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Fuzzy Based Energy Management Strategy for Hybrid Micro Grid with Battery Storage System

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Abstract: *By connecting it to the hybrid micro grid system, this explains the combination of wind, solar, and fuel cell power. Renewable energy is frequently used today. Distributed energy sources like wind, solar, fuel cells, etc., can operate concurrently with a larger utility. The majority of people today want to use sustainable energy sources like solar, wind, tidal, geothermal, wave, etc. A tiny grid produces the necessary electricity. In this project, energy storage and utilisation with a micro grid are demonstrated. This project serves as an example of how a micro grid can be used to store and use power. We usually allow the Micro Grid to use us by producing this energy. The system is a composite that utilises renewable resources such fuel cell, a solar array, a wind generator, and an energy storage system (ESS) that uses a battery as one of its renewable energy sources. Power Electronics converters are crucial to the system since they enhance power management and control strategies for various sources. The single-input Fuzzy logic and speed controllers are utilised to track the maximum power point for the wind and PV subsystems, respectively (MPPT). A power management method based on battery state of charge (SOC) was created and put into use to maintain the hybrid system's energy balance. A proportional integrative (PI) controller was used to supply a resistive load with a constant amplitude and frequency in order to regulate the AC output voltage was obtained. The proposed solution is deemed to be very promising for possible applications in hybrid renewable energy management systems based on the received bids. MATLAB/SIMULINK is to be used to develop the simulation.*

Keywords: Solar Energy System, Wind Turbine System, MPPT Technique, Microgrid system

I. INTRODUCTION

The integration of renewable energy sources with battery energy storage technologies, which are primarily utilised to maintain power reliability, is the current situation. As more renewable energy sources are used as distribution sources, new operational tactics are often needed to increase the reliability of the power supply and, consequently, the quality of the electricity. Micro grid refers to an electrical system with multiple loads and distributed energy resources that can be used simultaneously within the border utility grid. Micro grids or hybrid power systems have been demonstrated to be an efficient local connectivity architecture for the production of distributed renewable energy, loads, and storage[1-4].There is a fantastic opportunity to profit from the benefits of Micro grid given the ongoing and growing demand for enhanced reliability and energy efficiency across all business facilities. Distributed energy sources with multiple electrical loads, such as solar PV and wind energy systems, are also a part of micro grids. Both wind and solar power plants have the similar drawback of generating inconsistent electricity[5-6]. The most recent method, the maximum power point tracking algorithm, which is applicable to both wind and solar plants, is used to overcome this issue. loads, storage, and renewable energy. Analysis is done on the dynamic performance of a solar, wind, and fuel system. To examine the behaviour of all the energy sources, the MATLAB software programme is used. To achieve considerably greater generating capacity factors, a simple control technique monitors the maximum power from the wind/solar energy source. The outcomes of the simulation demonstrate the viability and dependability of the suggested solution[7-9].

II. HYBRID ENERGY SYSTEM

2.1 Implementation of Hybrid Energy System

Installing a hybrid solar, wind, or other energy supply system is mostly necessary because of intermittent energy sources and energy resource imbalance. The Solar PV Wind Hybrid System is appropriate for climates with seasonal variations in wind and sunlight. Using a single source would not be a viable choice because the wind does not blow all day and the sun does not shine all day[10-12]. An setup that combines energy from the sun and the wind and stores it in a battery would be a more dependable and practical power source. Even when there is no wind or sunlight, the batteries' stored energy can be used to power the payload[13-15].

Hybrid systems are typically created to design systems with the highest reliability and lowest cost achievable. Solar photovoltaic cells are less suited to bigger capacity designs due to their increased cost. The key benefit of wind turbines in this situation is their low cost as compared to solar cells. To store the solar and wind energy generated during the day, a battery system is necessary. The wind's presence is a benefit throughout the night because it improves the system's uniformity. It is appropriate to employ a hybrid solar wind system during the rainy seasons because the site's exposure to the sun is reduced[16-19].The configuration structure for hybrid systems-based solar and wind energy systems is depicted in Figure 1. A wind turbine's rotor, which has two or more blades and is mechanically connected to an electric generator, collects the kinetic energy of the wind. 4. One way to express the mechanical energy a wind turbine harvests from the wind is as follows:

$$P_m=0.5\rho ACV^3 \quad (1)$$

The theoretical maximum power coefficient value is 0.59. It is based on the pitch angle and the Tip Speed Ratio (TSR). The pitch angle describes the alignment of turbine blades with regard to the longitudinal axis. TSR is the rotor's linear speed in relation to the wind speed. Figure 2 depicts the "C Vsλ”" curve for wind turbines. For moderate speed turbines, the greatest possible range is in the range of 0.2 to 0.4, and for high speed turbines, it is in the range of 0.4 to 0.5. Figure 2 displays its maximum value (Cpmax) at opt. The turbine is then able to extract the most power possible from the wind with the highest level of efficiency.

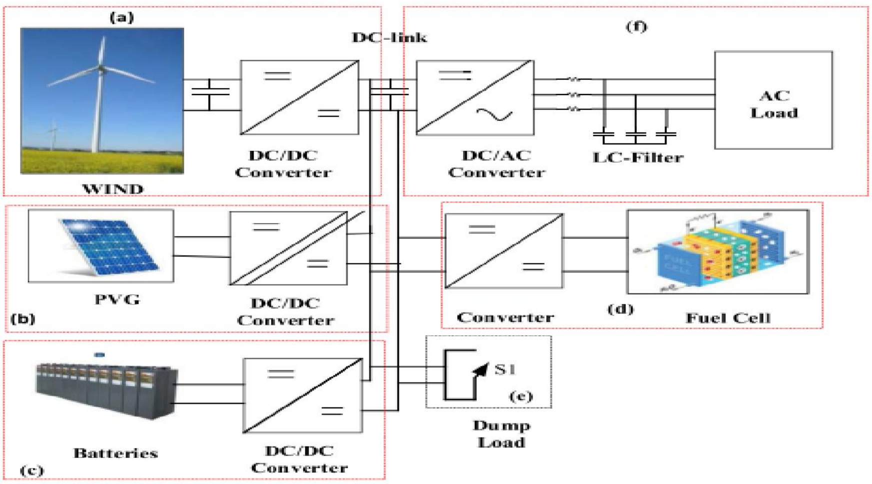

Figure 1. Configuration of Hybrid Energy System

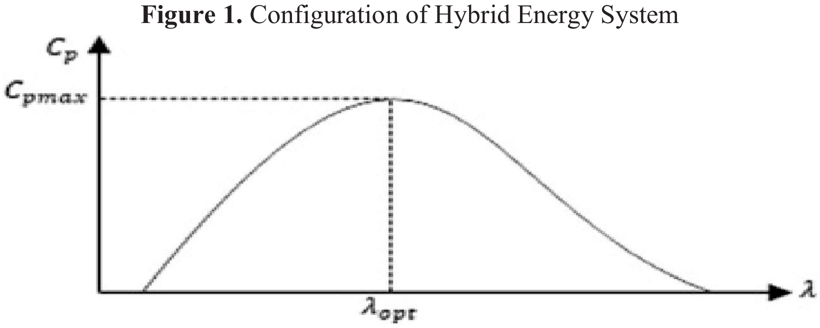

Figure 2. Power Coefficient Vs Tip Speed Ratio

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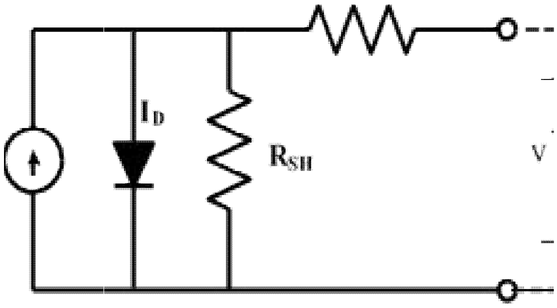

Figure 3. Equivalent circuit of PV Module

The fundamental element of a photovoltaic (PV) system is the solar cell. Solar cells coupled in series or parallel to produce the necessary current, voltage, and high power make up a PV array. Each solar cell has a p-n junction made of semiconductor material, comparable to a diode. The photovoltaic effect causes currents to be generated when light is absorbed at the junction. An insulating output power characteristic curve for the PV array is shown in Figure 4. On each output power characteristic curve, a maximum power point may be noticed. Figure 4 displays the PV array's (I-V) & (P-V) properties at various sun intensities. The current source is connected in parallel with a forward-biased diode to create the equivalent circuit of a solar cell. The output terminals are wired with load. The solar cell's current equations (2) and (3) are denoted as6 and 7.

$$I = I_{ph} - I_D - I_{sh} \quad (2)$$

$$I = I_{ph} - I_o [\exp (q V_D / nKT)] - (v_D / R_S) \quad (3)$$

Power output of solar cell is P = V * I

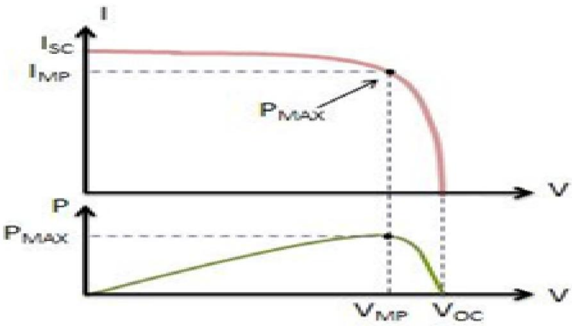

Figure 4. Output Characteristics of PV Array

Fuel cells come in a wide variety of varieties, but they all typically operate in the same way. They are made up of three nearby components: the cathode, electrolyte, and anode. Two chemical processes occur where the three segments converge. Combining the effects of the two processes results in the consumption of fuel, the production of water or carbon dioxide, and the creation of an electric current that may be used to power electrical equipment, or the load as it is generally known.A catalyst at the anode oxidises fuel, frequently hydrogen, to produce a positively charged ion and a negatively charged electron. The purpose of the electrolyte is to allow ions to pass through while preventing electrons from doing so. Free electrons move through a wire, creating an electric current. The ions go through the electrolyte to reach the cathode. At the cathode, the ions and electrons come back together and react with a third material, usually oxygen, to create either water or carbon dioxide[20-21].

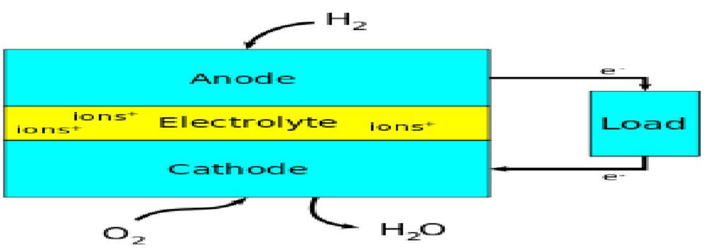

Fig. 5 Block diagram of a fuel cell

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III. BATTERY ENERGY STORAGE SYSTEM (BESS)GE LAYOUT

By using batteries and a power electronics device control system, the Battery Energy Storage System (BESS) converts alternating current (AC) to direct current (DC). Here, a battery's function is to transform electrical energy into chemical energy for storage. Batteries are charged and discharged using DC power. Power electronics with

bidirectional operation control the flow of electricity between energy storage systems and batteries. Depending on the battery type, it has a variety of benefits and drawbacks, including price, weight, size, power, and energy capacity. In terms of energy storage technologies, lithium-ion, lead acid, nickel cadmium, and nickel metal hydride are significant categories. Lead-Acid batteries are able to reach high discharge rates, making them a superior option for energy storage applications. High energy density, long cycle life, and charge or discharge efficiency are all excellent characteristics of sodium sulphur batteries. Compared to lead-acid batteries, nickel-cadmium (NiCd) batteries are superior in every way and require less maintenance. However, these batteries are more expensive than Lead-Acid batteries. It is a pricey alternative choice. Because they are lightweight and compact, nickel metal hydride (NiMH) batteries are employed in hybrid electric vehicles and communications applications[22-24].

The Battery Energy System controller processes the data, estimates the State of Charge (SOC) and capacity of each battery cell, and ensures that all cells are operating within the intended SOC range.

The following are some of the financial and technological advantages of energy storage systems on a smaller scale:

- Electrical supply quality and reliability are improved.
- For critical loads it supplies backup power.

IV. MAXIMUM POWER POINT TRACKING (MPPT)

When solar and wind are set to operate at their peak power, Maximum Power Point Tracking (MPPT) increases the efficiency of the solar panel and wind turbine. There are numerous MPPT approaches. Incremental Conductance Method, Perturb and Observe, Fuzzy Logic, and Neural Networks are the most widely used methodologies. If the output power of the two systems does not match to their maximum powers, the initial reference voltage for the solar array and the initial reference speed for the wind turbine are adjusted[11].The same procedure is repeated until the wind turbines and PV array achieve their peak power points. Figure 4 displays the PV array's typical power curve. If MPPT approaches view it as an issue, it automatically determines the voltage VMP or current I and, under specific environmental conditions, the PV array should receive the maximum output power**[12]**.

V. SIMULATION AND RESULTS

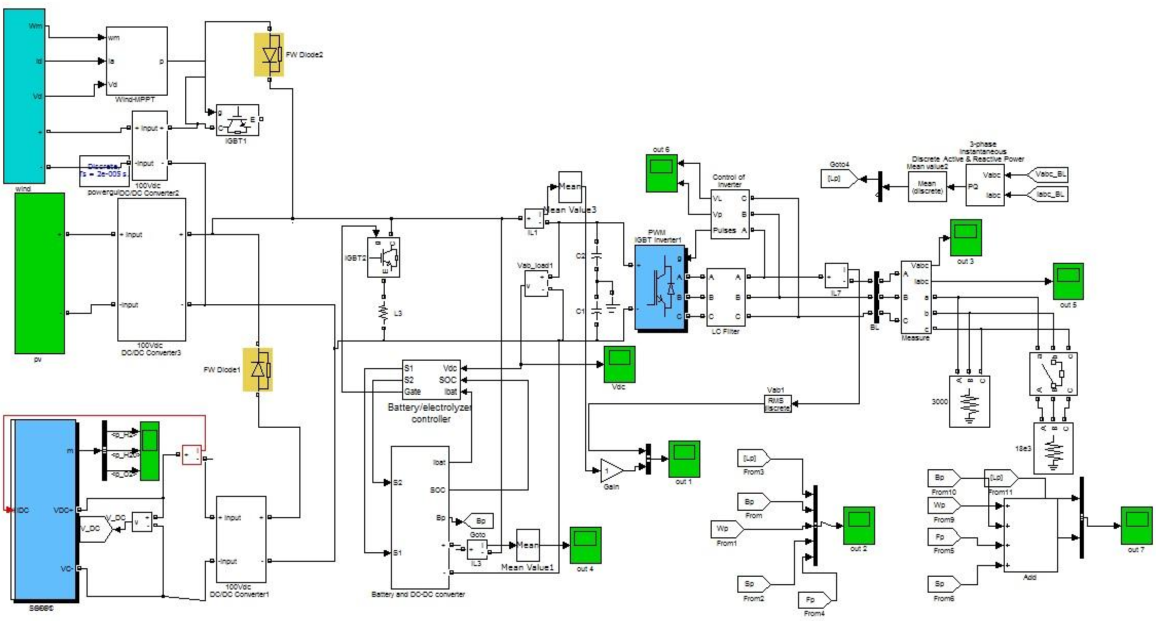

Figure 5: Simulation Diagram for Hybrid PV-Wind, Fuel cell and battery System

This study looks at a hybrid system that uses energy from multiple renewable sources, including wind, PVG, fuel cells, and storage batteries. While FC is utilised to maintain the battery fully charged and the storage battery is used as a supplementary or backup power source, wind turbines and solar panels are employed as the major energy sources. A simulation was performed using a system that includes of 5 kW WT, 5 kW PVG, and 6.2 kW FC. Fig. 5 displays the hybrid system's general schematic diagram. To test various operating situations, we presupposed that the battery SOC is 85% (roughly charged) and the SOC max is 86%. WT, PVG, and demand strength are variables utilised to analyse the performance of the suggested controllers under various climatic situations because FC is operated as a continuous source.

The DC link voltage fed to the inverter with PI controller can be viewed in the below graph of fig.6.

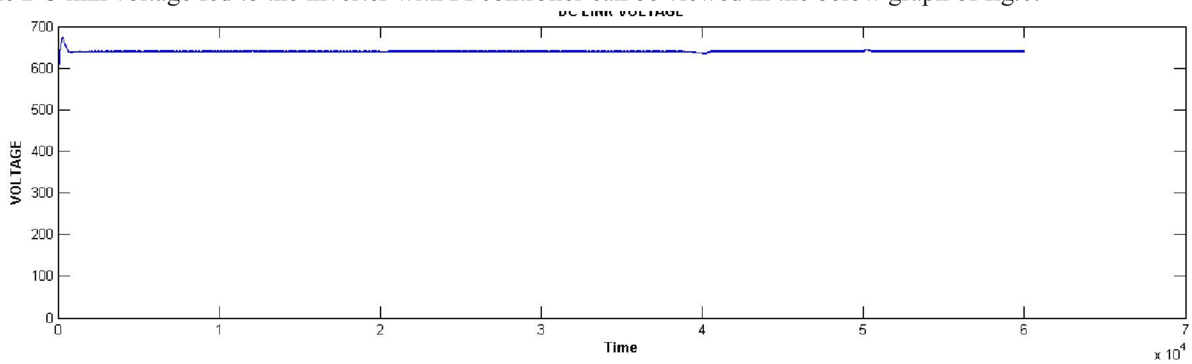

Figure 6: DC Link Voltage

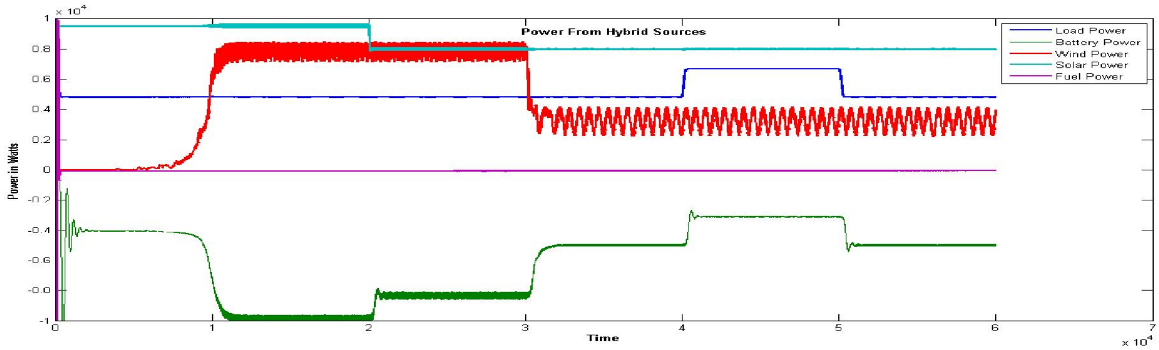

Figure 7: Source Powers and Load Power with PI controller

The power outputs of all energy sources used in the hybrid system are shown in the aforementioned fig. 7, together with load power.

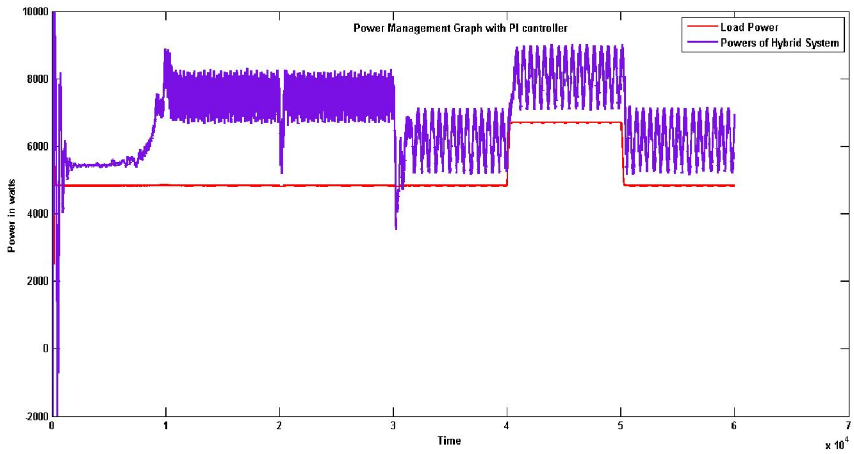

Fig. 8 Power Management graph of Hybrid System with PI control strategy for Inverter Control

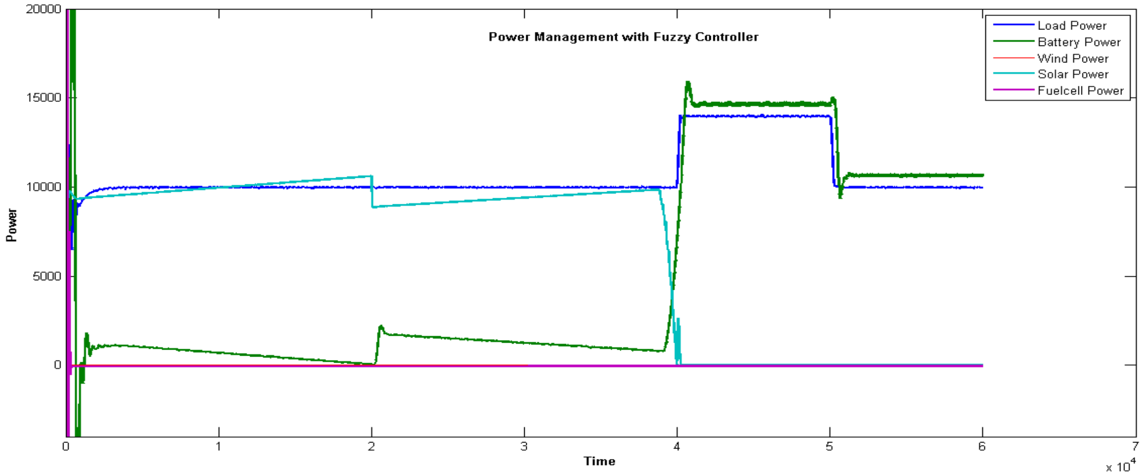

Fig. 9 Power Outputs of Energy Sources and Load Power

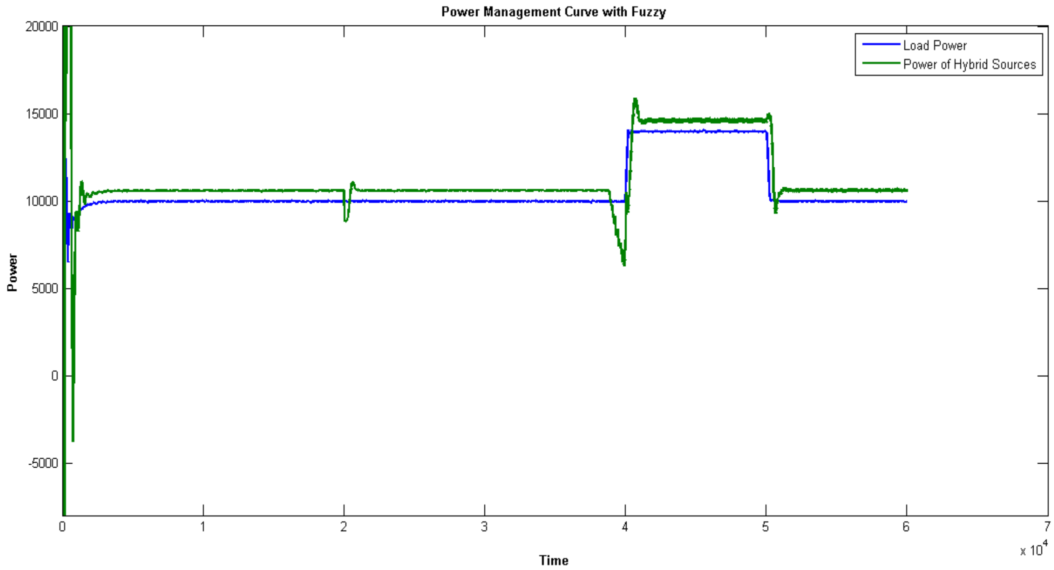

Fig. 10 Power Management graph of Hybrid System with Fuzzy control strategy

The energy outputs of the hybrid system and the load power with fuzzy controller are shown in Fig. 10 above. These outputs must be fulfilled by the sum of all the power sources for the proposed system's energy management. It is clear that fuzzy logic controllers outperform PI control strategies when used for inverter control of a hybrid system under consideration for power/energy management. The power outputs of all energy sources used in the hybrid system are shown in Fig. 10 above, together with load power. The energy outputs of the hybrid system and the load power, which must be fulfilled by the total power from all sources for the proposed system's energy management, are shown in Fig. 10 above. As shown in Fig., the load power need from 0 to 3 s is about 3.76 kw, which cannot be satisfied by the activated sources (PV and FC). As a result, the batteries start working to make up for the lost power; at this point, they are in discharge mode. The load increases from 3.76 kW to 4.7 kW at time t 4 s.The batteries always react more quickly than the other sources to changes in current, which enables them to boost their current proportionately to the increasing load. The WT is turned on at time t 4 s and takes part in power-sharing in the HES. The WT meets the load demand in this situation, and since there is more generation than consumption, it is possible to charge the batteries (charging Mode). It is possible to keep charging the batteries after the load provided to the circuit is initially reduced at time t 4 s. As a result, the power it generates will increase. At this time, the battery is still charging even when SOC is below SOCmax due to the continual load current. The battery's state of charge (SOC) reaches its maximum SOCmax (86%) at time t 4 (Fig. 10). A dump load is therefore activated to dissipate extra power in order to safeguard the battery from harm.

VI. CONCLUSION

In the proposed work, power/energy management of a hybrid renewable system that includes a wind turbine, photovoltaic, fuel cell/battery systems, and a variable load is realised. It was suggested to regulate the power electronic converter, or inverter, of the system by maximizing the control and energy management strategies of the various sources. Using a proportional integral (PI) controller to supply a resistive load with constant amplitude and frequency, the AC output voltage regulation was accomplished. Additionally, fuzzy logic control, which performs better than PI controllers and shows great promise for use in hybrid renewable energy management systems, was implemented for output regulation.

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