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The Design and Realization of Smart Energy Management System based on Supply-Demand Coordination

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Abstract: Sub-Saharan Africa in recent years have been faced with many power challenges including limited and unreliable power supply, high cost of power supply and underdeveloped power infrastructures with serious negative impacts on the socio-economic development. This paper presents the development of Smart Energy Management Solution (SEMS) for buildings. The work seeks to propose a generic algorithm that supports existing wiring infrastructure of buildings in Africa to provide 24/7 reliable power supply and efficient management of limited power supply in buildings. SEMS focuses on the use of robust, distributed and heterogeneous power sources connected in islanding phenomenon to ensure reliability and also using a dynamic approach with energy efficiency measures to provide a balance between power supply and demand in buildings. A demonstration of SEMS for buildings was performed in MATLAB Simulink using actual data obtained from selected buildings at Kwame Nkrumah University of Science and Technology (KNUST), Ghana. SEMS revealed higher power reliability and efficiency in energy usage.

Keywords: Smart Energy Management Solution (SEMS), building automation, energy efficiency.

1. INTRODUCTION

Many developing countries in Sub-Sahara Africa in recent years have been faced with many power challenges including limited and unreliable power supply, high cost of power supply and underdeveloped power infrastructures [1]. The current power generation, distribution and consumption in these countries are not sustainable [2]. This is caused by the accelerated population growth and the changing consumption habits by energy consumers. Scheduled blackouts is very common in most of these countries. Large scale energy generation from renewable energy sources and efficient energy management strategies used to balance energy supply and demand has received a lot of attention among researchers lately [2]. Renewable energy sources including hydro, solar, biogas, geothermal and biomass gasification are being developed in Africa [2]. These alternative power sources require efficient energy management strategies to ensure optimization. Energy efficiency requires providing more energy services with the same amount of energy or less energy. This solution can be achieved by optimizing the demand side with the aim of reducing the energy requirements per unit output while maintaining a fixed or minimal cost of power supply.

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Such energy management strategies can be fully automated, semi-automated or manual. Among the numerous energy efficiency and management algorithms and models implemented include [3-11]. Autonomous demand side management in [8] considered the implementation of energy consumption scheduling devices in smart meters to determine optimal energy consumption schedules for users. Real time energy consumption monitoring and displaying of statistics and real time data to enable user take decision is another energy management strategy used by [9]. Some works on smart grids have been proposed in [12-13]. Majority of proposed algorithms focus on controlling individual devices in buildings based on predefined conditions.

The current wiring infrastructure of most buildings in most developing countries does not support the controlling of individual loads. Applying most existing solutions to control individual loads in these buildings will call for rewiring to be done which makes this option expensive. The cost of rewiring usually deters people from implementing or investing in energy management systems for building automation and control. In order to avoid or reduce this extra cost of rewiring, SEMS is therefore designed to support these buildings with no or less retrofits by controlling certain set of devices connected to dedicated control systems (switches) on smart distribution boards. Optimization of energy is also ensured in SEMS by using occupancy sensors in certain rooms based on the occupancy pattern of these rooms.

SEMS provides a generic algorithm which focuses on the new approach for meeting electricity demand with a

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distributed and heterogeneous source of power supply to ensure reliable power supply [13] and energy efficiency in buildings. Our proposed solution will be very critical for industrial, commercial and residential power users who would like to avoid depending strongly on the power from the unreliable national grids by accepting to generate their own power (backup supply) and wish to stay within the capacity of their energy production.

This study provides some crucial benefits to Industrial and Commercial Building users by allowing them to maintain their normal operations while gaining additional economic value from energy savings. The next section provides an overview of system designed from the proposed algorithm and details of the SEMS. This is followed by simulation results which discuss reliability and energy savings.

1.1 System Description

The overall overview of the designed system from SEMS is shown in figure. 1. The distributed power sources are coordinated in islanding phenomenon to provide reliable power supply [12] [13]. Energy management strategy is done at the smart distribution board side to provide a balance between the supply from the distributed sources and the demand in the building. This is done in order to achieve 24/7 reliability and user functionality in buildings. The smart distribution board (DB) consists of smart devices (control switches) such as programmable logic controllers (PLCs) or Programmable control device (PCD) connected to conventional DBs to automatically control circuits as indicated in figure 2. Communication is done through Power Line Communication systems [3]. SEMS also promotes the use of smart meters to provide real time power production and energy consumption patterns and records of the energy performance of buildings. Energy consumption data can be logged and analyzed in either a graphical or numerical ways. Energy efficiency is also achieved through installation of occupancy sensors, which help to automatically turn on and off loads when needed. These together with the use of energy saving devices such as bulbs provide some energy savings in the building.

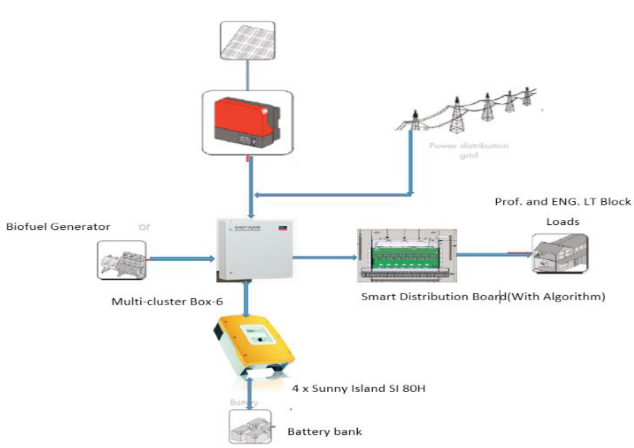

Fig. 1. Proposed system architecture for SEMS.

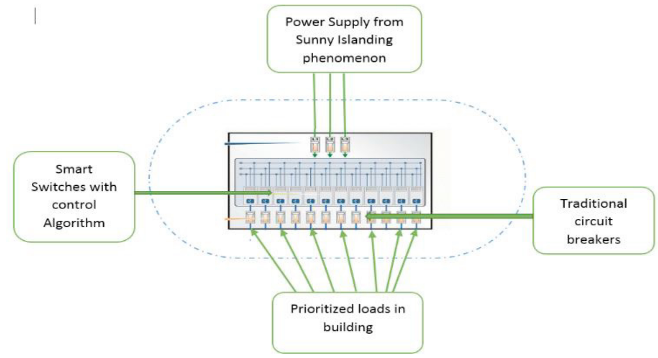

Fig. 2. Smart Distribution Board controlling dedicated circuits (devices).

2. DESIGN OF PROPOSED SEMS

2.1 Building Structure and Occupancy Pattern

A survey is first conducted on the selected building to gather information about the wiring topology, room types and number, shutdown strategies, building usage and occupancy schedules. The current or implemented energy efficiency measures in the building are also reviewed.

2.2 Power Dimensioning

The power dimensioning gives the information on the type of electrical power sources installed or to be installed in the building, their capacities and the cost of operation. The overall power supply available to the building is obtained from this information. In addition to this, the various available power sources are ranked based on availability and cost of operation. This information is therefore used to design an efficient strategy to implement a power network for the building. A typical example is the network of power sources (grid, solar PV, generator, battery etc.) in the sunny islanding solution reported in [12] [13].

2.3 Load Assessment

Load assessment provides information on the kind of loads used in the various rooms in the building, their consumption ratings, how sensitive (priority) they are to users and scheduling hours. A model for power demand and supply can be found given the following parameters:

L_i= Energy consumed per hour by a specific load (kW)
C_r= load demand of a specific room (kW)
E= Total daily demand in the building (kW)
h= Number of hours scheduled for a day
n= Number of a specific load in a specific room

$$C_r = \sum_{i=1}^{N} h \times n \times L_i \quad (1)$$

$$E = \sum_{r=1}^{N} C_r \quad (2)$$