

DEVELOPMENT OF HOME ENERGY MANAGEMENT SYSTEM SIMULATOR

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ABSTRACT: HEMS provide the owner the ability to control energy utilization in his/her homes based on their own priorities of load requirement. Renewable energy sources such as solar and wind generate energy at intermittent times thus requiring energy management systems to effectively use this energy. Distributed generation of renewable energy such as solar systems in homes require localized energy management systems termed as home energy management system. This paper develops the hardware for a home energy management system simulator to develop new algorithms and test existing algorithms. The simulator provides GUI for easier consumption and control to technical data.

Keywords:Energy management system (EMS), Renewable energy sources, Energy monitoring, Home automation, Distributed generation.

1. INTRODUCTION

In recent times the energy efficiency is becoming more important. Traditional power grids lack automation and sufficient monitoring tools which have caused major blackouts in recent times [1]. To address this issue, energy management systems have been developed.

Energy management systems (EMS) have widely been used in critical systems such as power stations to monitor the energy flow and to reduce the losses. Until recent times EMS were implemented in bulk energy system, but the realization of people to reduce energy consumption has led to smaller EMS such as home EMS (HEMS).

Energy consumption in India from 2000 to 2015 has almost doubled [7]. This increase in energy demand is exponential and to avoid further increase this needs capping. Schemes from the government to develop smart cities help Cap the energy demands of cities.

Decentralized generation reduces stress on grid power but have to increase the energy generated to meet the demand. This type of energy generation is positive in terms of reduced transmission losses but due to its intermittent availability cannot be relied on. To improve reliability of decentralized generation energy management systems play a vital role. The quest for EMS for homes results in HEMS.

This paper goes through the process of developing a hardware simulator to understand and make others understand HEMS and develop new algorithms or test existing algorithms to reduce energy consumption, monitor energy and rescheduling loads. Algorithms such as binary back tracking search [2], demand –response, peak shifting and load shifting techniques have been developed for HEMS application [3]. HEMS can also schedule operation of appliances reduce peak demand as discussed by authors in [4] [5].

Most HEMS present in the market across the world today are operated to schedule load on price signals. Apart from this few HEMS system also can manage power intensive loads to limit the peak demand. These are few commonly implement algorithm for HEMS. Testing of these algorithms with appropriate hardware under laboratory condition for a better understanding of renewable energy management is the subject of this paper. This paper presents the HEMS simulator hardware demonstration in a laboratory environment. Importance is on HEMS simulator setup and electrical measurements of source and load energy.

2. DESCRIPTION OF THE PROPOSED HEMS SIMULATOR

2.1 Overview of the Proposed Simulator

The concept of simulator is shown in the Fig. 1. The overall setup comprises of an independent solar PV system along with the monitoring and control functionalities. The raspberry-pi is the interface between the programmer and the PV system. The focus is on providing simple HEMS, whose algorithm can be modified without major change in hardware [6].

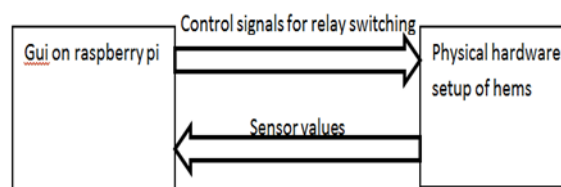


Fig. 1. Concept of HEMS simulator

2.2 Architecture of the HEMS Simulator

The HEMS comprises of a controller/processor and the physical measurement devices and switches. They are mere I/O devices to the processor. The algorithm used in the processor is what is important and this can be changed by the user to test their own algorithm.

3. HEMS SYSTEM

An independent solar PV system is made using a 10 W solar panel having an open circuit voltage of 20 V and short circuit current of 0.6 A. The panel charges a battery rated at 12 V, 7.5 Ah. The charging is via a Dc-Dc buck convertor. The input voltage range of Dc-Dc buck convertor is (2-32) V the output voltage range is (2-30) V. Dc-Dc buck convertor is made using LM2596 IC which is a switching regulator. The output voltage of this convertor is set to 12.5V using the potentiometer provided in the circuit. The battery supplies the inverter which is rated at 45 W. This inverter is extracted from a portable home/CFL UPS available in market. The output of inverter is single phase 220V AC. This inverter can supply a R.M.S current of 0.2 A. For the load, a 10W L.E.D bulb is connected.

DC Voltage sensors of range 0-25V are connected parallel across the solar panel and battery terminals. DC current sensor rated at 0-5A made of ACS712 IC is placed in series between 1) solar panel and battery and 2) Battery and inverter. These provide the necessary measurements to calculate energy. To provide control relays are placed following the current sensors.

All the sensors and relays are connected to the Arduino microcontroller. The Raspberrypi acts as a master and the Arduino as slave thus establishing communication via the UART protocol.

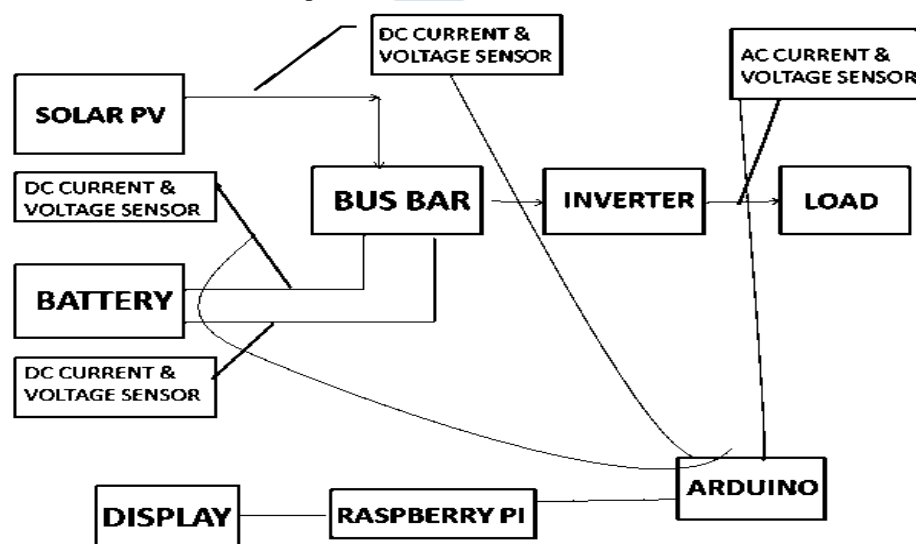


Fig. 2. Block diagram of HEMS simulator.

4. AUTOMATION

In the PV system once the battery is fully charge the solar panel is disconnected from the battery by the relay. The battery is fully charge when the battery voltage measures 12.8 V i.e.7.5 Ah can be extracted from the battery. When the voltage of the battery is measured 11V i.e. 0.5Ah. The inverter is switched OFF.

From the current and voltage measurements the energy generated by the solar panel is calculated, the energy consumed by the load and the amount of charge left in the battery is estimated by the raspberrypi computer. Algorithm used can provide automation of various types such as predictive control of loads, reduce loads during peak time, scheduling of load etc.

5. CALIBRATION OF SENSORS

5. 1. Current Sensor

Acs712 5a coupled with a 10 bit ADC (Arduino).

ACS712: Fully Integrated, Hall-Effect-Based Linear Current Sensor IC with 2.1 kvrms Voltage Isolation and a Low-Resistance Current Conductor. The sensor is shown in figure 3.



Fig. 3.Current sensor

Table 1. Calibration of current sensor

Sl. No	Load current	Sensor Output voltage	Adc value
1	0	2.5	512
2	5	5	1024
3	-5	0	0

5. 2. Voltage Sensor

Potential divider circuit coupled with a 10 bit ADC (Arduino).

The voltage sensor is a potential divider which attenuates the measured voltage by 5 times. It consists of two resistors that are connected in series. The sensor is shown in fig. 4.



Fig. 4. Voltage sensor

Table 2. Calibration of voltage sensor

Sl.no	Load voltage	Sensor output voltage	Adc value
1	0	0	0
2	10	2	410
3	25	5	1024

6. DEVELOPED HARDWARE

The assembled HEMS simulator is shown in Fig. 5.

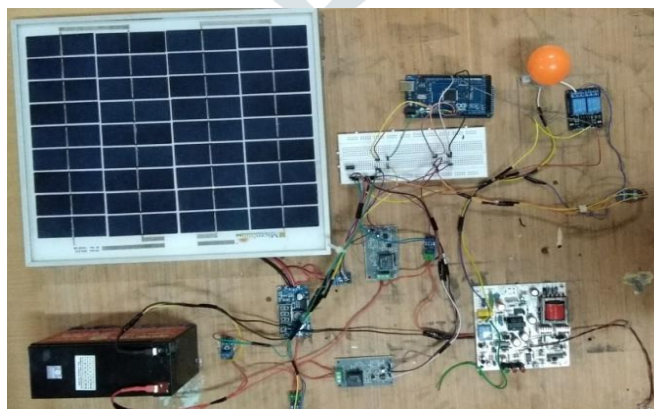


Fig.5. Assembled HEMS simulator

7. CONCLUSION

In this paper the development of the HEMS simulator is discussed in detail along the necessary hardware and software requirements.

The aim of this demonstration is to evaluate the HEMS performance on the algorithm it is running. Electrical measurement of the load energy consumed and potential maximum energy generated are present.

The HEMS simulator hardware demonstration comprises of a raspberrypi running a simple GUI application that was developed. The measured electrical measurements of the source and load confirmed that the simulator performed satisfactorily.

This paper will provide an insight into the overall HEMS simulator. The real world application of the proposed system will benefit the students of electrical engineering and to develop new and more robust algorithms for HEMS to be developed in near future.

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