Intelligent Control-Based Effective Utilization of Renewable Energy Sources

G. Anandhakumar, M. Lavanya, G. B. Santhi, and Chidambaranathan Bibin

Abstract A rapid development is taking place in the field of renewable energy sources to increase the power generation because these sources are eco-friendly, non-polluting, freely available in nature sources like solar wind, biomass, hydro, and tidal. These renewable sources are mostly uncontrollable and all the same time different methods should be done to build a power plant to generate a continuous and constant power. The selection of the renewable energy source for the plant is one of the important roles for energy optimization. This is mainly focused toward the solar and wind power combination, whereas the solar system is the major renewable energy source for energy generation. In this work, a dynamic hardware model for an intelligent control-based effective utilization of hybrid renewable energy sources and Battery Management System. It also explains the implementation of fuzzy logic algorithm. The Battery Management System (BMS) is simulated in MATLAB software by using fuzzy logic controller (FLC). BMS explains the charging state and discharging state of battery. Then, it is implemented in hardware model for effective utilization of renewable energy sources. The identification of each subsystem has been made, and then, the proposed system is modeled and simulated using MATLAB—Simulink package. The proposed control strategy has been experimentally implanted, and practical results are compared to those obtained by simulation under the same metrological conditions, showing the effectiveness of the proposed system.

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1 Introduction

The renewable energy is a growing technology to meet the demands of energy consumption, solve the problems of fossil fuels, and at the same time reduce the pollution in the atmosphere. In the near future, the solution to the energy crisis will involve using all available technologies together in the most beneficial manner. Conventional energy sources using fossil fuels will become more efficient and clean. Hybrid system using renewable energy source will continue to grow in near future. Energy use and demand will be optimized through time-of-use management and efficient technologies. Today, the advent of modern renewable energy sources greatly improves our ability to collect or harvest energy, but not store them. Modern renewable energy sources intensify the search for robust, cost-effective means to store energy. Intermittent energy sources such as solar panels or wind turbines require energy storage capacity if they are to provide consistent, on-demand power to the user, and be able to replace traditional fossil fuel sources. Many advances in electrical energy storage technology and methods have been made in recent times. These advances have come in the areas of batteries, large-scale pumped hydroelectric storage plants, compressed air energy storage, flywheels, superconducting magnetic energy storage, and supercapacitors. Chemical energy storage, most commonly applied in batteries, is the world's most prolific form of energy storage. However, there are several drawbacks in batteries for large systems, including cost, short lifetime, and disposal concerns. Energy storage systems will emerge and evolve that would enable renewable energy source deployment and greatly reduce the wasted energy inherent in the current system. Excess energy produced by wind and solar generators is not usable without a means to store it.

2 Proposed Method

The Hybrid Solar PV and Wind Renewable Energy System is shown in Fig. 1. The energy from photovoltaic power system is given to DC–DC converter. DC–DC converter converts only DC voltage to constant 12 V DC. Output energy from the windmills fed into the converter. Rectifiers are used to convert AC to DC. Both the converter and the rectifier are connected to the battery through DC bus bar. The resultant energy can be effectively utilized through fuzzy logic controller.

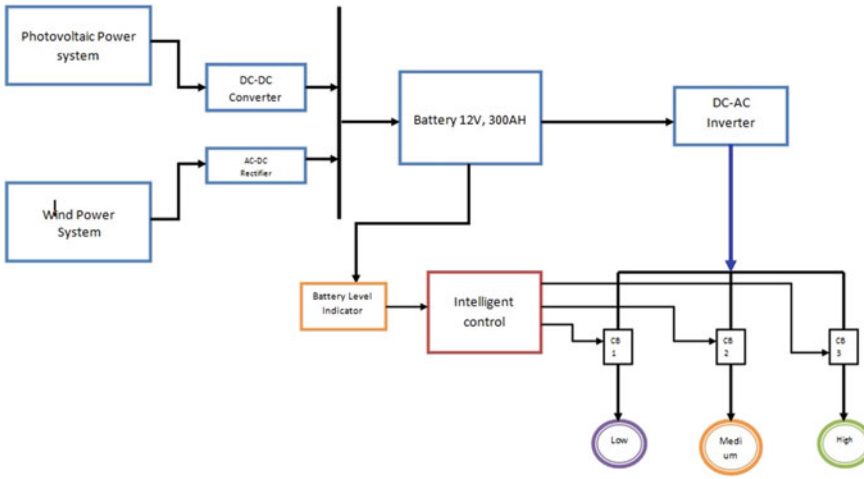

Fig. 1 Block diagram of proposed model

2.1 *Simulation Model for Batter Management System (BMS)*

Battery Management System (BMS) is simply battery monitoring, which keeps checking on the key operational parameters during charging and discharging such as voltages, currents, and temperatures (internal and ambient). The BMS normally provides inputs to protection devices which generate alarms or disconnect the battery from the load or charger when any of the parameters become out of limits. The major objectives of BMS are as follows:

(i) To protect the cells or the battery from damage.
(ii) To prolong the life of the battery.
(iii) To maintain the battery in a state in which it can fulfill the functional requirements of the application for which it is specified.

The MATLAB simulation model for Battery Management System (BMS) is shown in Fig. 2. The load is categorized like load 1, load 2, and load 3, and the voltage is distributed to loads through FLC. The loads can be controlled by circuit breaker through the controller. The output waveform of BMS simulation model is shown below.

If the fuzzy logic controller satisfies the condition 85% $\leq B_L \leq$ 100%, then the energy is distributed to all loads (load 1, load 2, and load 3). This is shown in Fig. 3. If the fuzzy logic controller satisfies the condition 75% $\leq B_L \leq$ 84%, then the energy is distributed to load 1 and load 2 as shown in Fig. 4. If the fuzzy logic controller satisfies the condition 60% $\leq B_L \leq$ 74%, then the energy is distributed to load 1 as shown in Fig. 5. If the fuzzy logic controller satisfies the battery voltage below 60%, then it switches off all the loads and connects the battery to charging mode. This is shown in Fig. 6.

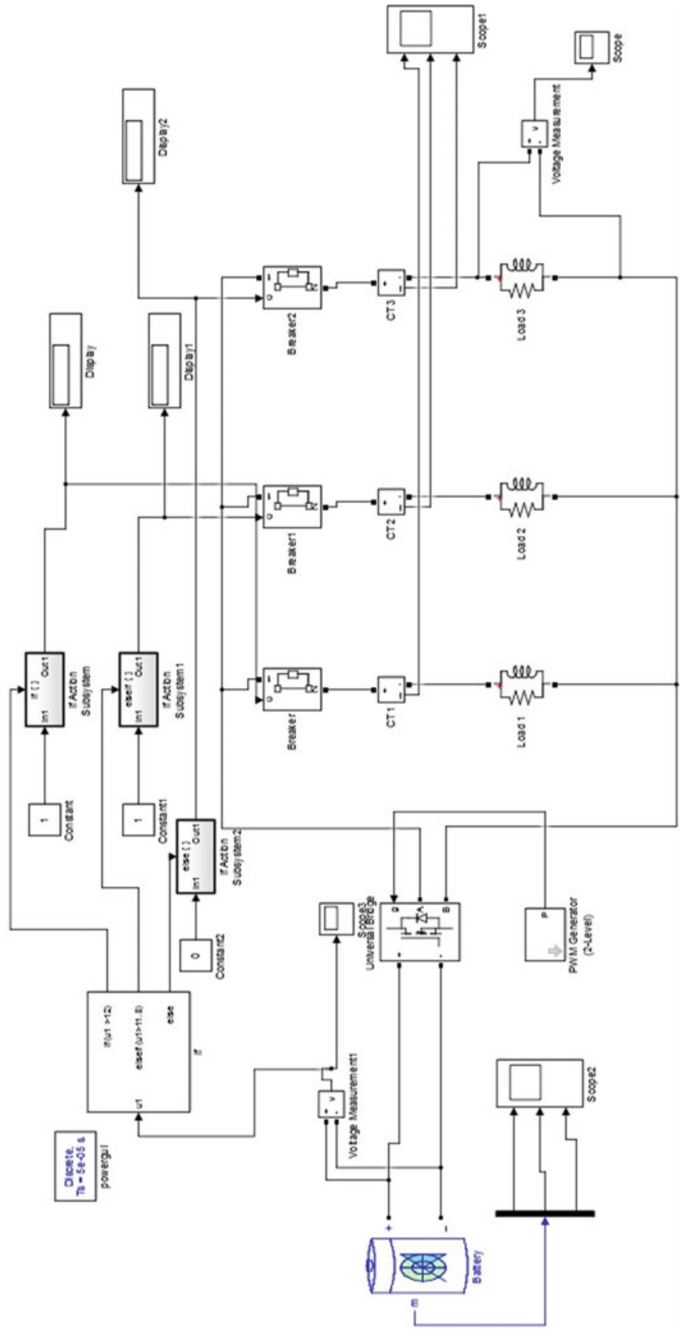

Fig. 2 MATLAB simulation model

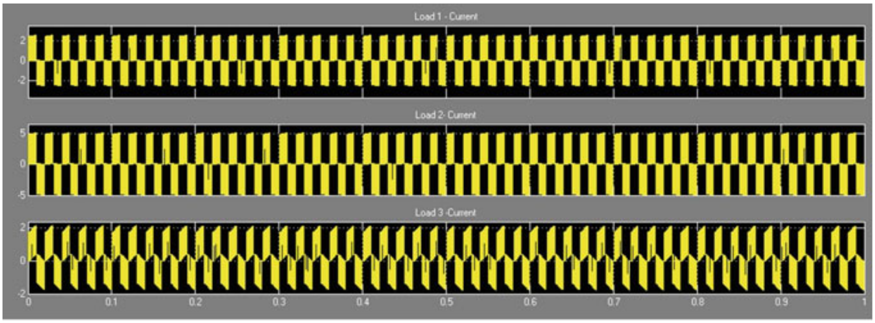

Fig. 3 Current waveform for all load

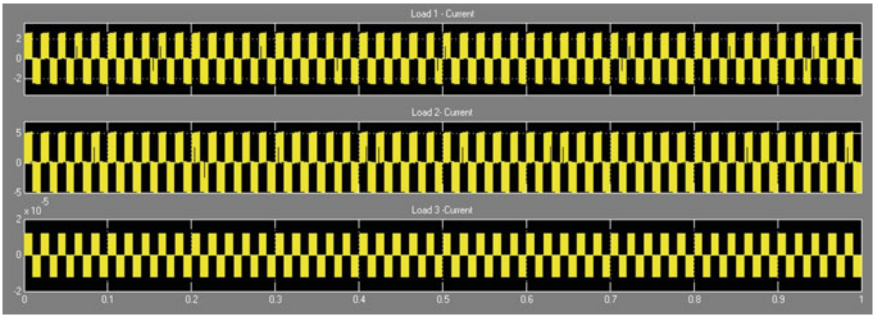

Fig. 4 Current waveform for load 1 and 2

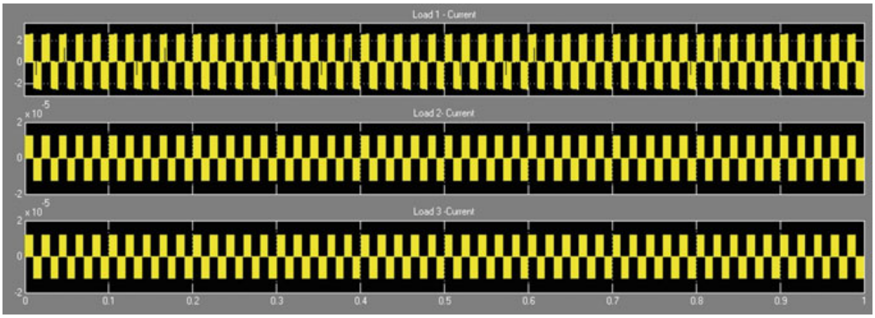

Fig. 5 Current waveform for load 1

2.2 Intelligent Control Hardware Model

An intelligent control hardware model is implemented for effective utilization of hybrid renewable energy sources. The fuzzy logic controller and fuzzy algorithm are used in the hardware model for proposed system. Loads are categorized for the

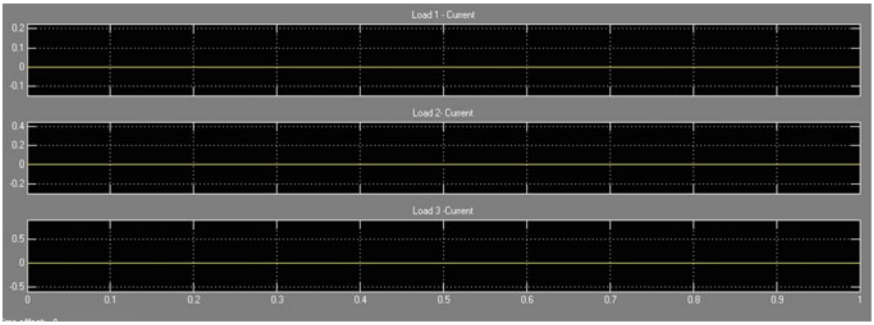

Fig. 6 Current waveform for no load

priority. The objective of this model is to utilize the optimized energy and energy management using fuzzy logic controller. In this model, the loads are connected based on priority.

2.2.1 Fuzzy Logic Algorithm

- Step1:- Start.
- Step2:- Read the Battery Capacity voltage and load the priority level.
- Step3:- Observe the Battery Capacity and load priority with the switch ON.
- Step4:- If the battery voltage is $85\% \leq B_L \leq 100\%$, then switch ON all the loads.
- Step5:- If the battery voltage is $75\% \leq B_L \leq 84\%$, then switch on P_{L1} and P_{L2} and switch OFF $P_{L3.}$
- Step6:- If the Battery voltage is $60\% \leq B_L \leq 74\%$, then switch ON P_{L1} and switch OFF P_{L2} and $P_{L3.}$
- Step7:- If the Battery voltage is below 60%, then switch OFF all the loads and connect to battery charging mode.
- Step8:- Repeat the step2 to step6 at every minute.
- Step9:- Stop.

Table 1 shows the fuzzy logic algorithm switching condition. The load priority can be selected based on the fuzzy logic condition. Load priority 1, 2, and 3 are

Table 1 Fuzzy logic algorithm switching condition

Condition	Load priority 1	Load priority 2	Load priority	Battery voltage in volts	Battery voltage in %
1	ON	ON	ON	13.3	95.4
2	ON	ON	OFF	11.7	83.7
3	ON	OFF	OFF	9.8	70.0
4	OFF	OFF	OFF	8.3	59.3

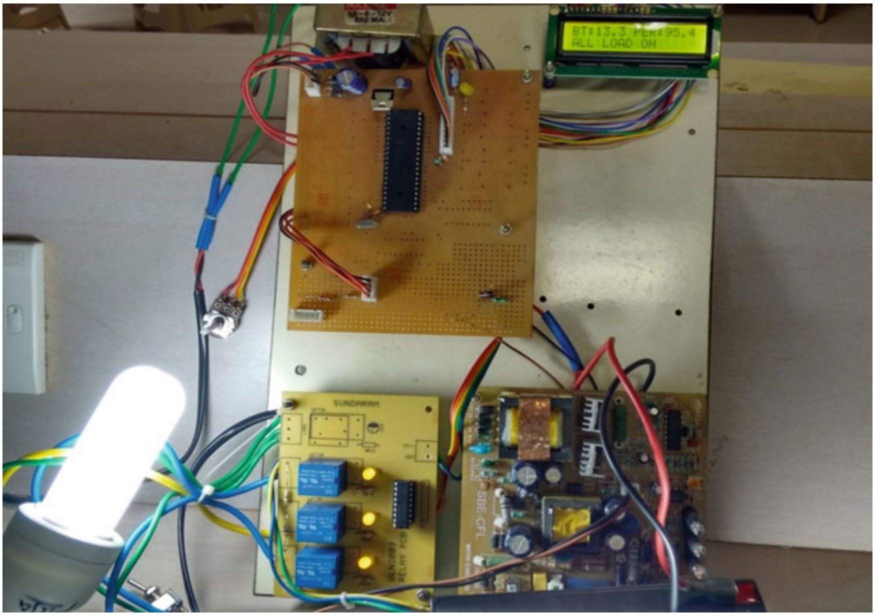

Fig. 7 Priority loads on

selected at condition 1, if it is satisfied where the battery voltage is 13.3 V and 95.4 in percentage. The load priority 1 and 2 are switched on and load priority 3 is switched off, if condition 2 is satisfied where the battery voltage is 11.7 V and 83.7 in percentage. Load priority 1 is switched on and load priority 2 and 3 are switched off, if condition 3 is satisfied where the battery voltage is 9.8 V and 70.0 in percentage. When condition 4 is satisfied, it shows that all the priority loads are switched off where the battery voltage is 8.3 V and 59.3 in percentage.

If the fuzzy logic controller satisfies the condition $85\% \leq B_L \leq 100\%$, then energy is distributed to all loads (load 1, load 2, and load 3) as shown in Fig. 7.

If the fuzzy logic controller satisfies the condition $75\% \leq B_L \leq 84\%$, then energy is distributed to load 1 and load 2. This is shown in Fig. 8.

If the fuzzy logic controller satisfies the condition $60\% \leq B_L \leq 74\%$, then energy is distributed to load 1. This is shown in Fig. 9.

If the fuzzy logic controller satisfies the battery voltage is below 60%, then it switches off all the loads and connects the battery to charging mode as shown in Fig. 10.

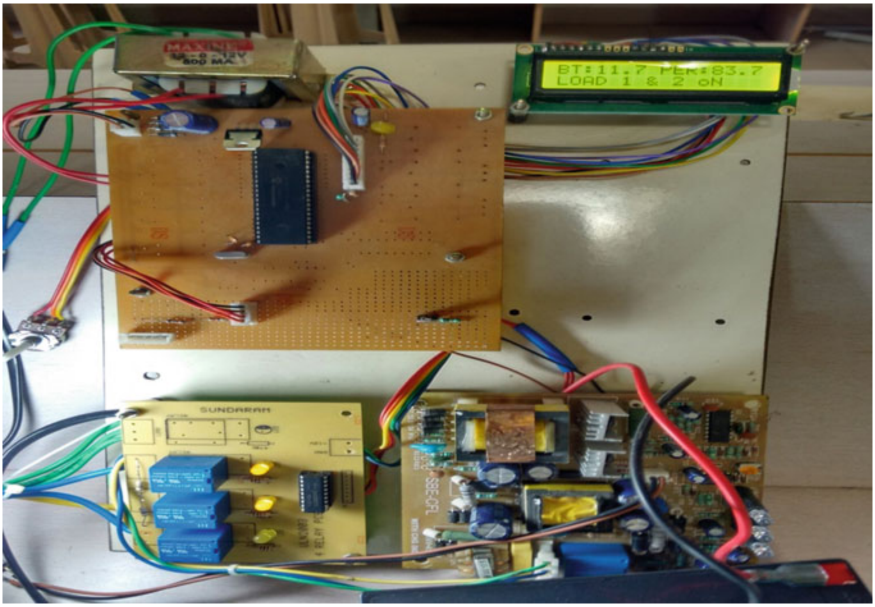

Fig. 8 Priority load 1 and priority load 2 are switched on

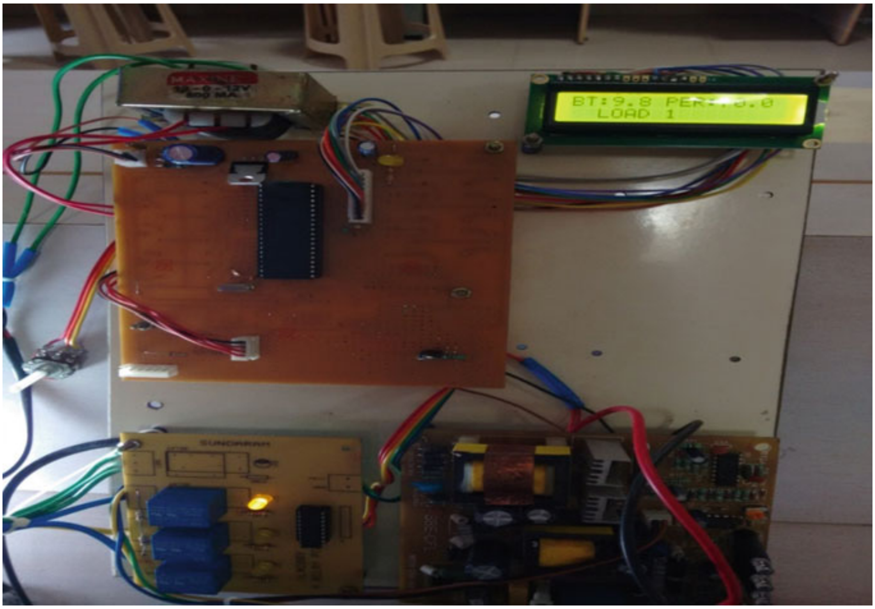

Fig. 9 Priority load 1 switched on

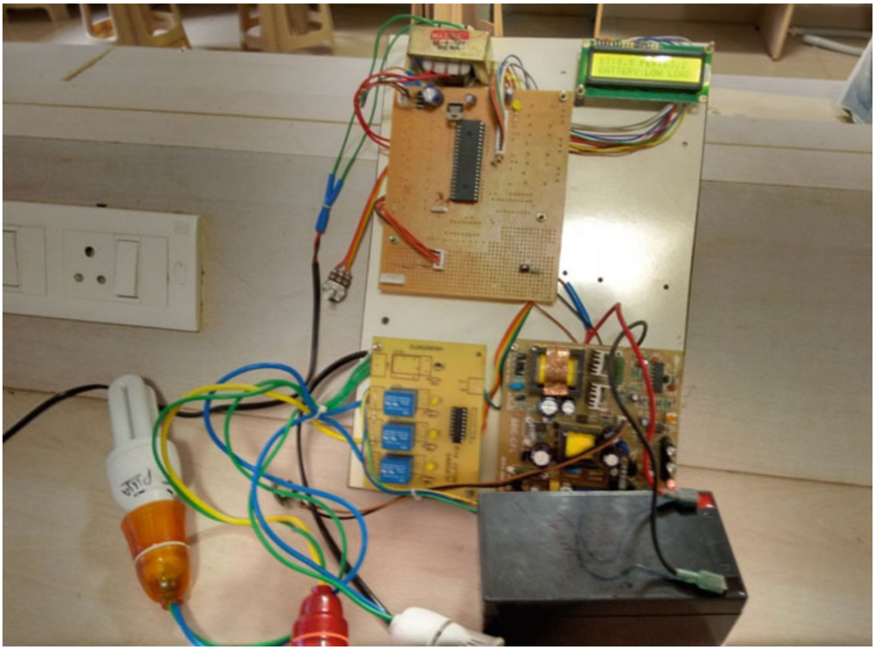

Fig. 10 No load and battery charging

3 Conclusion

An intelligent control hardware model is implemented for the effective utilization of hybrid renewable energy sources. The fuzzy logic controller and fuzzy algorithm are used in hardware model for proposed system. Thus, a Battery Management System for effective utilization of the renewable energy source has been achieved by effectively managing the charging time and draining time of the battery. The battery level indicator, which continuously monitors the status of the battery and indicates the battery voltage in terms of percentage, displays the connected loads. The priority of the load can be selected by fuzzy logic controller using fuzzy logic algorithms. Therefore, renewable energy can be utilized effectively.

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