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IMPLEMENTATION OF HYBRID SOLAR-WIND-BATTERY RENEWABLE ENERGY BASED MICROGRID WITH ENERGY MANAGEMENT SYSTEM USING ANFIS CONTROLLER

[1] CH. Sajan, [2] A. Ankitha, [3] E. Revanth, [4] D. Grushnesh Reddy, [5] K. Anand

[1] Associate Professor, [2,3,4,5] UG Students
[1,2,3,4,5] Department of EEE
[1,2,3,4,5] Jyothishmathi Institute of Technology and Science, Nustulapur, Karimnagar, TS, India

Abstract: This paper proposes an effective energy management system for a small-scale hybrid renewable energy source based microgrid. In order to evaluate the functionality of the hybrid microgrid, power electronic converters, controllers, control algorithms, and battery storage systems have been built. An energy management system maintains the power balance for both load demand variations and variations in renewable energy power generation. This microgrid offers a testing environment forvarious control algorithms, energy management systems, and test circumstances. It runs in standalone mode. Simulation results using ANFIS controller demonstrate the system's adaptability to fluctuations in both renewable energy sources and load demands, showcasing the effectiveness of the energy management system.

IndexTerms **- Microgrid, Energy management system, Solar energy, Wind energy, ANFIS controller.**

1.INTRODUCTION

Self-sustaining renewable energy systems have been developed around the world. This has resulted in renewable power generation systems that are able to provide self-sustaining power generation using multiple renewable energy sources [1], [2]. The two environmentally friendly power sources that are most frequently utilized are solar and wind power [3],[4]. Due to their intermittent in nature, both sources of energy require the usage of an energy storage system (ESS) in standalone applications [5], [6]. Hybrid renewable energy systems utilize multiple control mechanisms to ensure effective power transfer.

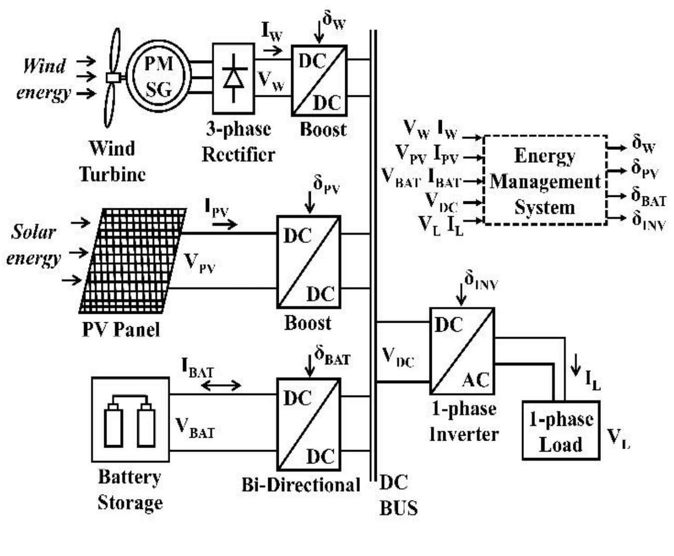


Figure 1. Components of small-scale wind-solar battery micro grid

The design of an energy conversion system depends on the type of converters employed at various sites. This requires significant technical attention and has prompted study in this area [7]-[9]. The simulation of hybrid energy system was examined and its performance under various load demand profiles and weather conditions was studied. This paper discusses a modelling system for coordinated microgrid energy management in both standalone and grid-connected modes [10], [11]. The ANFIS controller is used to simulate a hybrid wind-solar-battery ESS system and assess its state of charge (SOC) [12].

2. SYSTEM DESCRIPTION

The present framework consists of three parts: (I) the single-phase load-side inverter; (ii) the permanent generator that generates energy within the framework; Moreover, (iii) DC power transmission, a battery storage system, and converters enables renewable energy sources like solar and wind power to be harnessed. A wind turbine powered by a long-duration magnetically by synchronized generator makes up the wind energy transmission system. When the quantity of power produced by the wind and PV modules does not precisely meet the interest of the property, maximum power tracking is employed to operate the PV modules. The MPPT drains the battery when more power is produced than, it is required and stores the extra energy until it is safe to recharge the battery. The architecture for battery storage maintains the system's energy balance within acceptable limits. In other situations, a single-phase inverter receives power and this power cycle is managed by the operating system.

2.1 SOLAR ENERGY CONVERSION SYSTEM (SECS)

The SECS is composed of an MPPT regulator, a DC boost converter, and solar photovoltaic panels. The MPPT may switch between MPPT and off-MPPT modes based on the charge level of the battery storage system. The photovoltaic properties of solar chargers change with the amount of sunlight reaches them. These characteristics become apparent at a constant temperature of 250 °C and an irradiation value ranging from 400 W/m2 to 1200 W/m2. For 1000 W/m2, the maximum extreme power is 66 Wp at 17.6 volts.

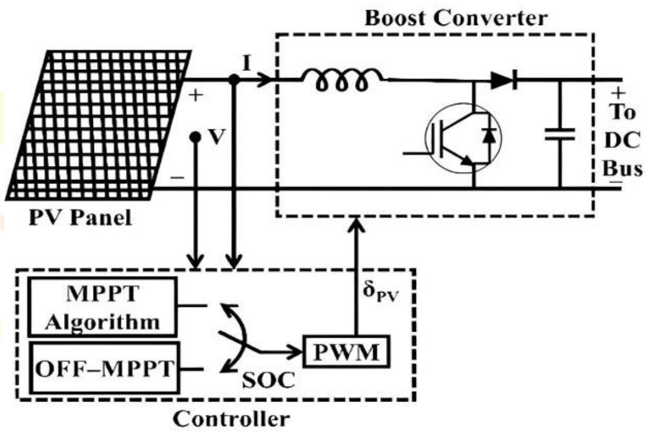


Figure 2. Solar energy conversion system with controller

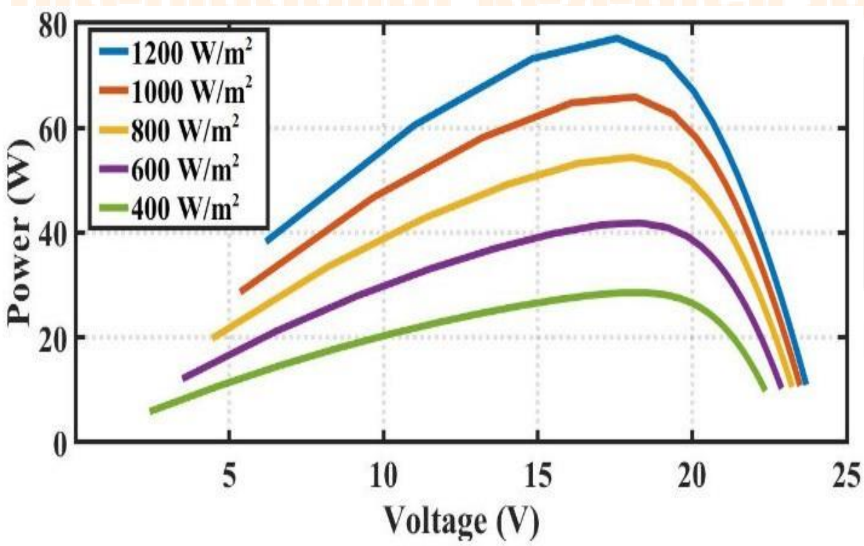


Figure 3. Effect of irradiance on PV array performance at T = 25^0C

2.2 WIND ENERGY CONVERSION SYSTEM (WECS)

The wind energy conversion system (WECS) is built using a wind turbine, inverter, PMSG, and DC boost converter. Power generated by the wind is

$$P_w = 1/2\, \rho A v^3 C_p(\lambda, \theta) \quad (1)$$

where v is the wind speed in meters per second and A is the area the rotor edges clear in meters. The power coefficient, or C_p, is determined by the pitch angle (θ) and tip speed ratio (TSR, λ). This technology makes use of a variable-speed wind turbine. The very low maintenance and running costs of this magnet simultaneous generator led to its selection. Wind speed affects the output of the generator. A DC boost converter raises the voltage level after a diode rectifier rectifies the three-phase output of the generator.

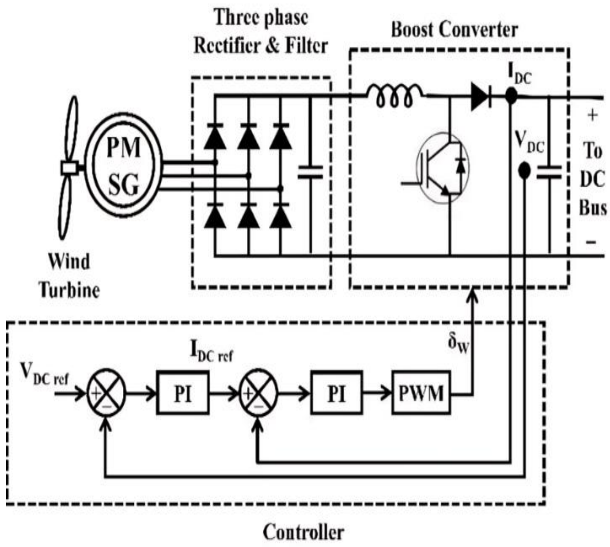


Figure 4. Wind energy conversion system with controller

2.3 BATTERY STORAGE SYSTEM (BSS)

A lead acid battery and a bidirectional DC buck-boost converter makes the BSS. This converter uses a PI regulator to maintain the DC transmission voltage. The state of charge (SOC) is given as

$$SOC = 100(1+\int I_{bat}\, dt/Q) \qquad (2)$$

where Q is the capacity of the battery and I_{bat} is the current through the battery. The battery's ability to charge and discharge depends on the amount of power produced by the solar and wind. The battery also works in these two modes to the best of its ability within the limits of the energy available.

$$SOC_{min} \le SOC \le SOC_{max} \qquad (3)$$

2.4 ENERGY MANAGEMENT SYSTEM

Serving as the main controller for the small microgrid system, the EMS plans and directs all control operations. In the first segments, every converter regulator functions according to the EMS control mode. Depending on the force applied, the boost converter of the solar-based energy change framework operates in either MPPT mode or off-MPPT mode. When charging or discharging batteries, the battery bidirectional converter maintains a constant DC bus voltage, and the DC boost converter of the wind energy change framework operates in this mode. Under different load scenarios, the power of the microgrid must be regulated, and the power is generated from the sustainable energy sources.

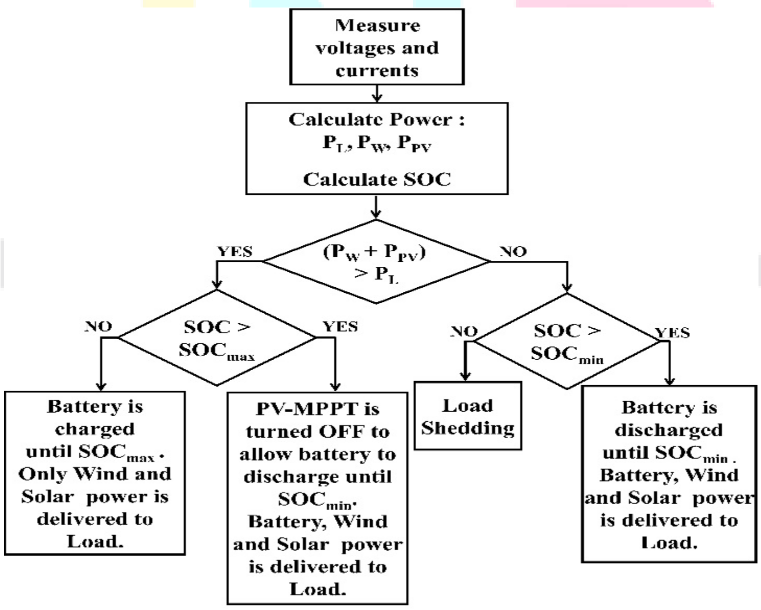


Figure 5. Energy management system

3. PROPOSED SYSTEM

3.1 ANFIS CONTROLLER

A counterfeit brain network known as a versatile neuro-fluffy induction framework, or versatile organization based fluffy deduction framework (ANFIS), depends on the Takagi-Sugeno fluffy derivation framework. The method was created in the mid-1990s. Given that it joins both fluffy rational and brain organizations, it very well has the option to bring the advantages of both into one system.ANFIS is in this way considered a widespread assessor. The ANFIS might be used more ideally by assuming the hereditary calculation tracks down the best settings. It could be utilized with situationally mindful energy executive's frameworks.

3.2 STRUCTURE OF ANFIS

The reason and outcome segments make up the two parts of the organization structure. All the more definitively, the design is made out of five layers. The principal layer figures out which participation capabilities match the information values in the wake of getting them. It is known as the fuzzification layer. The participation levels of each capability are registered utilizing the reason boundary set, {a,b,c}. The subsequent layer creates the terminating qualities for the principles. Due to the manner in which it works, the subsequent layer is known as the "rule layer". The third layer's responsibility is to standardize the assessed terminating qualities by partitioning each incentive for the complete terminating strength. The fourth layer gets the standardized information along with the outcome boundary set {p,q,r}. This layer returns the defuzzified values, which are then utilized by the last layer to deliver the ideal result.

3.3 FUZZIFICATION LAYER

An ANFIS network's top layer explains how it differs from a regular neural network. The characteristics are transformed into normalized values between 0 and 1 during the data pre-processing phase that neural networks often need to function. Here is an illustration: Assume that the network receives the separation between two points in two dimensions as input. The distance may have values ranging from 0 to 500 pixels, and it is measured in pixels. The membership function—which comprises of semantic descriptors like close, medium, and far—converts the numerical values into fuzzy numbers. A single neuron assigns a value to every potential language combination. If the distance is within the "near" category, the "near" neuron fires, with a value ranging from 0 to 1. If the distance falls inside that category, the neuron in the "middle" fires. Three distinct neurons are assigned to the input value "distance in pixels"—near, center, and distant.

3.4 APPLICATIONS OF ANFIS CONTROLLER

The non-linear system is often controlled by this ANFIS controller. Because it is superior to other controllers including traditional PID controllers. The temperature water bath controller uses this controller. These controllers are also used in aircraft nowadays for controlling them; research is being done on Intelligent aircraft, which are planes that can take off and land on their own and learn on the fly.it does not need a sigmoid function.

4. RESULTS AND ANALYSIS

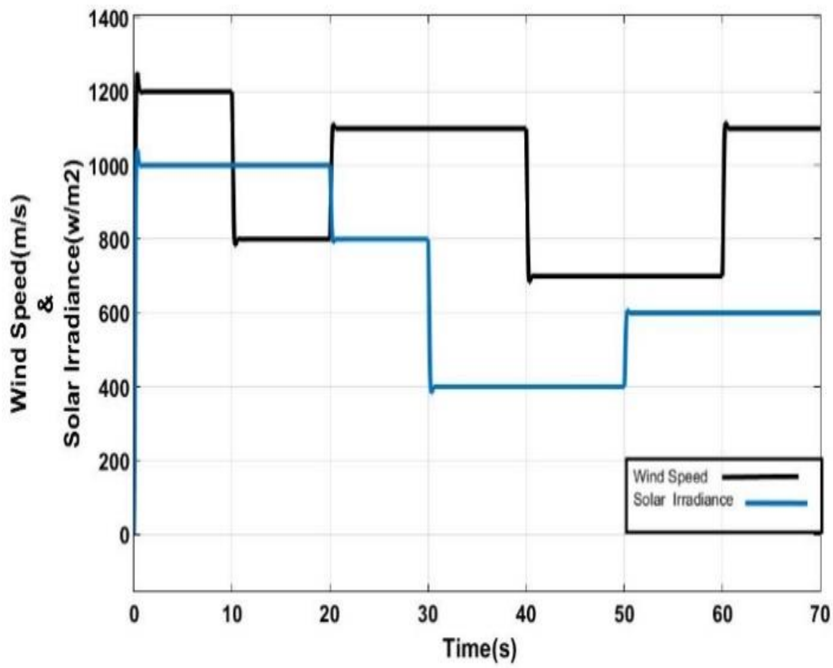


Figure 6. Wind speed and solar irradiance levels

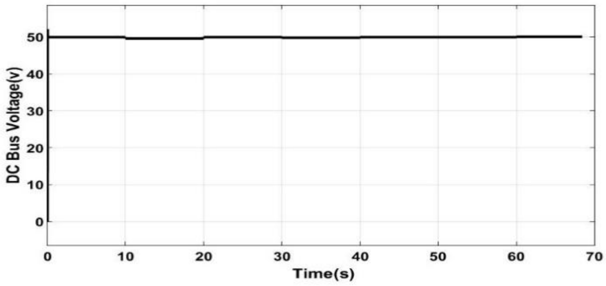


Figure 7. DC bus voltage for constant load with variable renewable energy sources

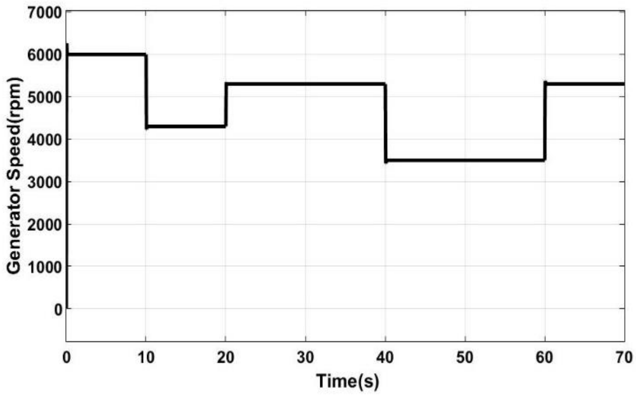
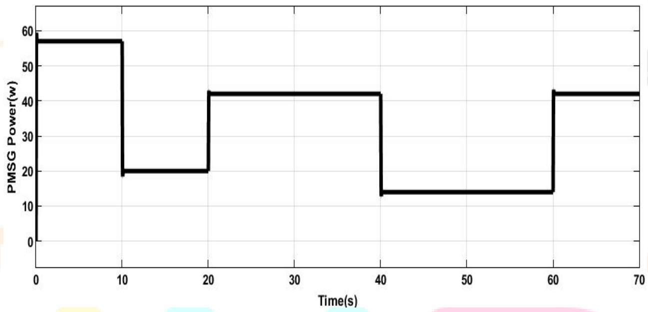
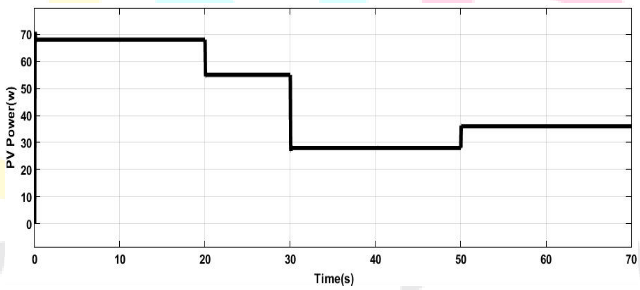


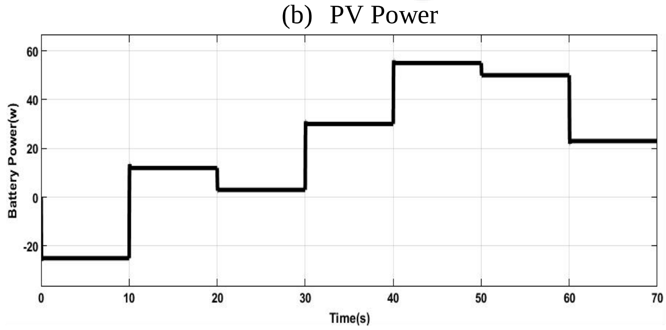
Figure 8. PMSG speed for constant load with variable renewable energy sources



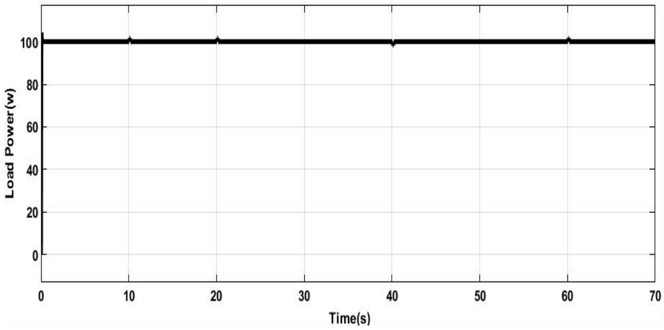
(a) PMSG Power



(b) PV Power



(c) Battery Power



(d) Load Power

Figure 9. Power at different locations of the microgrid for constant load with variable renewable energy sources

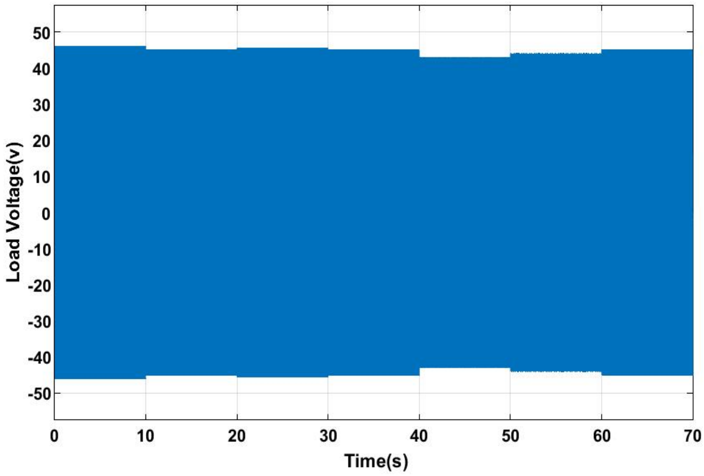


Figure 10. Load voltage.

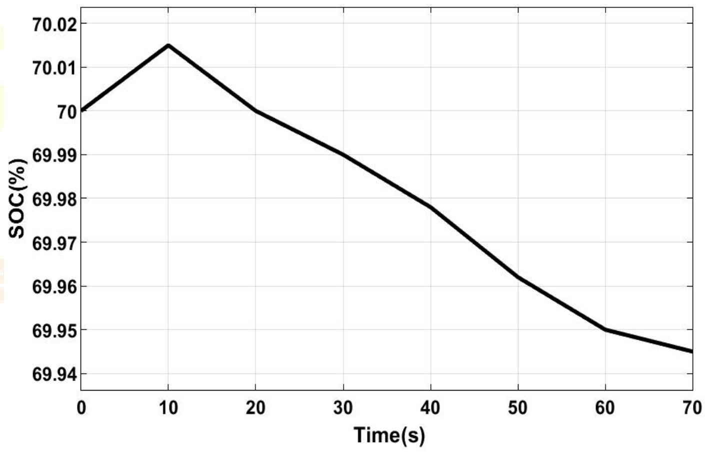


Figure 11. State of charge of battery for battery for constant load with variable renewable energy sources

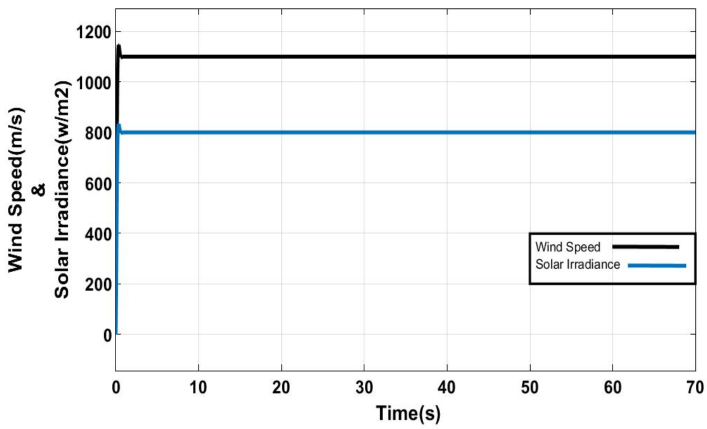


Figure 12. Wind speed and solar irradiance levels

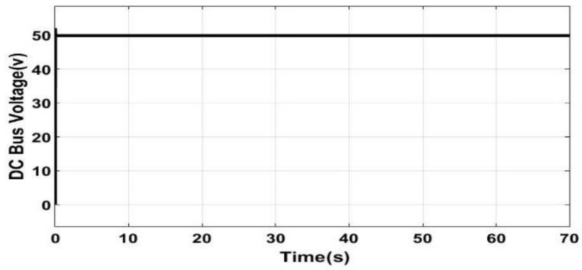


Figure 13. DC bus voltage for constant renewable energy sources with variable load

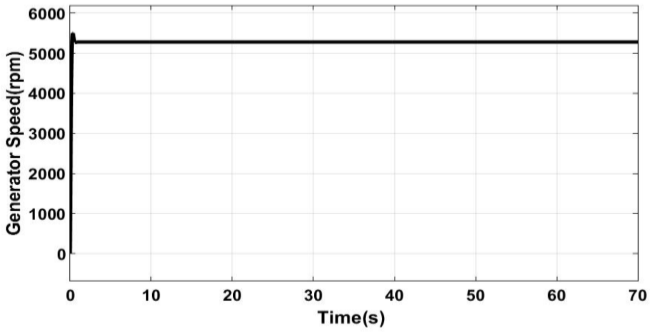
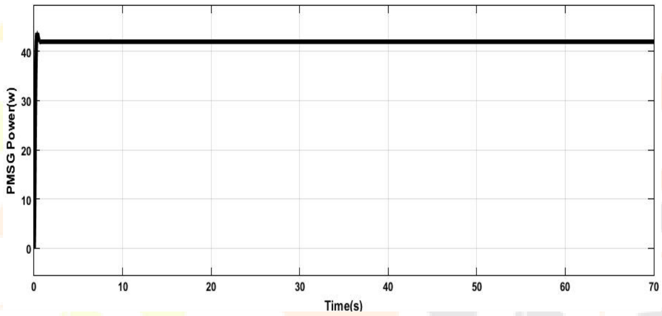
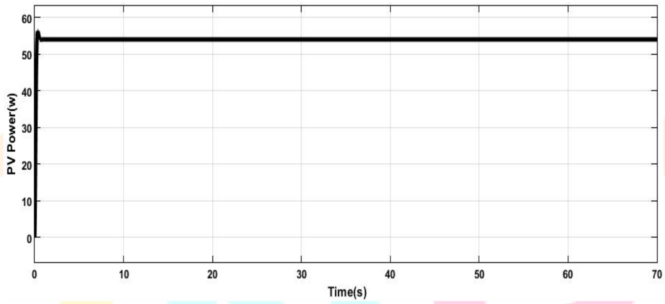


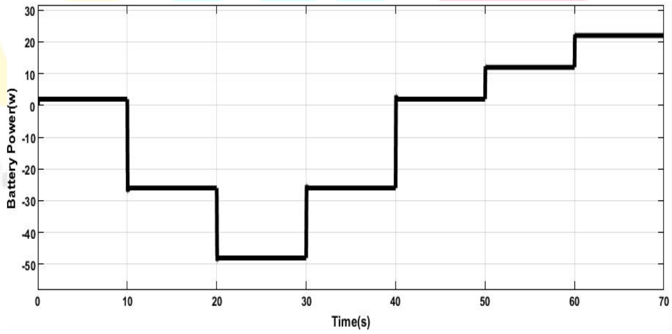
Figure 14. PMSG Speed for constant renewable energy sources with variable load



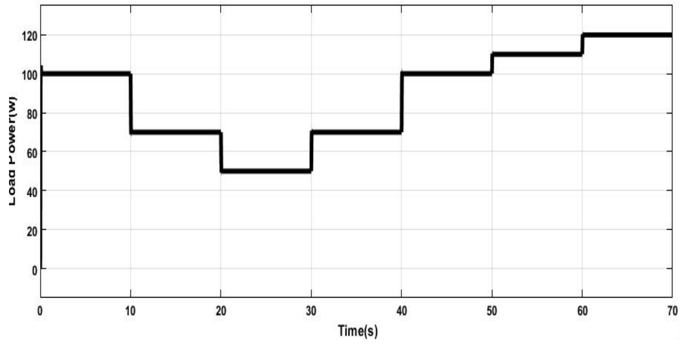
(a) PMSG Power



(b) PV Power



(c) Battery Power



(d) Load Power

Figure 15. Power at the microgrid for constant renewable energy sources with variable load

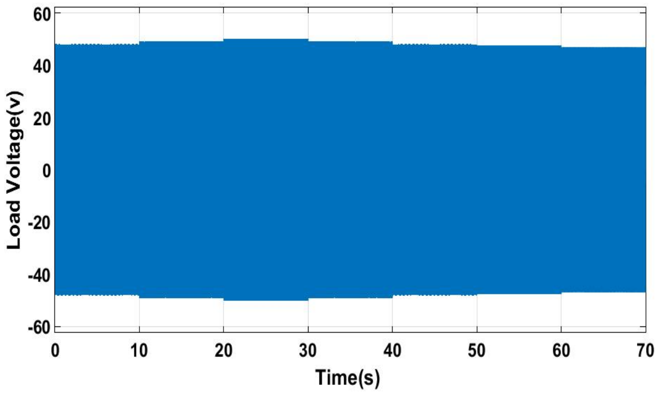


Figure 16. Load voltage

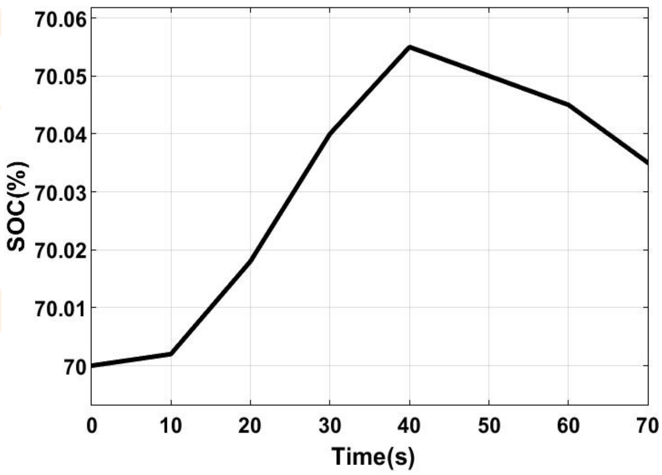


Figure 17. State of charge of battery for constant renewable energy sources with variable load

5. CONCLUSION

A hybrid solar-wind-battery microgrid with an energy management system is developed. The efficiency of the suggested energy management system was tested and that were run under various load demand and renewable energy source changes. An input solar PV array was used in the construction of a transformer-less grid-connected inverter. The converter runs in buck boost mode, which permits a large voltage fluctuation in the PV array. Furthermore, because the converter's construction is based on a toroid core, worries about leakage current in grid-connected transformer-less PV systems are eliminated. It is suggested to use a neuro fuzzy controller to regulate the gating pulses of inverters, allowing for quick corrective reaction. In order to prevent switching stress, the soft switching approach is applied. The simulation results using ANFIS controller shows the effectiveness of the energy management system.

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