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OPTIMIZING BATTERY STORAGE EFFICIENCY IN STAND-ALONE WIND ENERGY CONVERSION SYSTEMS: A CONTROL SCHEME APPROACH

#1 DR.MUDDASANI SAMPATH KUMAR , Associate Professor,
#2BHUKYA DIVYA
#3 NELLI PAVANI,

Department of Electrical and Electronics Engineering,
SREE CHAITANYA INSTITUTE OF TECHNOLOGICAL SCIENCES, KARIMNAGAR, TS.

ABSTRACT: Establishing an electrical network in a sparsely populated and remote area lacks economic viability. In addition to the amplified line loss, the establishment and administration of power transmission from one end to the other will incur exorbitant expenses.Therefore, when the wind speed ranges from 15 to 25 meters per hour, a stand-alone wind energy conversion system with battery storage is the more favorable option in such conditions (unconnected to the grid). The wind velocity fluctuates ceaselessly throughout the day.As a result, it is impracticable to satisfy the client's demands by maintaining the current voltage and frequency. In order to ensure a consistent frequency and power output despite variations in wind speed, a control system is implemented. This degree of control is achieved through the use of pitch control. Pitch control modifications have no discernible effect on power level or frequency.We shall then examine storage devices. It is impossible to maintain a continuous supply without the utilization of storage devices. In general, the cost of the storage device is higher, and its lifespan is comparatively shorter. A number of novel techniques, including maximum power point monitoring (MPPT), are implemented in order to increase the longevity.By eliminating harmonic components and improving charging efficiency with minimal ripple, this control method guarantees a steady battery charge and averts scorching. The battery control mechanism guarantees a consistent current and voltage. As a result, the battery banks demonstrate increased efficacy and a prolonged operational lifespan.

KEYWORDS: Stand-Alone Systems,Battery Storage Efficiency,Renewable Energy

1.INTRODUCTION

Energy is universally recognized as the most vital component of advancement. Presently, the escalating demand for electricity is being fulfilled through the utilization of renewable resources, given the depletion of conventional sources and the mounting environmental concerns that individuals have developed. The comparatively low production costs of wind energy make it one of the most promising renewable energy sources for the foreseeable future.

Conversely, wind patterns are frequently quite capricious. Hence, comprehensive laboratory testing is essential in order to enhance the regulation capabilities of the wind strength conversion system (WECS). The daily significance of their research regarding Wind Energy Conversion Systems (WECS) and the controls that are associated with them grows. At present, a number of self-governing entities are powered by recycled energy. Considerable research is currently underway to ascertain the optimal generator for stand-alone wind energy conversion systems (WECS), driven by the increasing attention towards wind energy generation. Software for wind farms enables an unprecedented comparison of synchronous and asynchronous turbines. By functioning at varying speeds, an asynchronous device can effectively extract energy from WECS while simultaneously mitigating torque fluctuations.

The principal advantage of this is outlined below. The induction generator is frequently regarded as the most suitable wind turbine generator (WTG) for off-grid operations on account of its robustness, low unit cost, and inherent ease of operation. On the contrary, capacitor batteries play a crucial role in supplying power to the induction generator situated in remote locations. This passage presents an examination of the self-excited induction generator (SEIG) and elucidates its operational mechanism.

The fluctuating wind direction provides the SEIG with its primary energy source. Both the frequency and magnitude of the voltage in the SEIG are influenced by the wind velocity. When the burden is released, linking a weight directly to a rapidly fluctuating voltage may result in instability and shimmering. Digital converters from power are utilized to link the WECS to the weight in order to maintain a constant load voltage. A wind energy conversion system also requires the implementation of an energy storage device due to the non-availability of wind-generated power. An examination is undertaken of the current garage technology that utilizes wind energy. Emphasis is placed on the advantages of utilizing a battery-powered garage as a remote wind energy conversion system (WECS). Currently, wind energy can be maximized through the addition of a solar-powered garage.

2.RELATED WORKS

Governments, corporations, and individuals have widely adopted wind energy due to its environmentally sustainable characteristics, economic feasibility, efficiency, and absence of pollution (A. D. Sahin et al., 2017). Since the 1973 oil crisis, wind energy has garnered considerable attention as a prominent form of renewable energy. An increasing number of sectors are adopting wind energy as a viable alternative to other energy sources, as a result of extensive research.

This article evaluates the feasibility of wind energy and promotes further discourse on the subject. It is imperative to conduct a comprehensive analysis of narratives pertaining to wind energy, wind power meteorology, the interplay between climate and energy, wind turbine expertise, the wind economy, wind-hybrid applications, and the worldwide installation status of wind energy capacity. Furthermore, it is advisable to incorporate recommendations for additional and expanded research.

Further authors cited in consist of R. Richardson, D., and G. McNERney, M. At present, wind energy is an indispensable and swiftly expanding form of renewable energy. Numerous power distribution networks are outfitted with sizable wind turbines capable of producing electricity at a rate of 6 to 8 MW.

An emerging phenomenon entails the direct connection of electricity-generating onshore and offshore wind farms to expansive power transmission networks. The expanding vertical dispersion of wind energy is significantly affecting the operation of the existing grid infrastructure. Presently, scholars are undertaking the integration of cutting-edge power electronics technologies into wind turbines with the dual objectives of enhancing blade efficiency and streamlining the connection to the power infrastructure.

Concurrently, novel challenges arise that necessitate ongoing reactions. This essay offers a comprehensive analysis of recent developments in power electronics technology and presents a detailed synopsis of the technologies employed in the generation of wind power. An initial analysis is provided with respect to the global market and state-of-the-art technologies.

This text examines fundamental wind turbine principles and power technology solutions applicable to both small wind turbines and enormous wind farms. Furthermore, potential technological solutions and challenges associated with power electronics in wind turbine systems are examined in the article.

Encompasses the scholarly works of notable authors, including K. Additionally, H. Solangi, M. R. Islam, N. A. Rahim, and R. Saidur were present. Numerous nations have been compelled, among other things, to conduct research and transition to eco-friendly energy sources as a means of mitigating the detrimental environmental effects associated with the incineration of residual fuel. Solar energy is among the most ecologically benign and efficient renewable energy sources. Numerous nations have implemented solar energy strategies in an effort to both reduce their dependence on fossil fuels and increase domestic solar energy production.

This research examines the diverse array of solar energy initiatives implemented by governments across the globe. Based on numerical energy research conducted by BP, the worldwide solar energy capacity experienced a notable growth of 46.9% between 2008 and 2009, culminating in a total of 22,928.9 MW. Additionally, the articles delineate the prosperous solar energy initiatives of a limited number of nations. Numerous nations across the globe have implemented FIT (Feed-in Tariff), RPS (Renewable Portfolio Standards), and incentives, all of which have been substantiated by extensive research as being extraordinarily effective energy policies. Significantly, the policies facilitate the development and implementation of renewable energy technology.

The increasing significance and scrutiny of wind farms and wind energy can be attributed to the worldwide energy crisis, volatile fossil fuel costs, and the intricacies associated with constructing and managing nuclear power plants. Among the numerous wind farms utilized for recreational purposes, the ranch power station stands out as the most renowned.

The induction engine transmissions of this power plant are capable of controlling a range of power outputs per unit. Induction with a winding rotor, synchronous with an endless magnet, collector cage induction, and synchronous with an agitated field are the four manufacturer classifications. Wind farms derive their most substantial benefits from the first two categories. Moreover, in comparison to the squirrel cage induction generator, the fixed-magnet synchronous generator exhibits superior power coefficient and efficiency.

The ongoing public interest in "alternative sources of energy," as demonstrated by the research conducted by G., has been sustained by the increasing need for enhanced fuel efficiency. Singh et al. (5) argue that the implementation of alternative energy sources, including biogas, solar, and hydropower, in conjunction with power generation distribution, requires the development of a production system that is both economical and efficient. This system should also be capable of functioning efficiently in remote regions with a significant number of primary movers. As an alternative to conventional synchronous generators, induction generators are the subject of research due to their reduced unit cost, enhanced durability, and simplified installation and operation.

The expansion observed can be ascribed to the rising prevalence of wind turbines and micro-hydro generators as viable alternatives for electricity generation. The variable power output rates of the induction generator enable its utilization in diverse modes—self-excited stand-alone operation, grid-connected operation, and in conjunction with a synchronous generator to meet local demand. Scholars have devoted the last three decades to examining the myriad obstacles that emerge when induction generators are used to meet future energy demands as opposed to synchronous generators. Small-scale hydro and wind power systems are employed to fulfill anticipated energy requirements, specifically in remote and unreachable areas where connecting to the grid would be uneconomical.

3.PROPOSED SYSTEM

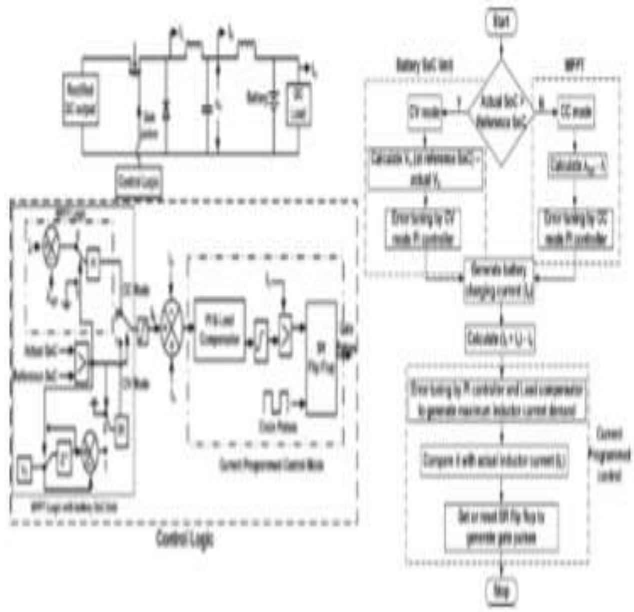
A research investigation is currently underway to evaluate the capacity of a hybrid wind-battery system to supply power to a single base telecom station (BTS). In the case that the BTS load is a direct current load, a regulated 50 volts is required. In order to regulate the load voltage, the ac-dc-dc power converter connects the WECS to the independent dc load. To charge the battery in a predetermined fashion, the proposed control strategy integrates the State of Charge (SoC) limitation concept of the battery with the most potent power-tracking approach of the turbine.

HYBRID WIND-BATTERY SYSTEM FOR AN ISOLATED DCLOAD

The proposed hybrid apparatus consists of a 400Ah C/10 lead-acid battery bank and a four-kW wind energy conversion system (WECS). Its purpose is to regulate a 3-kW direct current (DC) standby capacity. The validation of the device's design and control scheme has been completed. The appendix contains the detailed specifications pertaining to the wind turbine (WT), synchronous electric induction generator (SEIG), and battery bank. A toolkit with a 1:8 tool ratio, a 5.4-kilowatt horizontal axis wind turbine (WT), and a 5.4-horsepower Synchronous Electric Induction Generator (SEIG) for the Wind Turbine Generator (WTG) comprise the Wind Energy Conversion System (WECS). By connecting the capacitor bank to the stator conductors of the SEIG, the weight operates as an independent direct current load and generates its own excitation. The direction of the AC output is inverted utilizing three-phase unregulated diode rectifiers. Weight requirements necessitate the use of a secondary battery in the event that wind forecasts are inadequate. Effective operation of this wind-battery combination machine requires the application of sound judgment and appropriate control. The unregulated rectifier supplies the rate controller circuit of the battery with direct current (dc) electricity. With the capability of converting direct current to direct current (DC-DC), the rate controller regulates the battery's charging and discharging rates with extreme precision. The battery bank of the system can function as a power supply or burden, contingent upon its state of charge or discharge.

However, the battery guarantees a consistent voltage at the interface with the load. In order to charge the battery in a predetermined fashion, the proposed control method integrates battery state of charge (SoC) limiting logic with the most potent turbine power tracking system. The independent WECS system incorporates the pitch motor and battery recharge functions with the intention of augmenting efficiency.

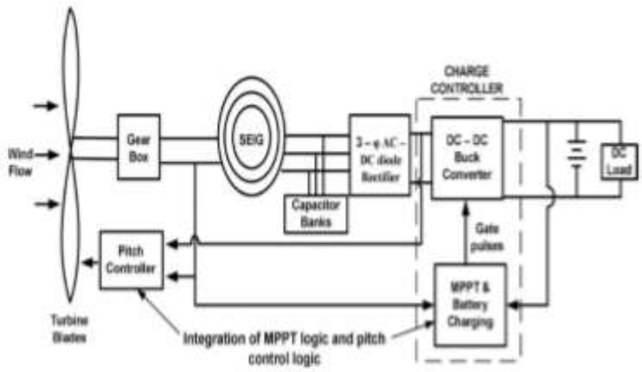
CHARGE CONTROLLER BLOCK DIAGRAM



CONTROL STRATEGY FOR STAND-ALONE HYBRID WIND-BATTERY SYSTEM

Directionally, the wind is erratic. In order to mitigate distortion and power imbalance, an ac-dc-dc converter is employed to establish a connection between the WECS and the stack. The control scheme of an independent hybrid wind-battery system comprises pitch control logic, which ensures that the wind turbine operates within its designated range, and a charge controller circuit for the batteries. Efficient administration of the WECS is guaranteed by the control logic, even when prospective disturbances are present.

CIRCUIT DIAGRAM



Charge Controller for the Battery Bank

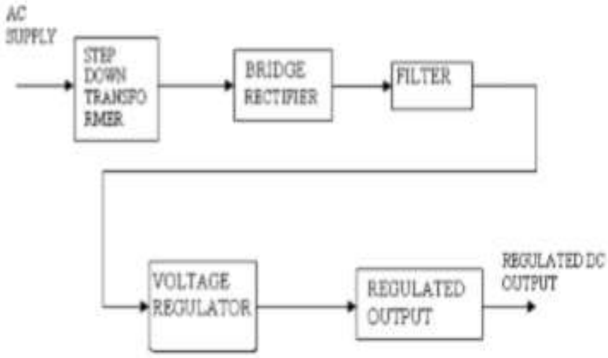
This segment provides an exhaustive synopsis of the methodology employed in MATLAB/SIMULINK to devise a charge controller circuit for a 400Ah, C/10 battery bank by utilizing a dc-dc buck converter. As per the guidelines provided by the manufacturer, the batteries ought to be charged at C/20, C/10, or C/5 rates. The C rating of a battery bank serves as an indicator of its capacity. A battery bank device capable of charge at 20, 40, or 80 Amperes is incorporated into the design.

This investigation consumes 40 amperes, which is equivalent to one-tenth of the battery's capacity. The voltage required to charge the battery bank is determined by the State of Charge (SoC) of the battery. Using a constant current (CC) method, also referred to as the C/10 rate mode, the majority of batteries are charged to a predetermined charge level (around 90% to 98%). "CC mode" denotes a distinct approach to charging a battery; when in constant current (CC) mode, the charge-to-charge efficacy is maximized. In the CV charging mode, a constant voltage (CV) is applied to charge the battery so as to preserve the terminal voltage in accordance with the State of Charge (SoC).

Control Strategy

Three hierarchical control loops make up the charge control code provided. The external control loop supplies power to the turbine by implementing the Maximum Power Point Tracking (MPPT) and State of Charge (SoC) limits of the battery. By comparing the present tipspeedratio (TSR) of the turbine to the optimal value, the MPPT algorithm is established. A PI controller modifies the error to attain the desired battery current when the state of charge (SoC) of the battery falls below the threshold for the constant current (CC) mode. The control logic implemented on the system-on-chip (SoC) strives to maintain a stable charging voltage for the battery. Therefore, through the restriction of battery power consumption, the battery bank is shielded from deception. In the middle control loop, the present order of the buck converter inductors is ascertained. It is critical to illustrate the correlation between the inductor current and the battery current (Ib) in order to construct the controller.

HARDWARE DETAILS POWER SUPPLY UNIT



It is no longer a secret that the availability of electrical resources is critical to the efficient application of newly acquired knowledge. We require a power source capable of adapting to the rapid changes occurring on a global scale. All electrical components, including diodes and Intel ICs, necessitate a direct current (DC) power source falling within the voltage range of -5 to +12 volts in order to operate in an appropriate manner. In order to achieve the intended result, we are manipulating and regulating the voltage using a practical and economical power source operating at a frequency of 50 Hz and 230 volts. A concise overview of this will be provided in the following sections.

STEP DOWN TRANSFORMER

Through the process of connecting to the primary winding of a power transformer, one can modify the alternating current (AC) in order to generate the intended direct current (DC). Step-down is accomplished in our course by connecting the lower wire to a 230V/0-12V converter, which converts 230V AC to 12V AC. Negative is the reference point of the transformer; its maximum value can be ascertained through a solitary adjustment to the data. A shift will transpire inadvertently due to the subsequent modification. Our endeavor utilizes a transformer with a 1A electrical capacity. Moreover, it eliminates the existence of alternating current (AC) voltages and establishes a separation between the circuits that supply and generate power.

DIODE BRIDGE RECTIFIERS

By utilizing a 230/30V step-down transformer, the voltage from the primary source is decreased. By rectifying stepped-down AC power with a diode bridge, DC voltage is produced. The diode bridge rectifier is composed of two segments of four stacked diodes. AC electricity that has been reduced is utilized to supply power to the diodes. The image depicts diodes D1 and D4 in a forward biased state, due to the fact that the alternating current (AC) voltage is positive 50% of the time. Forward bias is applied to diodes D2 and D3 during negative half cycles. As a result, the DC-DC Converter operates on DC electricity that is generated.

BRIDGE RECTIFIER

In the diode bridge rectifier, the forward bias of diodes D1 and D4 is evident during the positive half cycle of operation. As soon as the diodes commence conducting, the load passes through diode D1, followed by the positive supply, the load, diode D4, and finally the negative supply. The loss of activity occurs in diodes D2 and D3 due to the inversion of their bias. Due to an inverted bias, diodes D1 and D4 cease conducting during the negative half cycle. By applying a forward bias to diodes D2 and D3, their conductivity is increased. The direction of flow of the discharge current is consistent in all instances. A pulsating direct current is produced from alternating current by the diode bridge rectifier.

FILTERING UNIT

In order to mitigate power disruptions, capacitor-based filter circuits are typically positioned subsequent to the rectifier device. Conversely referred to as a bypass capacitor or decoupling capacitor. By directing the 120Hz disturbance to the ground and displaying the output frequency in DC, this device achieves its purpose. In order to establish a stable ground connection, a series connection is made with load resistor R1. C1R1 aids in the prevention of waves. As a result of the characteristics of a low pass filter, C2R2 selectively blocks high frequency signals while permitting low frequency signals to pass through. From 1% to 2.5% is the ideal voltage range for the load resistor.

VOLTAGE REGULATORS

Voltage regulators are critical power supply components. The primary function of a regulator is to assist the rectifier and filter circuit in providing the device with a stable DC power supply. Unregulated power supplies dynamically alter their direct current (DC) voltage levels in reaction to fluctuations in the AC line voltage, which induce changes in the header voltage. By connecting a regulator to the direct current (DC) output, voltage regulation within a specified range is possible. The IC7805 provides the project with +12vDC power. In situations where a direct electrical connection is absent, signal and data exchange between hardware components or portions of an apparatus is frequently required. Despite operating on a 5V DC power source, a microprocessor has the capability to supply power to a MOSFET that operates at a higher voltage. This phenomenon may manifest when there is a substantial disparity in voltage levels between the source and destination, which may be considerable in magnitude. In this particular scenario, it is imperative to establish an unambiguous correlation between the two variables so as to protect the microprocessor from any potential harm resulting from an overcharge.

OPTO COUPLER

A photocoupler is comprised of two transparent components: an optical emitter, which is frequently a light-emitting diode (LED) composed of gallium arsenide, and an optical receiver, which may be a phototransistor or a light-triggered diode. Typically, between six and eight integrated circuit packages comprise a photocoupler.An uncomplicated obstruction divides their paths, facilitating the flow of light but hindering the movement of electricity. Furthermore, the conventional symbol for an optocoupler circuit serves to symbolize the fundamental principle. Typically, the phototransistor or diac electrical connections are situated on one side of the package, whereas the LED electrical connections are situated on the opposite side. They strive deliberately to reduce the frequency of their interactions with them. Between 500 and 7500 volts are admissible for input and output voltage processing by the optocoupler. Optocouplers are highly suitable for the transmission of complex data or on-off control signals due to their intrinsic design as automated or switching devices. In order to transmit analog communications, frequency modulation or pulse width modulation may be utilized.

When it comes to the preponderance of

optocouplers, the effectiveness of signal exchange, also known as the current transfer ratio (CTR), is the most crucial factor. This is a direct measurement of the change in input LED current that induced an equivalent change in the current of the output transistor. In general, apparatus featuring an output phototransistor demonstrate a CTR value spanning from 10% to 50%. Devices featuring a duo of Darlington transistors as outputs are subject to a 2,000% upper limit. Nevertheless, it is critical to acknowledge that the click-through rate (CTR) is subject to variation as a result of the power level exhibited by different devices. Peak current levels of approximately 10mA are uncommon for LEDs, and cascading effects at lower or higher current levels are uncommon.

MOSFET SWITCH-IRFP250N

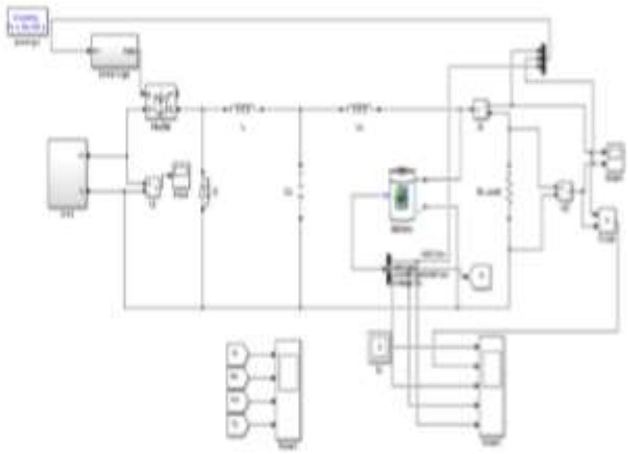
Metal oxide semiconductor field effect transistor is the abbreviation for EFT. The FET is the most frequently encountered and widely recognized form of field effect transistor.MOSFETs are components of integrated circuits comprised of PMOS (p-channel) or NMOS (n-channel) transistors. Their purpose is to supply electrical energy to the integrated circuit or to the multiple processors comprising the circuit.

INDUCTORS

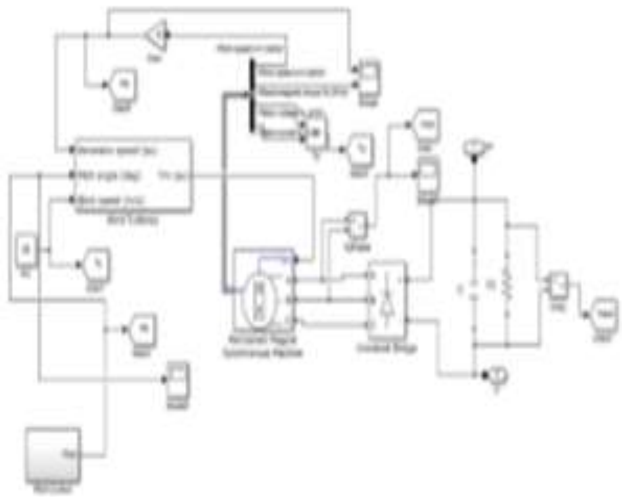
A reactor, alternatively referred to as an inductor, functions as a passive electrical element where energy is stored within the magnetic field produced by the electric current flow. The capacity of an inductor to store magnetic energy is quantified in henries; it is denoted as inductance. An inductor is a coil-shaped wire that possesses the ability to conduct electrical current. As per Faraday's law of induction, the coil's internal circuits contribute to the generation of a robust magnetic field.Because of their ability to alter the form and latency of alternating currents, inductors are considered to be critical electrical components. Electrodes are susceptible to temporal fluctuations in both current and voltage.

The sole characteristic of an energy distributor referred to as a "ideal inductor" is inductance; capacitance and voltage are absent. As indicated by the variation in electrical resistance caused by the resistive characteristics of the wire, capacitance is a component of a valid inductor. Inductors demonstrate resonance-like characteristics over a broad frequency spectrum, frequently exceeding the anticipated frequency, due to the intrinsic self-capacitance of the components. Power loss can occur in magnetic core inductors as a result of hysteresis and wire resistance. Due to the non-linear characteristics of these devices, they may exhibit undesirable characteristics when exposed to high levels of electrical current.

4. SIMULATION RESULT

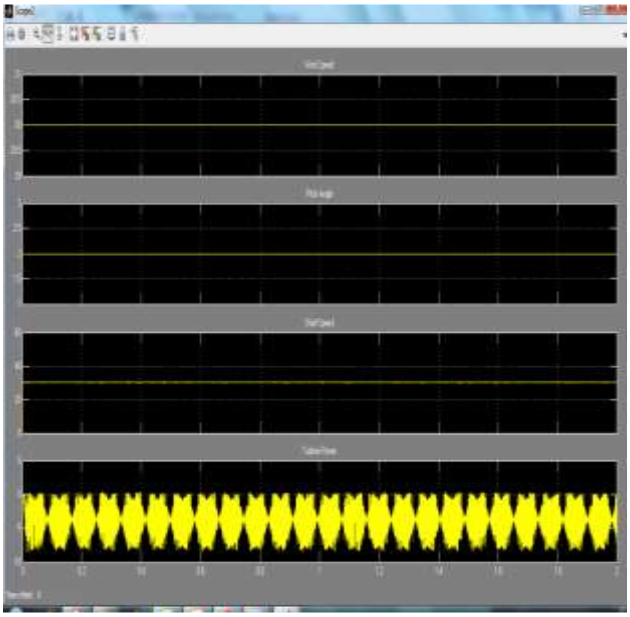


WINDSYSTEM

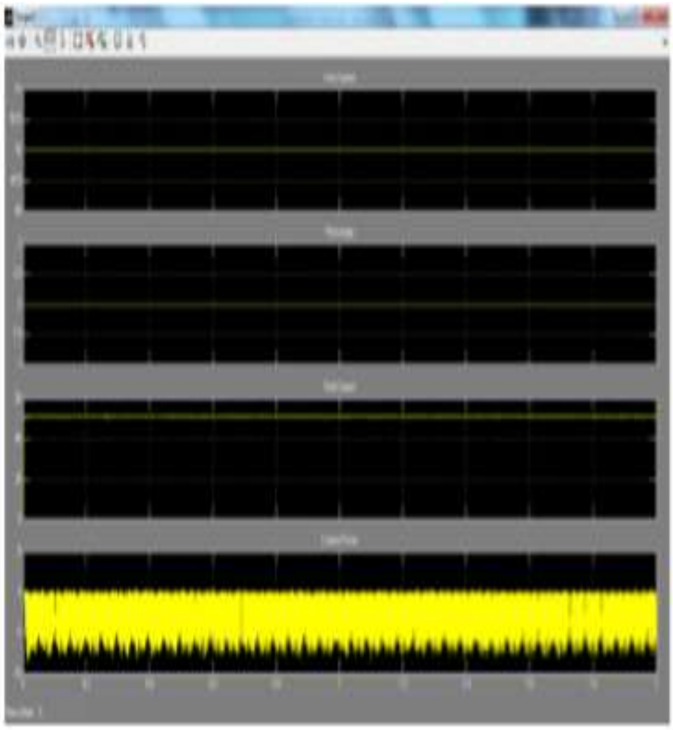


SIMULATIONOUTPUT

This approach produces thirty wind sources in total. Notwithstanding the outcomes, the overarching authority will remain unaltered.

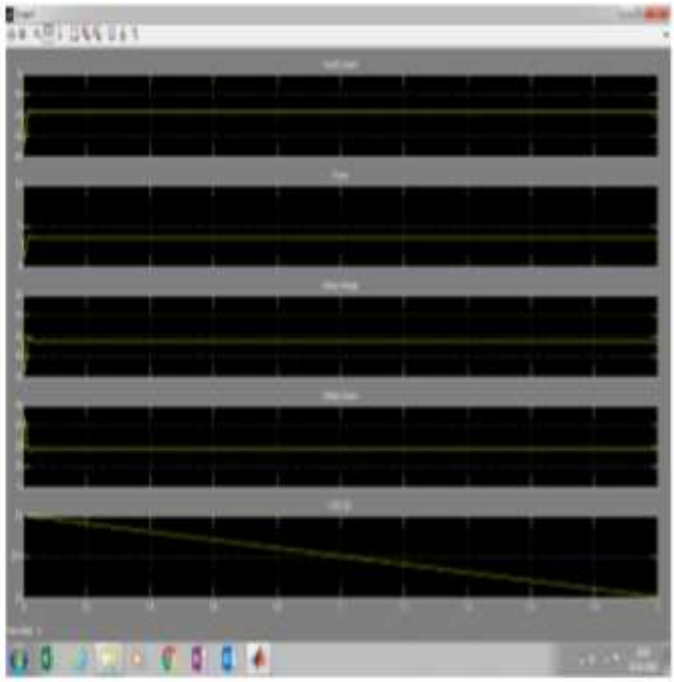


At this phase, the wind source is initialized to a value of fifty. Irrespective of variations in variables like velocity, the overall power remains consistent.



OUTPUT

Both wind sources produce an equivalent quantity of output.A wind speed of 20 mph is concomitant with a velocity of 50 mph.



WIND MILL

BATTERY VOLTAGE

SOURCE VOLTAGE

4.CONCLUSION

The energy production of a Wind Energy Conversion System (WECS) is conditionally dependent on the particular conditions at hand. Consequently, in order to satisfy the demand, a Wind Energy Conversion System (WECS) is incapable of ensuring a consistent power supply. For capacity requirements to be consistently met, it is vital to have the appropriate storage device. The power source with the highest efficiency in this volume is generated by a hybrid wind-battery system. By means of the required controls, the burden is connected to the WECS, thereby preventing random fluctuations in wind flow.In order to optimize the electrical system and user safety, the combined design's control logic implements Maximum Power Point Tracking (MPPT) to regulate the pitch of the wind turbine and set the charge of the battery bank. The charge processor oversees the utmost allowable electricity consumption in order to charge the battery bank in a secure manner. Additionally, it evaluates whether the discharge current of the battery is below a threshold of one-tenth of its capacity.

Designed-for process-specific control mechanisms safeguard the buck converter intrinsically against excessive current. Nevertheless, circumstances may arise in which the power supplied to the Maximum Power Point Tracking (MPPT) system surpasses the power consumption of both the application and the battery. In instances of power divergence, the pitch action can be modified to alter the pitch angle, thereby facilitating the synchronization of the wind turbine's output power with the aggregate demand. Furthermore, it possesses the ability to modify WT freedom, and the pitch control logic averts a condition of overvoltage brought about by the rectifier voltage.

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