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Modeling of an Intelligent Battery Controller for Standalone Solar-Wind Hybrid Distributed Generation System Matlabs / Simulink

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Abstract

This paper describes a novel distributed generating that is independent and hybrid method. Because renewable energy supplies are intermittent, a single supply based on renewable energy sources of electricity system decreases power system reliability. To solve the problem, the storage system had to be extremely large, which increased overall system costs and significantly reduced flexibility. To address the issue, a freestanding power supply hybrid system generates electricity using solar and wind power. The mixed method provides dependable electricity to the consumer while increasing capability for generation without expanding storage capacity. Developing and testing the proposed system with Matlab/Simulink under varying load and source conditions.

Keywords : Solar, wind, MPPT, hybrid, and power efficiency all refer to renewable energy

Introduction

At the moment, daily energy demand has increased due to population growth, putting a strain on conventional energy resources, as the majority of electricity generated comes from fossil fuels. Most fossil fuels used to generate electricity are depleted. Expanding the scope of electricity generating power with fossil fuels contributes to fuel resource depletion. As a result, the only way to meet future energy demands is to use renewable energy sources that do not deplete after electricity production. When fossil fuels are used to generate electricity, however, they emit hazardous gases into the surroundings and polluting the environment. As a result, renewable energy sources have received priority attention in order to protect our environment and support the nation's long-term development. A standalone distributed generation system is developed. The modeling of an intelligent battery controller for standalone solar-wind hybrid distributed generation system involves the development of a control system that manages the power flow between the different sources and the load to ensure efficient and reliable operation. The goal of this controller is to optimize the battery charging and discharging processes, which can significantly impact the overall system performance and lifespan. Standalone solar-wind hybrid distributed generation systems have gained increasing attention in recent years due to their potential to provide clean and sustainable energy in remote areas or areas with unreliable grid connections. These systems typically consist of a combination of solar and wind energy production systems, a battery bank for power reserve, and a power management system that controls the electricity flow between various sources and the load.The performance of these systems is heavily dependent on the efficiency of the battery charging and discharging processes, which can be impacted by factors such as battery capacity, battery health, solar and wind power availability, and load demand.

Proposed Configuration

A hybrid distributed generation system typically consists of multiple power sources that are connected to a common grid or load. These power sources can include green energy technologies like solar cells and wind turbines. A solar PV array is a renewable energy that can be used to generate power from sunlight. The solar panels can be installed on rooftops or in open fields to capture sunlight and convert it into electrical energy. A wind turbine is another renewable energy source that can be used to generate electricity from wind. The wind turbine can be installed in areas with high wind speeds to generate electricity. A battery bank is employed in the storage of excess energy generated by the the sustainable resources during periods of low demand or when the energy generated exceeds the load demand. The stored energy can be used later when the demand is high or when the renewable sources are not generating enough power.

System Design

The basic diagram of self-contained hybrid power supply system that uses solar and wind energy are showed in below fig.1

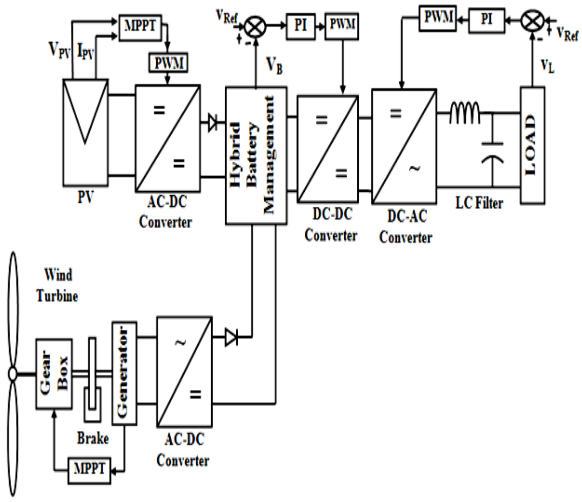

fig.1 A self-contained hybrid power supply system that uses solar and wind energy.

The first step is to determine the load's power requirements and the energy output of solar and wind sources. This involves the daily energy demand of the load, and estimating the amount of energy that can be generated by the solar panels and wind turbine based on the location and environmental conditions. The selected components must be integrated into system that can effectively manage

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the flow of power between the solar panels, wind turbine, battery and loads. This will require the use of a change controller to manage the charging of the battery and the distribution of power to the load. An effective hybrid power supply system must be monitored and controlled to ensure that it is operating efficiently and effectively. This can be done through the use of sensors and control systems that can monitor the energy output of the solar panels and wind turbine, the battery's level of charge, and the power consumption of load. The system can then be optimized to maximize energy efficiency and minimize energy waste. Finally, the hybrid power supply system must be properly maintained and kept in good working condition.

Buck converter

A Buck converter controlled by an incremental conductance(IC) based MMPT controller is a type of DC-DC converter that is used in PV (P) systems to regulate the output voltage of a solar panel and increase the amount of power given to the load. The Buck converter reduces the voltage of the solar panel to a level adequate for the load. The Buck converter's output is controlled by the IC-based MMPT controller, which adjusts the converter's duty cycle to keep the output voltage at the MMPT level. This ensure that the maximum power is provided to the load. The buck converter's output voltage is

$$V_{out} = DV_{in}$$

where D stands for the duty cycle, Vin is the buck converter's input voltage, Vout is its outpu5t voltage.

Performance and circuit diagram of a photovoltaic cell

Photovoltaic (PV) cells directly convert solar irradiance to electricity. In MATLAB Simulation software a PV model based on Sun Power E20/ 435 W data was created. The I-V and P-V characteristics of the array are shown in Figs. 2 and 3 when the environment temperature is constant.

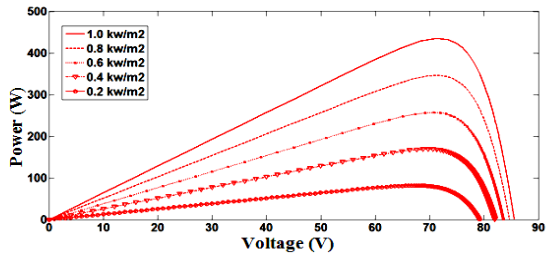


Fig.2. PV curve of PV array

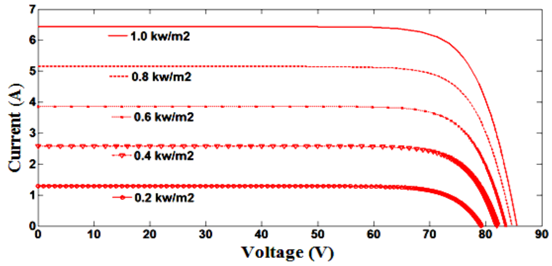


Fig.3. I-V curve of PV array

Incremental conductance (IC) method

Incremental Conductance (IC) method is a technique used to track and control the maximum power point (MPP) of a photovoltaic (PV) system. The MPP is the operating stance at which the PV module or array generates the maximum power output. The IC method adjusts the employed DC-DC converter's duty cycle in PV system in order to maintain the MPP under varying conditions. The IC method works by measuring the instantaneous current and voltage of the PV system, and then calculating the incremental conductance (dI/dV) at that point. The incremental conductance is then compared to a reference value, which is set equal to zero when the system is operating at the MPP. If the incremental conductance is positive, the MPP is becoming farther from the operating point and the DC-DC converter's duty cycle is adjusted to bring the system back to the MPP. If the incremental conductance is negative, the operating point is the operational point is heading towards the MPP towards the MPP, and no adjustment is needed.

The IC-based MPPT method's driving equation is

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = I + V\frac{dI}{dV} = 0 \quad (2)$$

The PV array's voltage vs. power curve for a constant solar irradiation is shown in Fig. 4. The power that may be extracted also varies with voltage. At dP/dV=0, the PV array produces the most electricity.

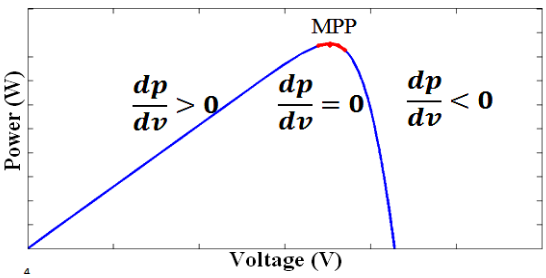


Fig.4 The typical IC algorithm's operating power (P) and voltage (V) curves.

According to the picture, if the operational voltage of the PV array is lower than the voltage under maximum strength conditions, equation 2 changes to

$$\frac{dI}{dV} > -\frac{I}{V}; \left(\frac{dP}{dV} > 0\right) \quad (3)$$

It shows that the PV array can handle less power with lower voltage. But, when the PV array consumes less energy because the operating voltage is too high. once more, and equation 2 changes to

$$\frac{dI}{dV} < -\frac{I}{V}; \left(\frac{dP}{dV} < 0\right) \quad (4)$$

Equation 3 represents the side of the highest power condition on the left, while equation 4 satisfies the right side, as seen in Fig. 4.

Incremental Conductance (IC) algorithm for MPPT controller

The Incremental Conductance (IC) algorithm is commonly used as a MPPT controller for photovoltaic (PV) systems. Here's a basic outline of the IC algorithm for MPPT. Measure the instantaneous voltage and current of the PV module or array. Calculate the incremental conductance (dI/dV) at the current operating point using the following equation:

dI/dV = (I - Iprev) / (V - Vprev)

where I and V are the current measured values of current and voltage, and Iprev and Vprev are the previous values of current and voltage. Compare the incremental conductance to a reference value, which is typically set to zero. If dI/dV is greater than zero, the MPP is becoming farther from the operating point and the duty cycle of the DC-DC converter should be adjusted to bring the operating point closer to the MPP. If dI/dV is less than zero, the operating point is moving towards the MPP, and no adjustment is needed.

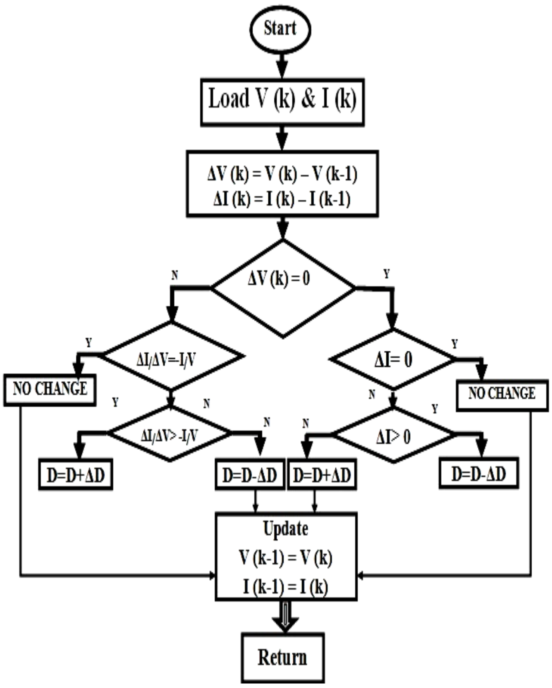


Fig.5 Incremental Conductance (IC) algorithm for MPPT controller

The algorithm for an IC-based MPPT controller is depicted in Fig. 5. where D denotes the duty cycle, which controls the associated DC to DC converter to keep the highest power level, and k denotes the counter. The duty cycle is simultaneously in use throughout modified to achieve the MPP circumstance at various irradiances, temperatures, and load conditions. In this case, the counter measures the current voltages V (k) and I (k) and calculates the conductance. Using network conductance to attain the MPP shown in equations 2-4, the duty cycle varies according to the measured conductance.

Wind-powered energy generation Turbine

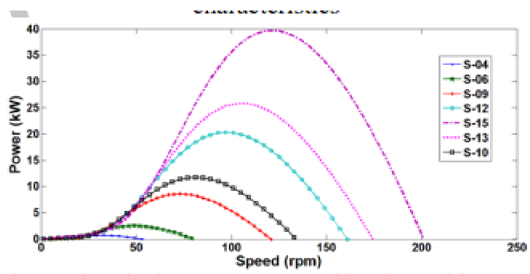
Wind turbine (WT) mechanical torque moves the shaft of an electrical generator to produce electrical energy. The power output of the wind turbine is

$$P_w = 0.5AC_p(\lambda,\beta)\times(V_\omega)^3 \qquad (5)$$

where P is the air density (in kilograms per cubic meter), V is the wind speed (in meters per second), and A is the area swept by the blades. the power coefficient of a turbine rotor

$$\lambda = \frac{\omega_\omega R}{V_\omega} \qquad (6)$$

Where ω_ω is the rotor's angular velocity (in rad/s), R is its radius (in m), and V is the rotor's upstream wind speed (in m/s).



ig. 7 Electrical power generated by the turbine as a unction of the rotor speed for different wind speeds

Optimal torque control (OTC)

The torque of the generator is regulated to its ideal value at various wind speeds in the case of the OTC MPPT approach. However, it necessitates an understanding of the Cpmax and opt properties of the turbine. According to equation 6, if the circumstances are ideal, the rotor's ideal speed can be calculated as

$$\omega_{m\_opt} = \frac{v_{\omega}.\lambda_{opt}}{R} = K_w v_{\omega}.$$

Equation 5 and equation 7 put together produce the best mechanical power the wind turbine can produce, which is

$$P_{w\_opt} = 0.5AC_p(\lambda, \beta) \times \left(\frac{R\omega_{m\_opt}}{\lambda_{opt}} \right)^3$$

$$= K_{opt}(\omega_{m\_opt})^3$$

(8)

Moreover, using equation 9, the ideal torque is

$$T_{w\_opt} = K_{opt}(\omega_{m\_opt})^2$$

(9)

The generator torque is optimised for various wind speeds using optimal torque control. It does, however, necessitate knowledge of the Cpmax and opt properties of turbines.If the conditions are ideal, the rotor's ideal speed can be calculated using equation 9, where Kopt is a constant defined by the wind turbine's features.

Charge controller operation for the hybrid solar-wind off-grid power supply system

Compared to the charge controller design for a system based on conventional power sources distributed generation system off-grid using a single power source. A battery management system (BMS) is an important component of a hybrid power generation setup, as it helps to manage the battery bank and ensure that it operates safely and efficiently. In order to ensure the continuity of the energy flow and proper equipment protection, the updated form of a charge controller, which uses SPV and WTG as electrical energy sources, is shown in Fig. 8.

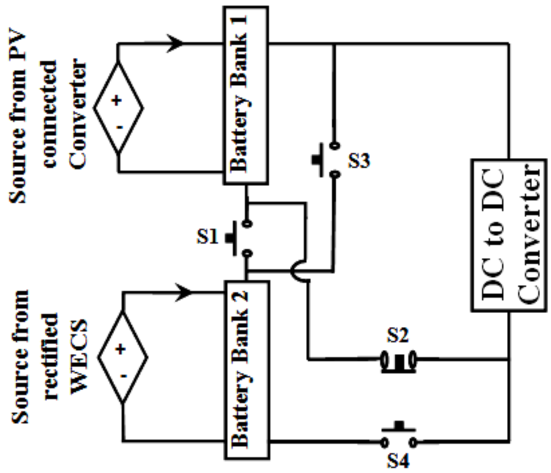


Fig.8 Battery management settings for a hybrid power supply system

When using a constant voltage source to synchronise two distinct sources, it is critical to maintain identical source voltages. Because the sources differ from one another and produce voltage that is not exactly the same from source to source, a specific charge controller is necessary to keep the energy flowing properly. In an off-grid hybrid solar-wind power supply system, the charge controller plays a critical role in ensuring that the system operates efficiently and reliably. It helps to maximize the lifespan of the battery bank and ensures that the load receives a steady and stable supply of power.

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Result

The independent PV system generates electricity using the Sun's different irradiance. Under ideal irradiation circumstances, 34 solar panels may provide 14.79 kW of power when they are joined in line to raise the working voltage. In order to increase the dependability of the power delivered, banks of batteries are connected to the system. In order to increase WECS is also connected to the system as a backup energy source because it produces electricity without increasing the size of the battery bank. The WECS harnesses wind energy to generate electricity, stores it in a battery unit, and then provides it when primary energy sources are unable to provide it to the consumer.

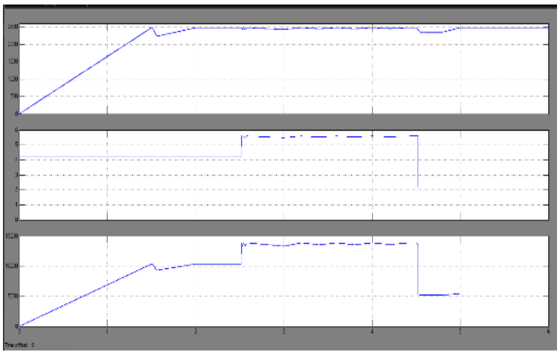

Fig.10 The PV array's (a) voltage, (b) current, and (c) power profiles were generated under varying Sun irradiation.

The performance of the PV array according to the variation in solar irradiation is shown in Fig. 11. The performance of the IC-based MPPT controller is poor at startup. Due to the solar irradiation of 0.699 kW/m2, it takes the controller about 1.8 seconds to reach the maximum power of 11 kW. At 2.54 seconds, the PV array produces 14.1 kW as the irradiance 9 changes to 0.920 kW/m2. The irradiance changes to 0.379 kW/m2 after 4.54 seconds, and the PV array produces 5.9 kW of electricity.

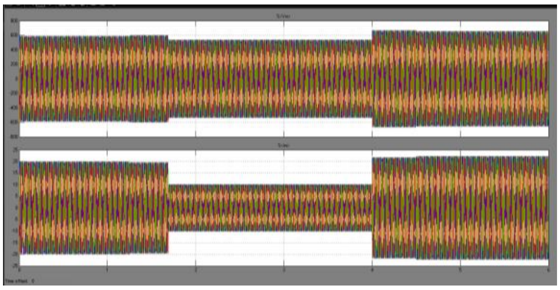

Fig. 11. Current profile and instantaneous voltage of the PMSG connected to the WT.

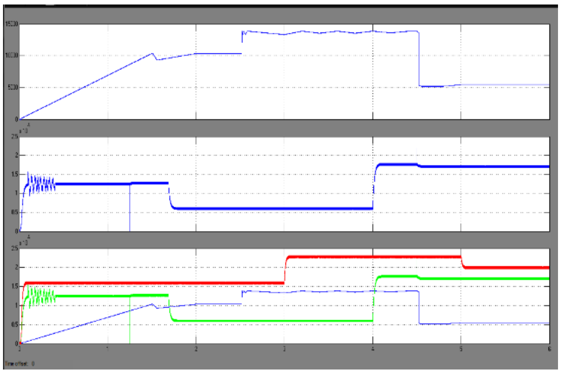

Fig. 12 (a) electricity produced by WTG (Pw) (b) electricity produced by a PV array (PPV) (c) a comparison of the electricity produced and used.

Conclusion

A freestanding hybrid energy system driven by solar and wind energy is successfully created in this study. The MPPT controller functions effectively under fluctuating irradiance, and wind speed, while retaining optimum power from the energy sources. The requisite power quality was successfully maintained by the converter and inverter assembly. The performance of the charge controller is appropriate for hybrid power management. System for managing hybrid batteries ensures transfer of energy to the load by using multiple switches included into the design. The various battery systems maximise the amount of energy you consume from renewable sources while delivering dependable electricity to the client while using the least amount of battery capacity.

FUTURE SCOPE

This thesis's work is restricted to PI controller. Further, To improve or design the system we can use Fuggy logic and Artificial controllers in the place of Boost converter or PI in order to reduce the harmonic generated in the system .

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