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MICRO PV/WIND HYBRID BASED SMART ENERGY MANAGEMENT SYSTEM

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Abstract

Along with the widespread use of renewable energy systems, grid integration with the sources such as wind, photovoltaic (PV) is becoming a matter of importance in micro grids. Micro grids can be installed where energy is needed. In this research, a smart grid system has been constituted in the sample micro level. The system consist from PV panels, Wind turbine, charge regulators, battery, microcontroller system, and grid system. Energy demand of the load group is provided from the wind and PV based on hybrid micro grid. The electrical information taken from the PV and Wind turbine device with the voltage divider and current sensor is transferred to the microcontroller system. The load electrical energy requirement is primarily provided by the PV / Wind energy conversion, then by the battery and the grid in the last stage, all of the cases have been managed by the proposed control algorithm. Also, the excess energy generated by the PV/Wind hybrid system is transferred to the grid. As a result, the usage of PV/Wind hybrid energy conversion system has been increased at the highest level to supply benefit and the unit cost of energy has been reduced.

Keywords: Photovoltaic energy conversion, Wind energy conversion, Hybrid energy conversion, On-grid system, Smart system.

1. Introduction

The importance of renewable energy sources has been gradually increasing because of the possibility of the fossil fuels being consumed until a next fifty years and also their damages on the environment. Nowadays, the use of renewable energy sources has been promoted through various protocols and agreements with the aim of protecting ecological balance [1].

Solar and wind energy have been most popular renewable sources because of being both renewable and environmentally friendly [2]. The electricity generated from these sources are also cheaper than from conventional fossil fuels. In long term, economic benefits are more than conventional types including installing costs. Because of this advantage, amount of electrical energy generation from renewable sources have increased mostly in recent years [3]. Some legal regulations have also been made to encourage entrepreneurs.

Renewable energy sources, unlike fossil-based fuels, are an energy source that can be recycled and does not pollute the environment. Solar, wind, geothermal, hydrogen and biomass are the major renewable energy sources. Today, they are also preferred by societies, governments and utilities due to fact that they can be found in nature and theirs damages are less that compared with non-renewable sources [4].

With increasing awareness of the communities the environment and the nature, nations and governments have trended into renewable energy sources. Additionally, technological developments on the operation of renewable energy conversion systems made micro grids in to foreground. However, electricity should be stored by established hybrid systems due to discontinuous problem of wind and solar/photovoltaic.

Micro grids have been introduced the end of twentieth century as a new grid topology and management system. They can be controlled independent from bulk power system, and provide the energy by small distributed power sources. The energy from these sources can be delivered and consumed by using on and off-grid topologies [5]. A micro grid can be operated as power islanding mode [6]. In micro grids, both AC sources and DC sources generate and deliver the electric energy to the consumers.

Micro grids cover the network management methodology of embedded sources and also are known as distributed electric power networks controlled independently. A typical micro grid is shown in Figure 1.

In this study, a smart energy management system is designed by using distributed small scale micro grid. Energy obtained from solar and wind power sources as renewable sources with battery power and utility. As result of this design, demand of energy to consumers will be generated from solar and wind energy primarily. As these sources are inadequate to provide all of energy demand, battery and grid will use respectively. As a result, energy was provided continuously. Primarily, renewable sources and battery, were used as energy source. The power grid was used as energy source secondarily. Therefore, cost of energy was decreased and economic benefits were obtained. In practical design level, a control circuit are designed which is controlled by a microcontroller. The microcontroller will be check the energy level in studied experimental setup and provide continuous and less expensive energy.

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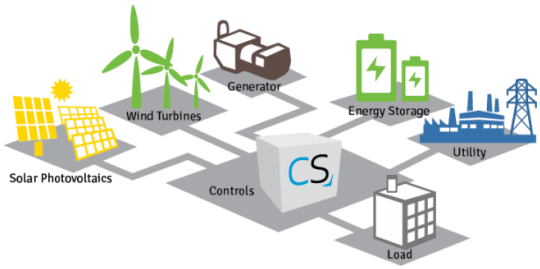

Figure 1.A typical smart micro-grid system

2. Energy Management in Micro-grids

Energy management system has been developed for the efficient use of energy. Nowadays, energy, society and nations are very important for their lives to survive, so it is important that they can be used efficiently [7-10]. The focus of the organization in energy management studies is the concept of "Energy Saving". Accordingly, the components of the generated energy management system are shown in Figure 2.

Energy management is very important in the design and set up stages of micro grids. Unlike conventional distribution grids, the integration and efficient use of different energy sources involved in the creation of micro grids can cause some difficulties and problems. Energy management needs to be implemented effectively in these systems in order to be able to perform the functions of the micro-grids and obtain the desired level of benefit. Figure 3 shows a typical energy utility scheme.

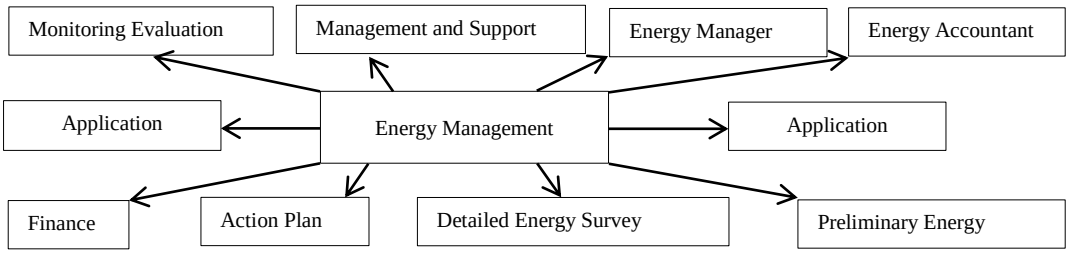

Figure 2. Components of energy management

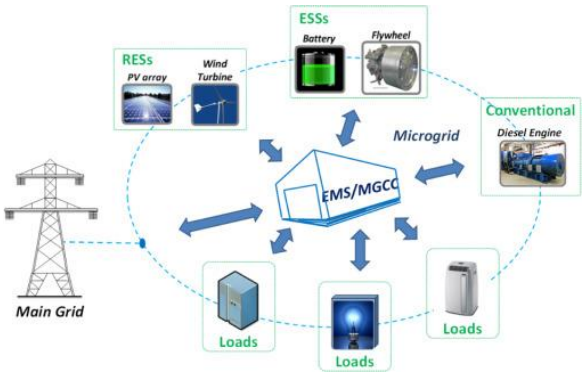

Figure 3. Energy management in micro-grids

3. Experimental Setup

3.1. Design of practical application circuit

The primary goal in this work is to establish a micro grid system that continuously supplies the energy demand of the system without interruption and, together with this, the provision of renewable energy resources to meet the energy need. In the event that there is no possibility of obtaining energy from renewable energy sources, it will be covered by the battery, otherwise, the energy need will be met from grid. In addition, thanks to the on grid inverter in the system, the excess energy of the renewable sources will be transferred to the grid system. Thus, by using renewable energy sources at the maximum level, the grid energy use is kept at minimum level. This will get us an economic profit. The principle diagram of the application circuit is shown in Figure 4.

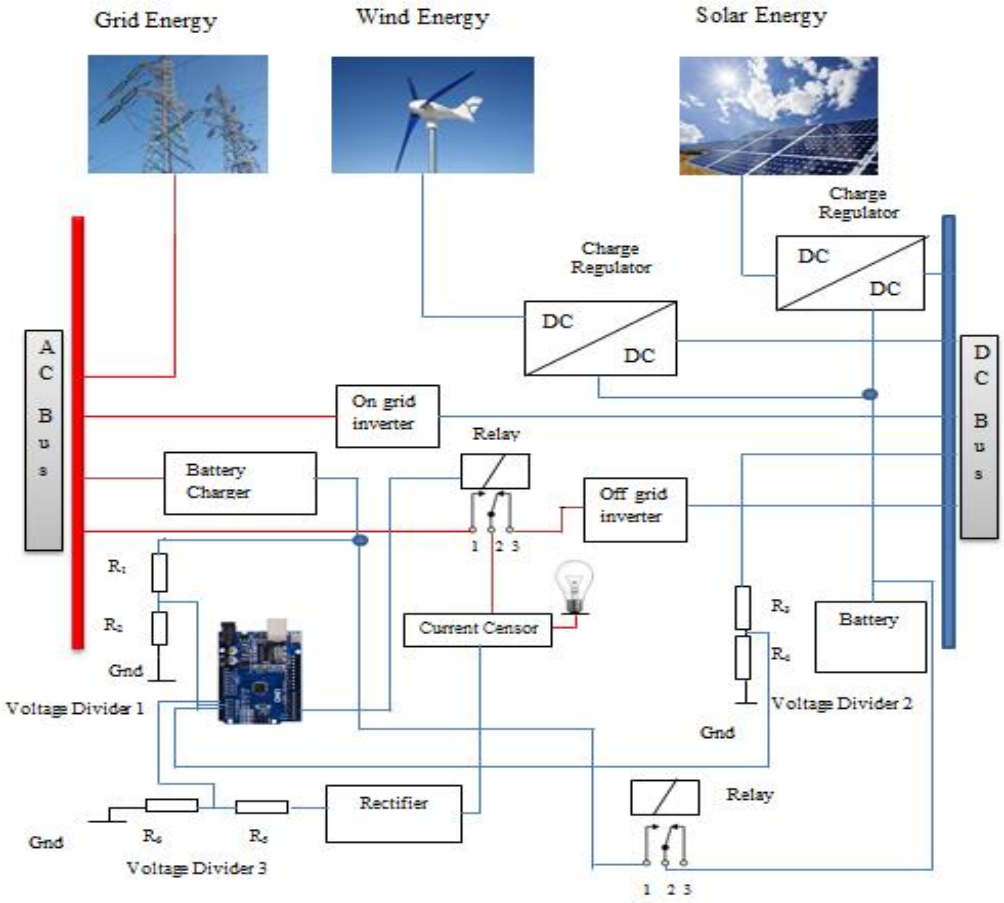

Figure 4. Experimental setup circuit diagram

3.2 Design of Energy Management System

The detected voltage values are compared with the voltage set values in the program loaded in the microcontroller and the energy source is selected by controlling the relays connected to the microcontroller output pins. The DC bus voltage set point is set to 12.1 V so that the charge regulator output voltage and the battery voltage value are DC 12 V and that the charge does not fall below 50% of the fill rate. The change in fill rate of the load is shown in the Figure 5 below.

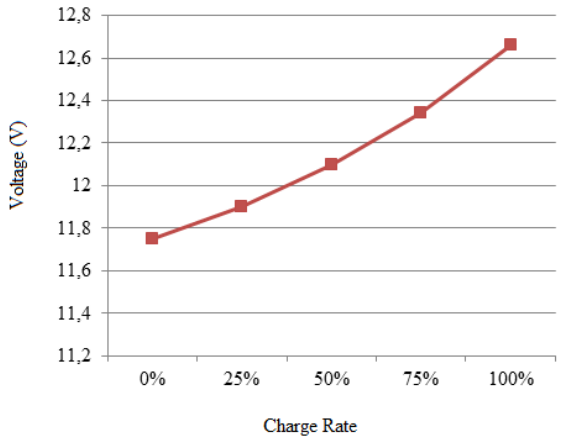

Figure 5. Battery charge rate voltage values

Because of grid voltage is 220 V alternating voltage, it is not possible for the microcontroller to directly detect it. For this reason, the battery charger connected to the grid and used for charging the battery is provided to be able to be detected by the microcontroller by utilizing the DC 12 V at the output terminals and this voltage is used to charge the battery in the circuit. Because of this, the set voltage value of AC bus is set to 12 V. In calculating the load voltage with the same method, alternating voltage is converted to DC 12 V by a rectifying circuit and it is detected by the microcontroller. The detected system voltage values are controlled by the relays connected to the digital output pins of the microcontroller by operating the program loaded in the microcontroller. In this case, the voltage values need to be compared. Cases that may occur in the system are shown in Table 1.

Table 1. Energy states that can occur in the system

Case	Renew-able Energy	Grid	Battery	Feeding
1	ON	ON	ON/OFF	Renewable source
2	ON	OFF	ON/OFF	Renewable source
3	OFF	ON	ON	Battery
4	OFF	OFF	ON	Battery
5	OFF	ON	OFF	Grid
6	OFF	OFF	OFF	No energy

The flow chart of the microcontroller program based on the energy cases that can occur in Table 1 is shown in Figure 6.

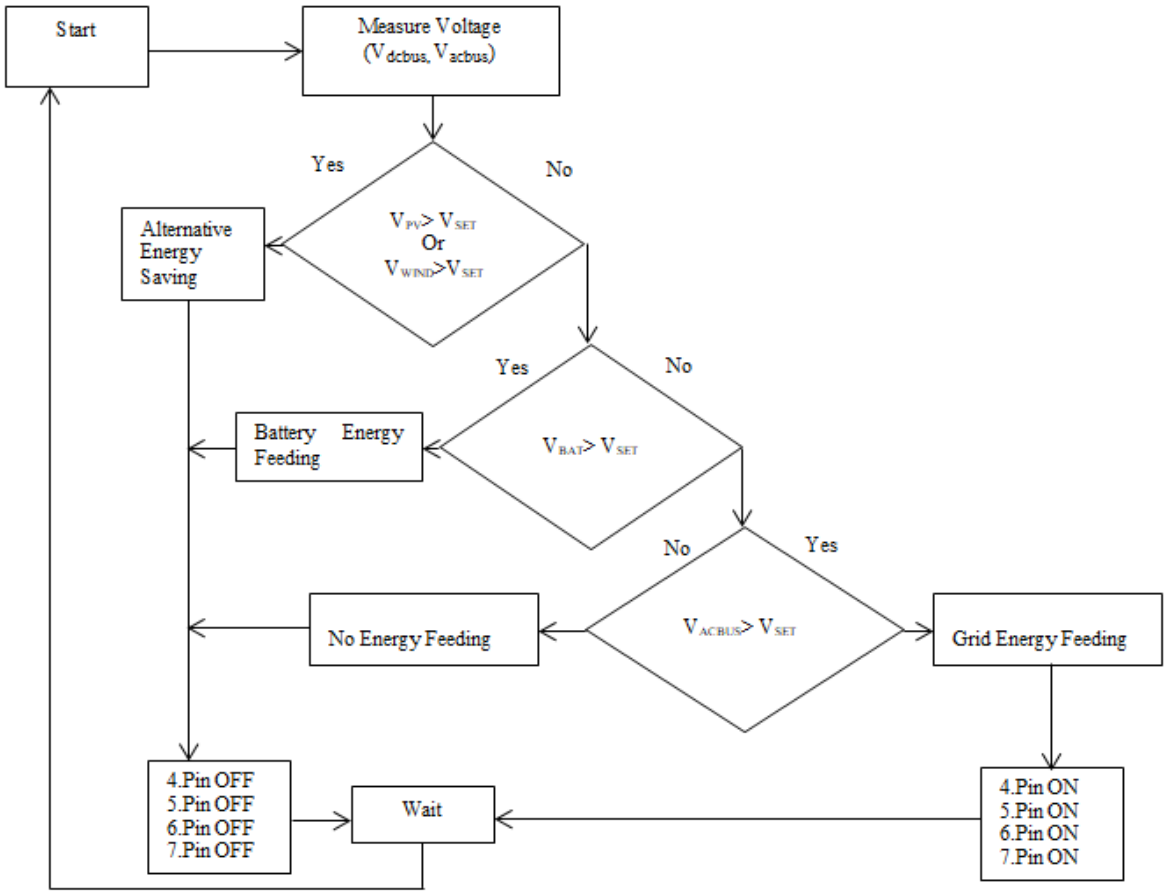

Figure 6. Flow chart of the circuit

If there is sufficient energy in the renewable energy sources (case 1, case 2), the energy need will be provided primarily from these sources. The obtained voltage is transferred to the DC bar via the battery. When the DC bus voltage is detected by the microcontroller, there is no reason to have energy in the battery or grid. So the relays in the microcontroller control are not energized, the load voltage is provided by the AC voltage obtained from the off grid inverter connected to the normally closed contacts. The amount of renewable energy used in the system is calculated by measuring the load voltage, load current and time obtained by operating the microcontroller program.

If there is not enough energy in the renewable energy sources (case 3, case 4), the energy requirement will be provided by the battery. The battery energy is transferred to the DC bar and the microcontroller detects it so the relays are not energized as in case 1 and case 2, the bus energy is transferred to the off grid inverter.

If the energy of the battery and renewable sources are not sufficient enough (case 5), the DC bus-bar voltage will be below the set voltage. The relays connected to the pins 4, 5, 6 and 7 of the microcontroller are energized and energy provided to load by the grid voltage that connected to the normally open contact of the relays.

If there is not enough energy at any source (case 6), the load is without energy. However, the microcontroller continuously monitors the energy states of the systems and, when it detects energy from any source, will provide energy by controlling for the relay.

The DC bus set voltage value and the DC bus voltage values that can occur in the system are shown in Figure 7. For the voltage values above the DC bus set voltage, the load energy requirement has been provided from the renewable energy sources, while for the values under the DC bus set voltage value, it is provided from the grid.

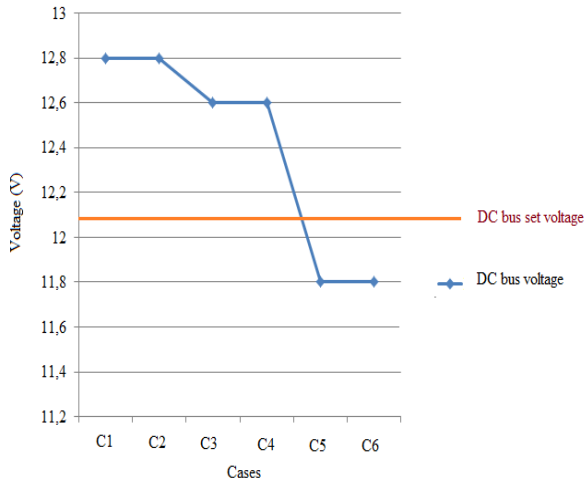

Figure 7. DC bus voltage values in energy states that may occur in the system

Conclusions

In a microcontroller-managed smart grid application device carried out in a laboratory environment, energy need is provided from these sources as long as energy is available in renewable energy sources, and load energy is supplied by the battery in adverse changes in atmospheric conditions. In other cases, the energy of the load is met by the grid power. The microcontroller keeps the loaded program running constantly, enabling the use of the power of the grid at the minimum level by enabling the use of this energy in the event of renewable energy. As a result, an economical advantage has been achieved. It can also be applied to microcontrollers such as SCR, IGBT and TRIAC, which can be used in microcontroller control with current and voltage transformers and microcontroller. This application system implemented in micro level can become applicable in macro grid thanks to various circuit elements. For macro network applications, current and voltage values at high levels can be converted to levels that can be detected by the microcontroller using current or voltage transformers. Switching operations can be done with semiconductor circuit elements such as MOSFET, IGBT or TRIAC, which can be controlled by microcontrollers. By means of these elements, relays or contactors can be energized to control high currents and voltages. Nowadays, classical networks have some problems because of the lack of energy and defects. The use of solar panels and wind turbine systems and equipment prices has become widespread as it is at a reasonable level relative to the old one. By integrating this intelligent energy management into its widespread usage areas, it is anticipated that the load of classical grids will decrease, economic gain will be achieved and the continuity of energy will be ensured. With the energy management system the utilization rate of renewable energy systems has been increased.

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