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A Smart Monitoring and Control System for the Household Electric Power Usage

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Abstract: The energy consumed is frequently derived from nonrenewable sources, which may be contributing to the planet's current state of global warming. People are becoming more aware of the dangers of energy waste and are increasingly seeking further relaxation by getting numerous appliances in their homes that are left on all day, and they sometimes leave their homes with a light bulb on, heaters on, televisions on, and so on. We present in this paper the formulation and construction of a home energy management system that provides householders with uninterrupted pieces of information on their power expenditure, allowing them to conserve energy. Even though the solution to this problem is already commercially unraveled, the goal of this research is to design and build a power control system that provides users with comprehensive information regarding his/her energy needs and permits for detecting, regulating, and advanced analytics by using sustainable energy as a source of power at the local level in a Nepalese micro-grid. This project highlights the importance of renewable energy in a microgrid.

Keywords: Behavior Sensitive Loads, DERs, Distribution Model, HEM.

1. INTRODUCTION

HEMS refers to a smart house that provides energy management services for effective monitoring and governance of electricity generation, power conservation, and energy storage technologies. In addition to household consumption status, HEMs provide facilities for distributed energy resources (DERs) and hybrid energy-storage systems (HESS). To engage in power conservation and respond to demand growth, HEMS must be more versatile in directing and maintaining electronic devices, as well as renewable energy resources.
The premise of HEM systems, or SHEMS, is far more than just bringing new energy-saving

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models, power management, or developing energy-efficient home equipment; it is more about raising consumer awareness and promoting people to actively participate in power-saving activities. The HEMs enable users to participate in the electric power market by allowing demand curve modulation based on the user's specific profile. HEM prioritizes load consumption in terms of both cost and energy availability. According to the findings of the study, monitoring energy use causes consumers to adjust their behavior when using household appliances, resulting in energy savings of up to 30% [2]. The presence of an electric vehicle in a smart grid scheme coupled with the HEMS application can help to balance supply and demand by reducing peak residential loads and valley filling. The research on the creation of HEMS can be divided into four categories: scheduling issues, automation and control, communication issues, and the HEMS system.

HEMS holds functions required for current epoch for effectiveness such as monitoring, logging, control, management, alarm and much more. The HEMS is a critical ingredient of the smart grid and offers significant advantages, which would include automation, gives accurate results and predictions, optimizes the generation units, reduces energy losses, helps manage end-users' load demand, remote control, energy management, and efficiency improvement. While pros of such system is evident, as such its cons in current developing Nepal. Because of the numerous obstacles that this technology faces, the HEMS has not been fully deployed. Many challenges are stated in the study, which is outlined here as expensive implementation cost, no standards for HEMS, Low consumer awareness, choice of Information and Communication Technology (ICT)[6], difficult to create a system that caters to various degree of customer understanding of HEMS, and last but not the least HEMS aggregation.

The HEM prototype database is made up of four essential aspects: Appliance model, Energy storage model, Distributed generation model, and Baseload model. The vast majority of HEMS are intended to manage power consumption, improve the operation of a smart grid, optimize needs, enable gadgets for in-home users, and so on. More specifically, HEMS smartly surveils and adapts energy consumption via smart meters, smart devices, equipment, and smart appliances, leading to more effective power and governance.

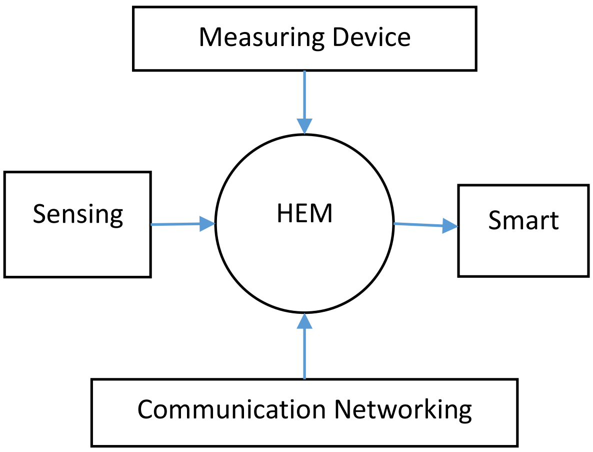

Figure 1 Components of HEMS

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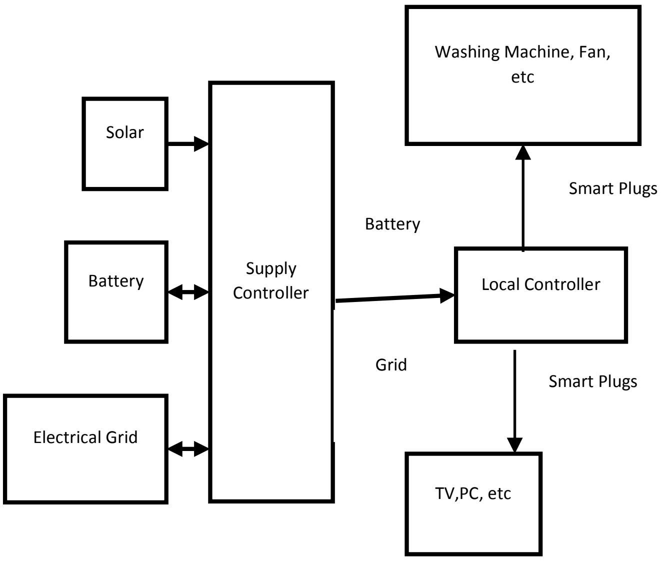

Figure 2 A Prominent HEMS's General Layout

2. METHODOLOGY

The key objectives that were met throughout this capstone project can be classified into two groups. To begin, extensive study and literature review were used to have a thorough understanding of the smart grid industry. The concrete outcomes are the second step in the smart research lab: It was previously possible to read data from sensors.

2.1 GUI Design and Model

In this section, we address the modeling considerations discussed in the following section before briefly describing how to include the models into a dynamic programming framework for simulation development.

Wide variety of regulated equipment and distributed energy resources (DER) may well be chosen to develop home models depicting domestic electricity power usage in changing phases when building separate HEM Simulink focusing on various control procedures. A GUI is built to help in the selecting process, as seen in Fig. 4.2.1. The main GUI platform enables the program creator to easily change the prototype used to depict TSLs and BSLs.

2.2 Design Considerations of The Hem

The purpose of the HEM system's software architecture design is to provide a single simulation platform for HEM as to make it easier to implement and test their control algorithms, the

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simulation engine, utility models, and distributed energy resources (DER) models are all included in the dwelling module, GUI may be used to set the parameters of the appliance and DER models, which are then communicated back to the HEM database and by reading data from the database, the GUI will present the findings

A home energy management system (HEMS) connects photovoltaics, grid power, and a battery as complementing power sources for a given dwelling. The photovoltaic system is directly connected to HEMS. Maximum Power Point Tracking (MPPT) management is used to extract the most power from the solar panel utilizing a unidirectional DC/DC converter. Cascade control, which consists of a series of voltage, current, and PWM controllers, pushes a unidirectional DC/DC converter to detect the power level estimated by MPPT control. The HEMS is also directly connected to a controller that includes a Power Conditioning System and a Battery Control System. A maximum power point tracker, or MPPT, is an electronic DC to DC converter that optimizes the match between the solar array (PV panels) and the battery bank or utility grid [6]. The MPPT monitors the voltage and current from the solar module to identify when maximum power is reached so that it can be extracted.

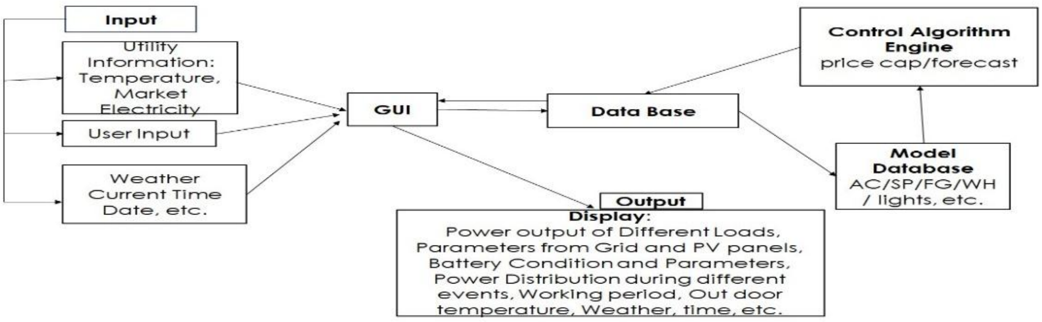

Figure 3 Architecture of the HEM

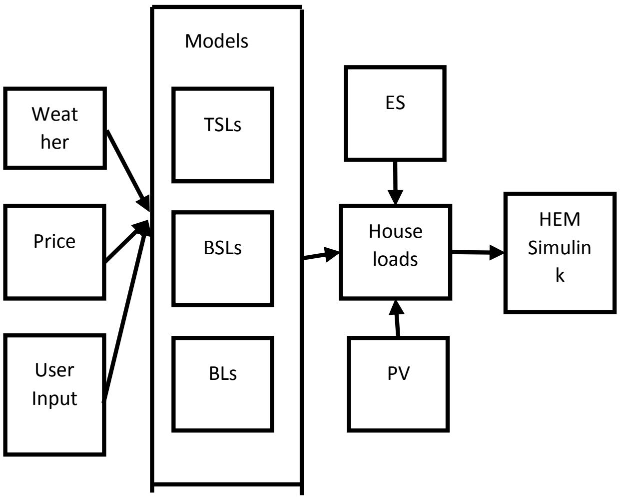

Figure 4 Algorithm Development

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When adopting multiple HEM techniques based on numerous performance requirements, separate configurations of controlled devices and DERs may be shortlisted to develop house models depicting domestic electricity energy consumption in varying seasons. Simulink model of house baseloads and controllable loads connected in parallel along with switching mechanism for battery and solar switches. Power during respective source is selected based on switching operation while different baseloads are connected in parallel.

In this section we design different components of HEMS and integrate them together for accurate and reliable result. Different components like power grid, battery, inverter, MPPT, PV array, House Loads, and different respective controller are designed in Matlab Simulink as shown in figure 5.

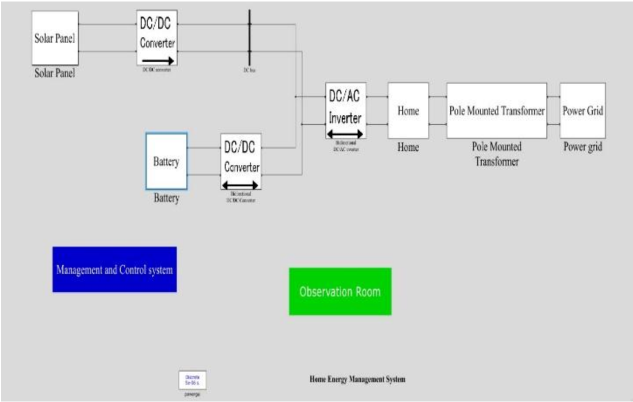

Figure 5 HEMS Sample

3. RESULTS AND DISCUSSION

Different combinations of controlled devices and DERs may be shortlisted when applying multiple HEM approaches based on various performance as requirements in order to construct home models that represent residential electricity energy consumption in various seasons.
When Simulink is run for Time period equivalent to 6T under different operation condition following output graph is obtained.

Operation Procedure:
Step 1: For a certain time of the day (9 am: 3 pm), the output of PV is a maximum and constant of 5000 W.
Step 2: Base Load Power Demand is 408.8 W (200 W+58.8 W+150) and Controllable Load is of 6000W (3000 + 3000 W)
Step 3: PV is constantly supplying with the power of 5000W.When the Grid is ON, then required another extra Power is supplied by the grid.
Step 4: When Grid is OFF and Battery ON. Then Controllable Heavy Load is off, only Base Load operates.
Step 5: When Battery is ON, Power Demand is only 408.8 W. Other extra power from solar is used to charge Battery.

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Step 6: When the Grid is ON then Battery becomes OFF. If only base loads or non are operated during the Grid ON period, then extra power is supplied to the grid

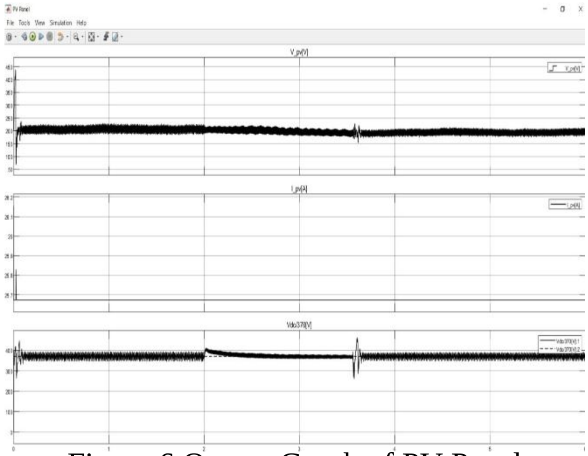

Figure 6 Output Graph of PV Panel

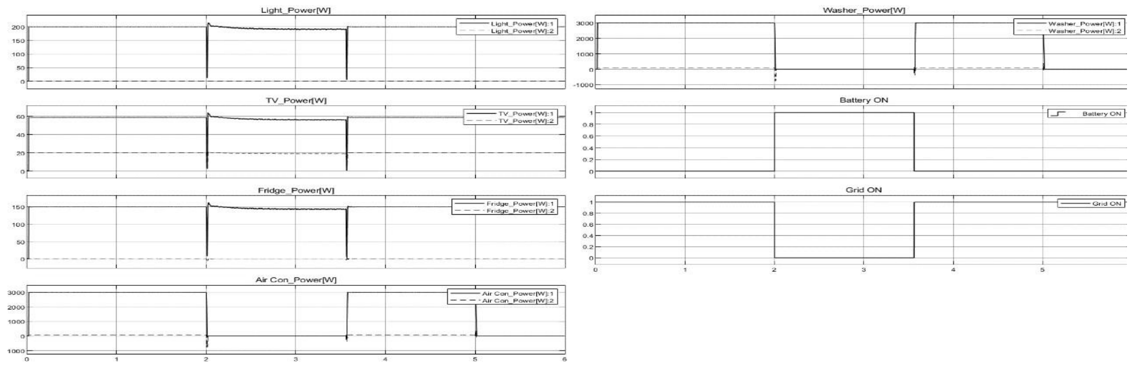

Figure 7 Output Graph of Load Power

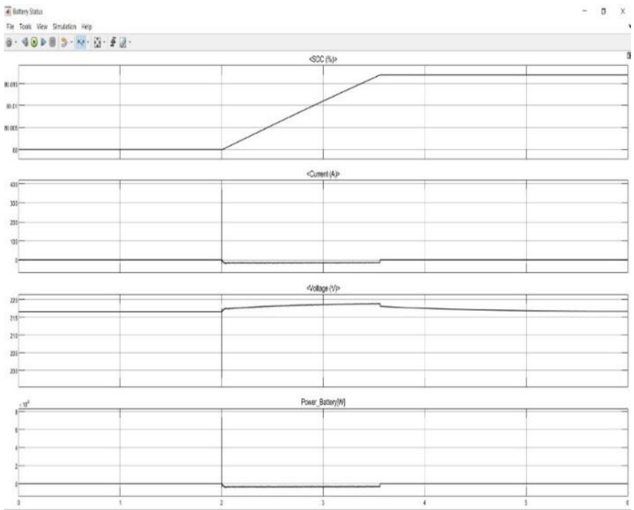

Figure 8 Output Graph of Battery

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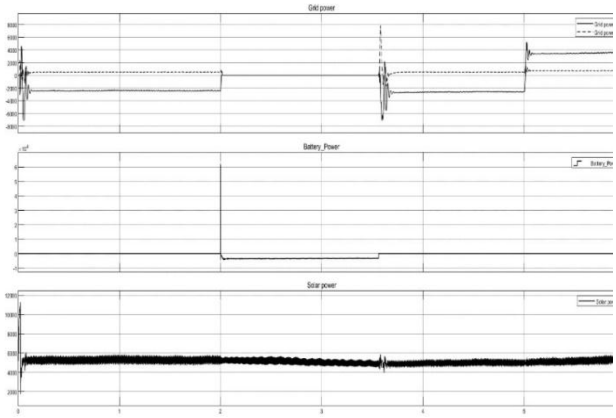

Figure 7 Output Graph of Power Source

Fig 7 shows the output power drawn by different baseloads and controllable loads for a time period of 6T. During 2T to 3.5T grid is down and the battery is instantaneously switched ON. The current, Voltage, and Power of the PV array are shown in Figure 6 during 6T. For PV, its parameters are constant for a given period. When Battery is ON, extra power by PV is used to charge the battery as shown in Figure 8. We can observe SOC is increasing during this period. From 0 to 2T, power supplied by PV is insufficient as compared to power demand, hence extra power is supplied by the grid as shown in Fig 9 during that time. But when the grid is OFF, then the battery is ON, and only base loads are operated. During that time PV power isn't fully utilized by load, so extra power is used to charge the battery. Also, during 5T to 6T when only the base load is operated, extra power is supplied to the grid as shown in above figure 9.

4. CONCLUSIONS AND RECOMMENDATIONS

As distributed renewable energy generation has become much more widespread, microgrids as local power systems that integrate HEMS have gained favor. HEMSs allow consumers to take management of their very own residences on a larger scale. Effective utility utilization management allows users to make energy-saving judgments without compromising quality. HEMS may play an important role in promoting the growth of integrated microgrids as a power system alternative in the future. HEMS reduces costs by allowing for greater energy efficiency, enabling microgrids more financially feasible. HEMS also provides substantial data on residential energy use via Neighborhood and Wide Area Networks, which operators can use to enhance grid integrity, reliability, and efficiency.

This study presents a Matlab-based toolbox for developing HEM algorithms. Other researchers designing similar test systems should benefit from the design considerations and modeling methodologies. Based on preliminary research findings from inventing HEM algorithms for PV system and responding to time-of-use and critical-peak-prices, the template not only helps in saving developers time managing various test scenarios, and moreover gives an accurate effective assessment approach to estimate the benefits of each methodology. Since home utility and DER models can differ, we recommend that the HEM developer community adopt a common modeling methodology. In order to employ more controllable resources and highlight the financial ramifications of HEM under multiple market alternative designs, we will incorporate appliance and DER models provided by other research institutions, as well as retail market data, in future projects.

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