A Smart Energy Management System for Residential Use

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***Abstract*—Smart energy management is a key research area and many strategies that enable control between household appliances and multi-power switching have been examined. However, a limitation of such strategies is that they enable automatic control of household appliances to avoid electricity interruptions and employ renewable energy sources to reduce electricity costs. For proper energy management to be realised, an algorithm needs to be developed that will control and enable the renewable power sources utilisation and automatically limit heavy loads which are in use during peak hours. These include high-consumption stoves, water and space heaters that should adhere to the set limit (automated distributed load limiting mechanism). Therefore, cost-effectiveness of energy and avoidance of electricity interruptions is realised. This paper examines smart energy management systems for residential use that have been implemented and we propose a model that results in the management of energy consumption of household appliances during peak hours based on availability of renewable power sources. Moreover, a smart algorithm that will switch between the various power sources to improve the Distributed Energy Resource (DER) and increase the profit of DER is discussed, as well.**

***Index Terms*—Energy management system, Energy measurement and communication unit, Load shedding, Renewable energy, Smart energy management**

I. INTRODUCTION

There are verifiable changes when current smart energy management is compared with the old ones [1]. There has been increased utilisation of renewable energy sources and automated distribution load limiting mechanism. In contemporary South Africa, there is lack of reliable intelligent energy management systems that integrate alternative green energy systems with the main traditional power supply, for instance Eskom. Factors like the time of day, season and load power should be taken into consideration when choosing the best source the load can cater for. It is also vital to arrange for intelligent switching off, of unnecessary loads during peak periods [2]. For the management of electricity to be realised, misuse of energy during peak hours to be avoided and multi-power sources switching technique problem to be solved: a system is to be analysed and investigated to replace the current Distribution Board (DB) [3].

An intelligent switch board will enable the automatic switching off, of power for a certain period of time during the day. For instance, in a household running on solar power that cannot supply the whole house – the system can switch off the heavy loads that are not in use at the peak hour and supply the households with electricity until the renewable power source runs out. Thereafter, it can switch back to the traditional power source. A number of embedded systems are known as multi-power sources switching technique embedded system [4]. These systems switching technique rely mainly on multiple renewable power sources to renew their energy need for extended operation [5]. Thus, the integration of renewable Distributed Energy Resources (DERs) is vital to reduce the overhead of the main electricity grid. However, an efficient system should be in place to manage these DERs efficiently. Presently, there are various solar power systems with a configurable device to control the power flow in the system. According to [6], this has proven benefits not only to the consumer, but also to the power utilities.

There is no automatic control algorithm to control the multi-power supply in the household based on the real time conditions of the DER. Therefore, the DER will develop an automated distributed algorithm that can switch between the supplied power of the grid and the renewable energy sources to the household based on time. The proposed system reduces energy consumption and provides alternative use of renewable energy to cut cost and prevent load shedding. This is achieved through the introduction of an automated distribution board with a switching unit that does an automatic switching for the power supplied in the house.

II. SMART ENERGY MANAGEMENT SYSTEM

A. *Benefits of the System*

There are many benefits that can be realised by implementing the smart energy management system. Firstly, automatic switching off, of heavy loads during peak hours is achieved. Secondly, provision of a channel for alternative use of renewable energy, for example solar energy, is achieved.

Thirdly, communication between the user and the household is made possible. Fourthly, power blackout and damage to household appliances like television sets, refrigerators, etc. can be avoided. Fifthly, different consumers have different energy requirements. This can be encompassed into smart grids to optimise energy utilisation and storage. It provides consumers with options of which source of electricity to use.

This paper looks at vital impacts of power use and its control for optimal use by consumers. With more and more consumers being connected to the grid, we propose innovative suggestions to ensure systems that are sustainable, cost-effective and environmentally-friendly are adopted to avoid a shortfall in electricity supply.

B. *Data Collection*

Data from houses will be collected based on the following factors. Firstly, the power wasted during peak hours (between 10 am and 5 pm when heavy loads are on) will be compared to when they are switched off. Secondly, the use of renewable energy as an additional power to the household will be considered. Thirdly, comparison of other methods of communication between the user and household utilizing Global System for Mobile Communication (GSM) technology will be carried out.

Once all data has been collected and examined, the smart energy management system will be modelled. The modelled system will be simulated on Matlab/Simulink and a comparison will be made of the graphical results with the collected samples from the houses. This will be done serially during different climatic conditions to make sure this system is stable and can help us manage electricity without being affected.

III. METHOD

A model of distribution board will be modelled on Matlab/Simulink with the major switches like geyser, lights, plugs, swimming pools and gates for the household. Based on this, the switches will be operated automatically during peak hours (between 10 am and 5 pm). During this period, if there are heavy loads that are not in use but are switched on, they can be switched off automatically.

Through the model of this distribution board, a channel will be provided for alternative use of renewable energy like solar energy. It should be able to supply the entire house during the peak hours. In the worst case where the renewable energy cannot supply the entire house, the DB will switch off the loads not required during those hours to provide sufficient power for the required ones.

For a user to have a proper communication between his/her household electricity and appliances while away, the integration of mobile communication (GSM technology) will be adopted. The use for GSM technology for Short Message Service (SMS) is direct and appropriate for this system which notifies the user which appliances are switched off at peak hours.

Smart energy management system which is based on both an automated distributed load limiting mechanism and multi-power sources switching technique can reduce load shedding. In the distribution board, the switches inside will be replaced with automated switches. This is to help consumers to install renewable energy sources. Then there will be a unit designed to integrate with the switches in the DB. This unit will be designed using microcontroller and GSM technology that will help with the switching off, of the power sources automatically. Whenever there is a switch between the power sources, the GSM wireless communication system will report to the user based on what power the household is running on. This switch will take place based on research that most people are not in their houses between 10 am and 5 pm and also there should be sufficient energy from the renewable energy source to supply the household when the switch-over takes place.

A. *Automated demand side management system with the objective of achieving energy efficiency*

Demand side management initiatives can be classified as [7, 8]: Energy Efficiency programs and Demand Response programs. The former are designed to lessen electricity use during the year by reducing power use and energy demand. The latter are automated programs having a processing unit that can turn off certain appliances, for example pool pumps, washing machines and air conditioners for a short period of time at consumer sites.

In terms of supplying the house using renewable energy in this case with solar energy, if the available sunlight is not enough to supply the whole house; the unit is designed to automatically switch off the heavy loads in the house during these peak hours. The communication between the Energy Measurement and Communication Unit (EMCU) and the server at residences utilises ZigBee – a little power device used for transfer of information [5]. Energy and power data from the outlets are gathered by the home server and allows it through Zigbee access point. The home server then analyses the data gathered and profiles utilisation of electricity by lights at residences and for appliances, as well. Energy and power information can be accessed through the home server which shows the energy usage of different lights and appliances [9].

A typical architecture of a Zigbee and Programmable Logic Control (PLC) based optimisation of energy utilisation in residences involves integration – traditional and renewable energies to help deal with the problem of electricity cost and energy efficiency [10]. This smart grid concept is enhanced by the implementation of low power energy management system. Wireless sensors which enable Energy Management System (EMS) capabilities in homes have been proposed [10, 11]. [9] explain that Smart Home Energy Management System (SHEMS) balances energy efficiency and its energy savings in an easy way for homes. [13] have focused on consumers to remotely track, manage and measure use of electricity by home devices that are linked to the system. For a decade, multiple power sources seems to be the solution to load shedding but the challenge is how households integrate the multiple power and distribute it firmly to avoid load shedding. There have been many ideas around it but it is necessary to identify the one which is user-friendly, cost-effective and much convenient to consumers. [14] propose a switching system called Multi-Tiered System of Supports (MTSS)

whose principle relies on advance time. [15] present a model which integrates renewable energy in smart grids based on demand side management algorithms and modelling.

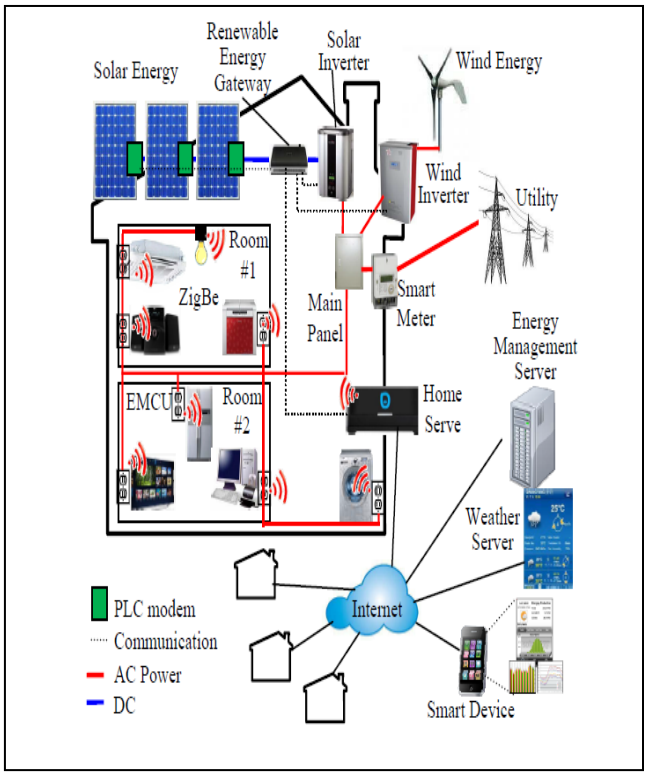

Figure 1. Design of optimisation of energy utilisation in residences taking into account power utilisation and production [16].

[17] propose a system that utilises Energy Management Decision Support System (EMDSS) which synchronises and optimises (independently) the control of power utilisation, conservation and for sale to power utilities and consumers – both in industry and residences. The network is made up of hardware and programs integrated into already implemented systems for optimisation of energy use, or set up as recent infrastructure. Incorporation of two key areas is achieved: within the building and its communication with other EMDSSs and the electrical grid. A proposed implementation system that utilises Automatic Meter Readers (AMR) and General Packet Radio Service (GPRS) technology provided by GSM networks is discussed by [18].

According to [19], this system of energy management is about the integration of the traditional energy and the renewable energies to help deal with the problem of electricity cost and energy efficiency. Their execution of sensor networks utilising little power strengthens this smart electrical grid model in residences allowing EMS potential [12]. SHEMS stabilise efficiency of power and cost-effectiveness ensuring consumers' satisfaction. Optimisation of energy utilisation in residences provides one of the following benefits [13]. Firstly, educational benefits where details of power utilisation is outlined. Secondly, self-operating benefits where consumers may prioritise use of equipment in their residences as well as for production. Thirdly, progressive benefits where details, motorization and management is achieved remotely or jointly with selected people. Finally, there are incorporating benefits which includes possibility for forecasting and scheduling of loads and generations at household level. However, the question is whether the system is friendly to all consumers especially in the urban areas in terms of them using wireless sensor networks.

By utilisation of the proposed system and its effective use, electric power will be optimised and saved. It is advantageous not only to residences, but also to the industry. Cost-effectiveness in power utilisation and use of renewable energy sources can be realised. Power utilisation requires efficiency and a software that will be incorporated into the smart electrical grid that will benefit residential electricity users

SEMS follows recent advancements and unfolding technological inventions that enable cost-effectiveness and efficiency for power utilities and consumers. In [20], the main focus is for the consumers to remotely track, manage and measure use of electricity by home devices that are linked to the residence energy system.

A lot of EMS enable the observation of meters used to monitor electricity consumption. Data recorded can be utilised to predict energy consumption yearly. It can be utilised in the generating, transmitting and distributing electricity in the electrical power grid. There are power losses that are inherent with the traditional electrical power grids. These, in addition to inefficiency, are often unaccounted for and not tracked. With more and more consumers of electricity, there is a discrepancy between demand and supply of electricity. This has resulted in power utilities worldwide implementing smart electrical grids. Information and Communication Technology (ICT) has also been incorporated in this transition from the traditional electrical power grid to smart grids. The improvement in ICT can be utilised to implement remote monitoring and motorisation for effective Demand-Side Response (DSR). In a case study in Thailand [21], utilisation of smart grid is key to the efficiency and growth of the organisation. The Provincial Electricity Authority (PEA) smart grid utilises software that monitors electric power being consumed. This includes creating a load profile that enables consumers to be selective of the devices they use at specific times, for instance Heating Ventilation and Air Conditioning (HVAC) equipment.

B. Automated demand side management system with the objective of acting in crisis situation to avoid electricity interruptions

[21] posit that the automated multiple power sources switching and monitoring system need to be in operation for 24 hours so as to maintain a continuous function of monitoring and controlling on load power. [22] considered the challenge of power utilisation of an isolated microgrid powered by Photovoltaics (PV) with storage. The microgrid is structured in such a way that a supervisory EMS communicates over a network with remote Real-time Control System (RCS). Forecast of power accessible is generally dependent on the forecasted generation, State of Charge (SOC) of batteries

utilised and the load. It is used to evaluate and advise the users on estimated duration of time left before the occurrence of an outage so as to introduce a preemptive load shedding in order to support critical loads. [23] propose a controller that automatically shifts between a Power Limit Switch (PLS) and adaptive Maximum Power Point Tracking (MPPT) modes to control the extraction of wind. MPPT is utilised when the wind speed provides the highest power levels but lower than the expected power level. The adaptive MPPT memory bank increases the maximum power search procedure by utilising Turbine Speed Ratio (TSR) equivalent parameters. This TSR is the turbine's aerodynamic efficiency and at a turbine's distinctive optimum TSR, maximum power is extracted for all wind speeds. GSM has become the wireless communication standard for more than half of the world's mobile phones. In this paper, the GSM wireless communication is used to avoid human error in terms of reporting. There have been similar implementation in Europe to ensure regulation of power use through load shifting with smart energy appliances [24].

This paper proposes automatic reporting system to reduce human involvement. An intelligent operation is necessary today in order to serve mankind and avoid tedious work. [23] propose an intelligent power meter system which uses GSM technology to report the power consumption to the clients. Based on that, it shows that GSM has a wide range for proper communication system. The GSM transmission is used to establish connection between clients and the server. The consumer's energy meter is on real time communication with the server. To transmit data over a distance of many kilometres, GSM proves to be very efficient.

C. *Transmission Protocol*

The GSM transmission is used to establish connection between client and the server. The consumer's energy meter is on real time communication with the server.

IV. CONCLUSION

In conclusion, the proposed smart energy management system will help conserve energy and improve the efficiency of power sources for residential houses. This is achieved by integrating renewable energy sources in the provision of power to households. Further, this will result in reduced electricity cost through the management of energy consumption of household appliances in use during peak hours based on the availability of renewable power sources. With the demand for energy becoming more and more, systems to utilise energy efficiently and optimise existing sources are vital.

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