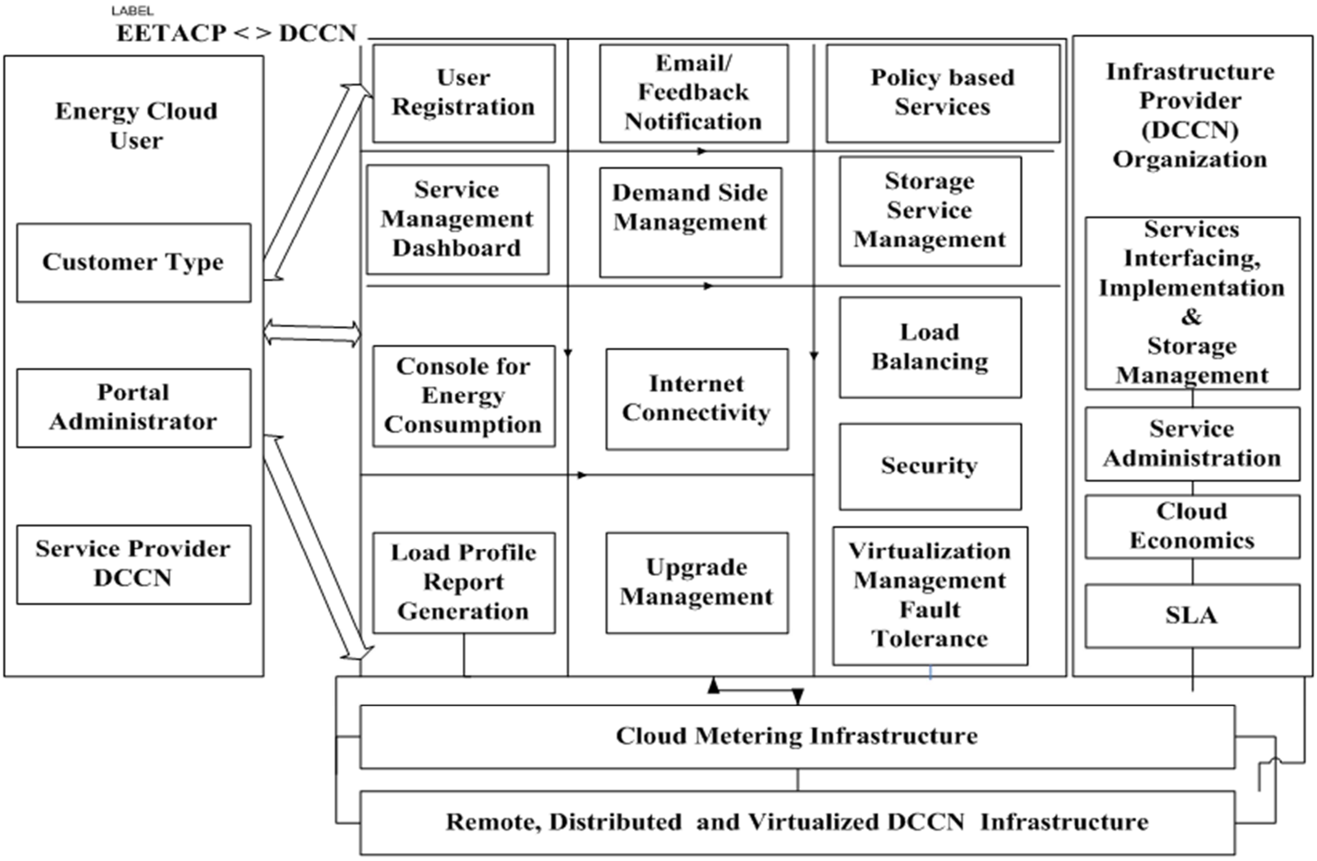

Fig 9. *Proposed logical architecture of EETACP on DCCN*

The various components of the logical architecture are discussed below:

i. Login-in Phase: In the implementation, the cloud user selects his meter *id* managed by service management dashboard according to the requirements after registration. The console manager monitors and displays the consumption parameters via load profile report generator.

ii. Load profile: The load profile allows parameter selection via year, month, day, and time of consumption. The user selects monitoring load profile interface and generates report consisting of current (A), voltage (V), active power (W), power factor, meter id, user location, etc.

iii. Feedback Notification: The feedback notification allows for administrative communication such as feedback to customers. The DSM is supported by a remote startup or shutdown of a meter ***id*** via internet connectivity.

iv. Upgrade Assistant: Besides, the portal services could be upgraded via upgrade management console. When deployed on the DCCN, the EETACP in active mode displays policy based services such as load balancing, fault tolerance, dynamic scaling, virtualization management and server connectivity map.

v. Security: The security aspect of EETACP provides the login option for each stakeholder and it asks the user for username and password with high level encryption. Every stakeholder is provided with a background set of user privileges for viewing the load profile. Every customer is authorized to perform desired tasks.

vi. Database: For the EETACP database, cloud economics addresses the issues of database optimization in the DCCN storage system. The application details are stored into the various database tables via: Admin login DB, User login DB, Provider DB, and table of values DB tables.

vii. DSM: This allows the user or the administrator to shut down or startup the remote meter at peak load times. Via tariffs and penalties, users are discouraged from using high energy consuming loads at peak times.

viii. Cloud Metering: This is used to meter the renewable generated power in terms of end user load consumption. Using its communication RF interface, energy data are transmitted into the DCCN of the utility vendor while allowing valid users to access the EETACP. SLA conditions must be met.

ix. Virtualized DCCN Infrastructure: While Virtualization, interface segmentation, security and QoS characterizes the DCCN for EETACP deployment, there is need to validate these considerations in the SGEMS architecture. This supports the load density on the network and enhances the QoS profile of the network also.

4.2. Software Requirements

The requirements to run the proposed system for optimal performance are listed below.

- Microsoft windows vista or windows7 while using linux Mandrake for cloud production deployment.
- HTTP Server Monitor.
- Oracle JAVA Netbean 7.0.1& above
- MYSQL version 4.1.0 & above
- All browser compatible
- Operating system requirements includes:
- Adequate temporary space for paginations to virtual memory
- 64-bit and 32-bit compatible
- Windows 7/ and Linux Red hart

-Nonempty XAMP htdocs_HOME
-MySQLdatabase

4.3. Hardware Requirements

The minimum hardware requirements include:

- Test case Monitor
- 4GHZ or faster processor
- 4GB of RAM
- 1TB of available hard-disk space
- 1280 X 800 display with 64-bit video card
- Memory requirements:

1 GB for the logic instance (grid control)

- Disk space requirements:

– 2GB of swap space
– 500 MB of disk space in the /tmp directory
– Between 1.5 GB and 3.5 GB for the EETACP
– 2.4 GB for the preconfigured database (optional)
– 4.9 GB for the flash recovery area (optional).

5. System Implementation

JAVA programming language and its JSP variant was used for the implementation of the system owing to its platform independent nature.

This is very acceptable in cloud computing context. The only difference between traditional web applications with the EETACP (cloud web application) is the ability to scale perfectly. The EETACP application is designed to cope with unlimited amount of job tasks given unlimited hardware in the DCCN. Fig 10 shows the Oracle JAVA Netbeans development platform. The full implementation snapshots is shown in Fig 11 for EETACP service selection on meter *id* C0007. Fig 12 shows the DSM on the EETACP. Table 1 shows a typical load profile from meter id C0007. The system was tested while offering desired performance both in deployment context and on simulation in Riverbed Modeller [40].

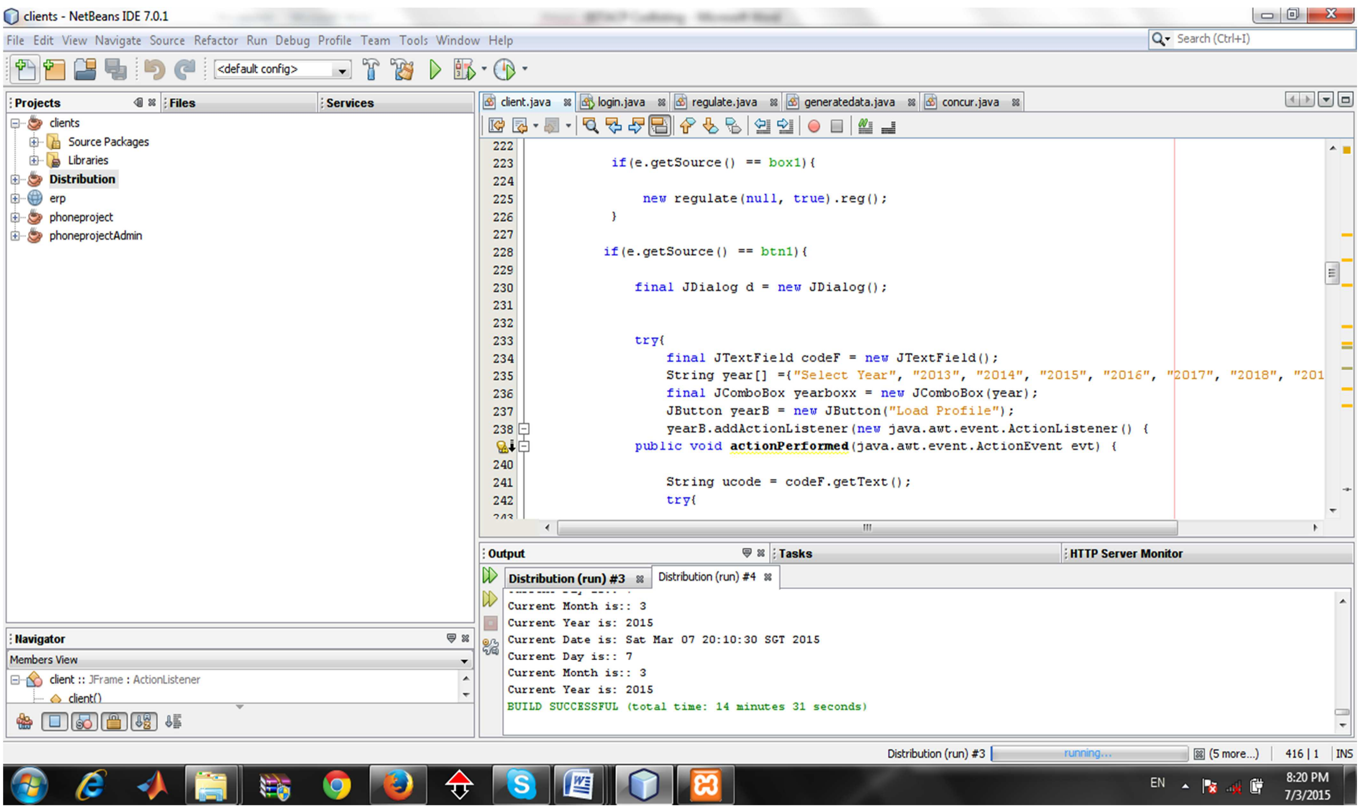

Fig 10. EETACP Programming Environment with Oracle Netbeans 7.0.1

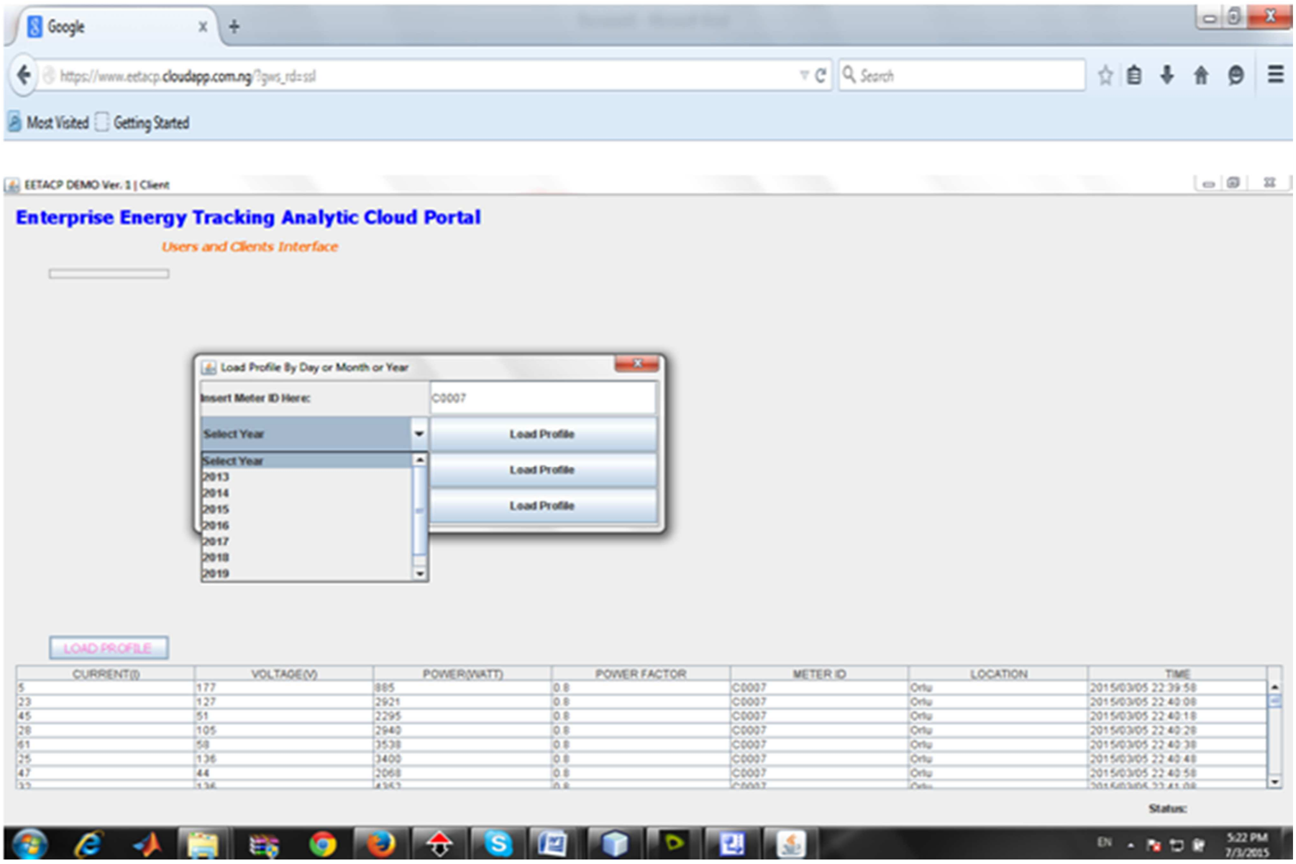

Fig 11. EETACP service selection on meter id C0007

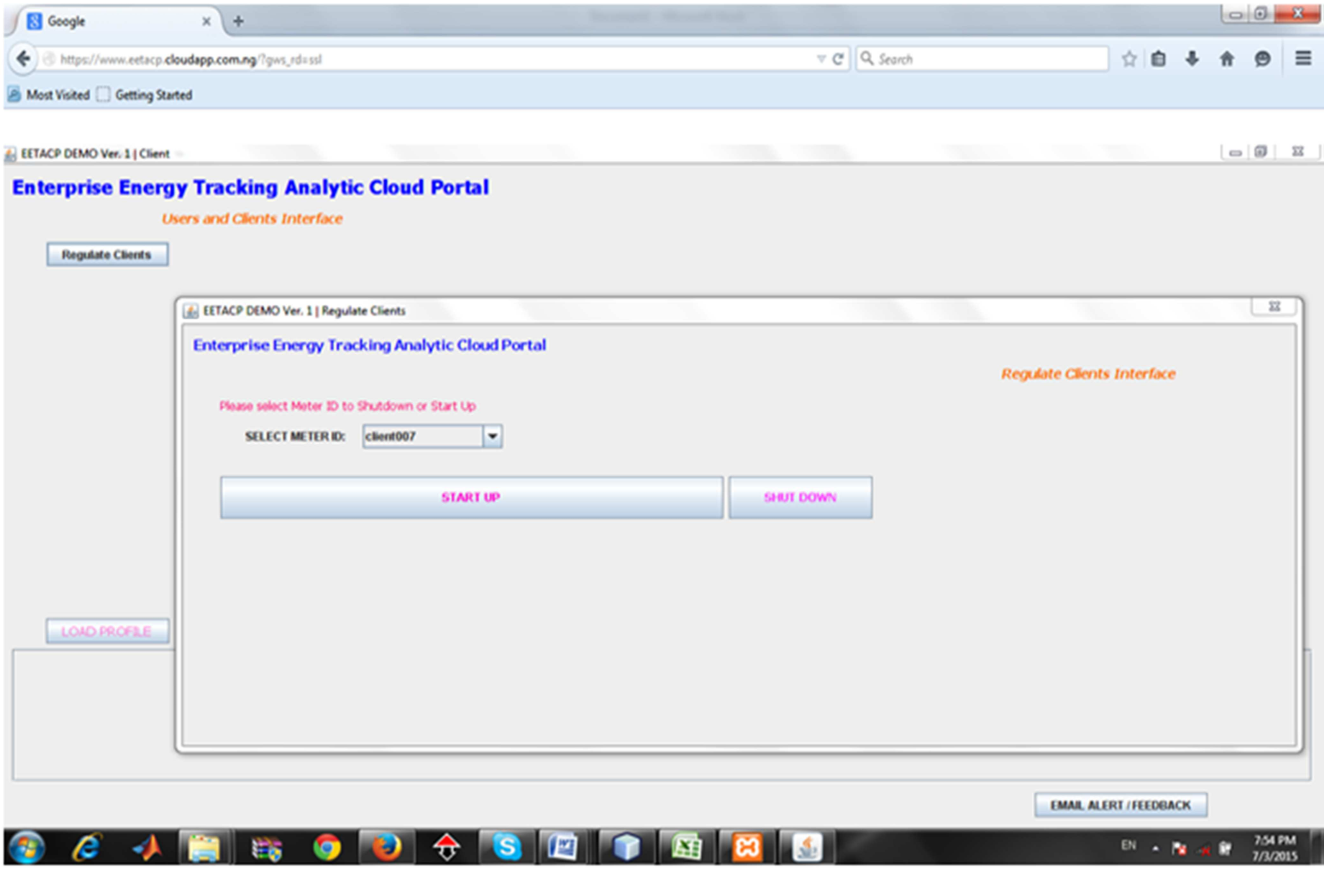

Fig 12. EETACP Regulator Demand Side Control Strategy

Table 1. *Data Acquisition load Profile form Meter id C0007*

Current (I) A	Voltage (V)	Power (W)	Power Factor	Meter id	Location	Date/Time/Year
5	177	885	0.8	C0007	Orlu	5/3/2015 22:39
23	127	2921	0.8	C0007	Orlu	5/3/2015 22:40
45	51	2295	0.8	C0007	Orlu	5/3/2015 22:40
28	105	2940	0.8	C0007	Orlu	5/3/2015 22:40
61	58	3538	0.8	C0007	Orlu	5/3/2015 22:40
25	136	3400	0.8	C0007	Orlu	5/3/2015 22:40
47	44	2068	0.8	C0007	Orlu	5/3/2015 22:40
32	136	4352	0.8	C0007	Orlu	5/3/2015 22:41
7	58	406	0.8	C0007	Orlu	5/3/2015 22:41
87	150	13050	0.8	C0007	Orlu	5/3/2015 22:43
155	149	23095	0.8	C0007	Orlu	5/3/2015 22:43
131	192	25152	0.8	C0007	Orlu	5/3/2015 22:43
70	179	12530	0.8	C0007	Orlu	5/3/2015 22:43
91	123	11193	0.8	C0007	Orlu	5/3/2015 22:44
65	30	1950	0.8	C0007	Orlu	5/3/2015 22:44
1	62	62	0.8	C0007	Orlu	5/3/2015 22:44
112	179	20048	0.8	C0007	Orlu	5/3/2015 22:44
174	63	10962	0.8	C0007	Orlu	5/3/2015 22:44
75	137	10275	0.8	C0007	Orlu	5/3/2015 22:44
161	86	13846	0.8	C0007	Orlu	5/3/2015 22:45
116	58	6728	0.8	C0007	Orlu	5/3/2015 22:45
71	24	1704	0.8	C0007	Orlu	5/3/2015 22:45
19	170	3230	0.8	C0007	Orlu	5/3/2015 22:45
20	197	3940	0.8	C0007	Orlu	5/3/2015 22:45
61	85	5185	0.8	C0007	Orlu	5/3/2015 22:45
140	56	7840	0.8	C0007	Orlu	5/3/2015 22:46
102	96	9792	0.8	C0007	Orlu	5/3/2015 22:46

6. Conclusion

In this research, a renewable energy resource was integrated with cloud energy meter that communicates with the EETACP in a DCCN (R-SGEMS). A Java based EETACP application that captures energy data from a CEMS into the DCCN storage network was designed, implemented and tested. It was proven that communication between the utility gateway server and CEMS results in managing the peak consumption using DSM. By leveraging the potential of cloud computing network for EETACP deployment, users can effectively make informed decisions on their consumption pattern while allowing peak and off peak consumption controls. The R-SGEMS shows greater prospects for the developing economies and demonstrates improved capabilities compared with existing systems. Future work will focus on energy billing in EETACP platform for end users.

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