Charge Control of Ess in Seig by Using Mppt and Soc

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ABSTRACT

In recent times, renewable energy sources such as wind, solar, and micro-hydro have seen increased usage for electric energy generation. This paper presents a wind-based standalone hybrid energy system designed for remote area power applications. There is still significant growth potential in the field of renewable energy resources in the coming years.

With the renewed interest in wind turbines as an alternative energy source, induction generators are being considered as a viable alternative to well-developed synchronous generators due to their lower cost, inherent ruggedness, and simplicity in operation and maintenance. Induction generators can generate power at varying speeds, making them suitable for self-excited standalone (isolated) mode and grid-connected mode, supplementing local loads alongside synchronous generators. Extensive research is being conducted to select an appropriate generator for standalone Wind Energy Conversion Systems (WECS). To ensure a continuous power supply, suitable storage technology is used as a backup.

Energy Storage Systems (ESSs) play a vital role in wind power applications by controlling wind power plant output and providing auxiliary services to the power system, thereby enabling increased integration of wind power. A charge controller for the battery bank, based on turbine Maximum Power Point Tracking (MPPT) and battery State of Charge (SoC), is developed to ensure controlled charging and discharging of the battery. The mechanical safety of the WECS is assured using a pitch control technique. Both control schemes are integrated, and their efficiency is validated through various load and wind profiles in MATLAB/SIMULINK.

INTRODUCTION

Traditional energy sources are not only limited but also contribute to environmental pollution. Consequently, there has been a significant shift towards exploring renewable energy sources such as wind energy, fuel cells, and solar energy. Among these, wind energy stands out as the fastest-growing and most promising renewable energy source due to its economic feasibility. Research focuses on harnessing wind energy for electricity generation with an emphasis on cost-effective utilization for quality and reliable power supply. Selecting the appropriate generator, turbine rating, and distribution network is crucial in establishing a wind energy system. Commercially available generators and turbines must be coordinated for efficiency, cost, and maximum power generation in an iterative design process.

Operating Wind Turbine Generators (WTGs) at variable speeds is advantageous due to the fluctuating nature of wind energy. This approach reduces physical stress on turbine blades and drive trains, improves system aerodynamic efficiency, and enhances torque transient behaviors. The selection of the generator depends on factors related to the primary energy source, load type, and turbine speed. System configurations vary based on applications (standalone or grid-connected), interruptibility, and output cost and quality.

Asynchronous generators, including squirrel-cage induction and synchronous with permanent magnet types (self-excited), offer significant advantages for wind-farm power plants. Synchronous generators and permanent magnet types have higher efficiency and power coefficients compared to squirrel-cage induction generators and do not require power storage. However, the acceptance of self-excited induction generators depends on overcoming challenges such as poor voltage and frequency regulation, dynamic loading capabilities, and performance under unbalanced conditions.

Despite the abundance of wind power, its output varies with changes in wind speed throughout the day. The rate of power output from a WECS depends on the accuracy of peak power point tracking by the MPPT controller, regardless of the generator type used.

To meet the demand for a continuous power supply, energy storage is essential. Hybrid power systems combine two or more energy conversion devices or fuels to overcome inherent limitations. Hybrid energy systems, coupling renewable and conventional energy sources, can significantly reduce the total life cycle cost of standalone power supplies in off-grid situations while providing a reliable electricity supply using a combination of energy sources.

Wind Energy Conversion Systems

This chapter delves into the study of Wind Energy Conversion Systems (WECS) and provides a detailed comparison between asynchronous and synchronous generators for wind farm applications. It includes a comprehensive examination of the model of Self-Excited Induction Generators (SEIG) based on modeling equations, along with brief information on hybrid systems. Detailed comparisons between different energy storage systems are also presented.

Classification of Wind-Mills

Wind turbines are generally categorized into two types: Horizontal Axis and Vertical Axis. Horizontal axis turbines have blades rotating on a hub parallel to the ground, while vertical axis turbines have blades rotating on a hub perpendicular to the ground. Each type has various designs with specific advantages and disadvantages. However, horizontal axis wind turbines are generally preferred over vertical axis wind turbines.

Horizontal Axis Wind Turbines

This design is the most commonly used for wind turbines. The axis of rotation of the blades is parallel to the ground and aligned with the wind stream.

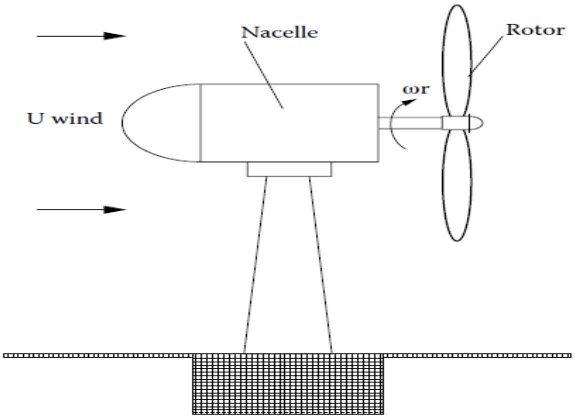

Fig. 1 Horizontal axis wind turbine

Horizontal Axis Wind Turbines (HAWT)

Almost all large turbines used in modern wind farms are Horizontal Axis Wind Turbines (HAWT) because they are more efficient at harnessing wind energy. However, HAWTs are subjected to reversing gravitational loads, which limit their size.

Vertical Axis Wind Turbines (VAWT)

Vertical Axis Wind Turbines (VAWT) do not exploit the higher wind speeds at elevated heights as effectively as HAWTs. The main vertical designs are the Darrieus, which features curved blades with an efficiency of 35%, and the Savonius, which uses scoops to catch the wind and has an efficiency of 30%. VAWTs do not need to orient themselves to the wind direction. Since the shaft is vertical, the transmission and generator can be mounted at ground level, making servicing easier, reducing weight, and lowering the cost of the tower. Figure 2.2 illustrates the Savonius and Darrieus types of vertical axis wind turbines (VAWT).

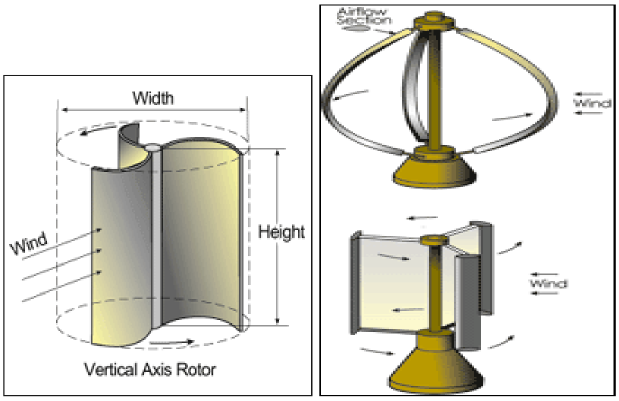

Fig 2 Vertical axis wind turbine

CONTROL TECHNIQUES

Control Scheme for Stand-Alone Wind-Battery Hybrid System

The control scheme for a stand-alone wind-battery hybrid system includes a charge controller circuit for the battery banks and pitch control logic to ensure the wind turbine operates within rated values. This control logic is designed to effectively manage the Wind Energy Conversion System (WECS) against various disturbances.

Buck Converter

In the buck converter circuit (Fig. 3.1), when the transistor is turned ON, the input voltage \(V_{in}\) is applied to one end of the inductor, causing the inductor current to rise. When the transistor is turned OFF, the current continues to flow through the inductor but now passes through the diode.

Assuming the inductor current does not initially drop to zero, the voltage at \(V_x\) will only be the voltage across the conducting diode during the entire OFF time. The average voltage at \(V_x\) depends on the average ON time of the transistor, assuming continuous inductor current.

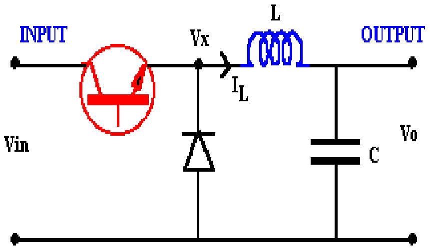

Fig 2 Buck converter

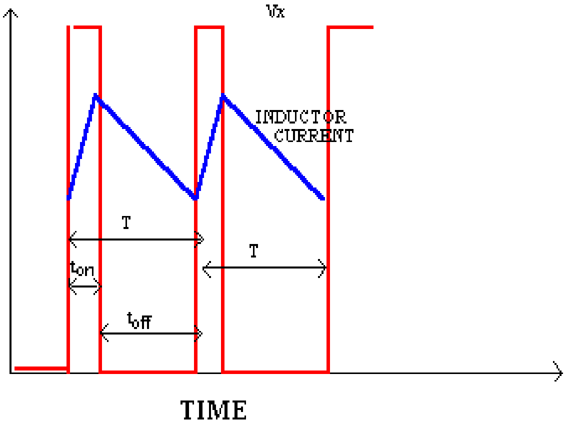

Fig 3 Voltage and current changes

MPPT CONTROL METHODS:

The wind generation system has garnered significant attention as a renewable energy source due to the depletion of fossil fuel reserves and environmental concerns associated with their utilization. Wind energy, while abundant, fluctuates frequently as wind speeds change throughout the day. The power output of a Wind Energy Conversion System (WECS) depends on the accuracy of peak power point tracking by the Maximum Power Point Tracking (MPPT) controller in the WECS control system, regardless of the type of generator used. Various algorithms for maximum power extraction can be categorized into three main control methods: tip speed ratio (TSR) control, hill-climb search (HCS) control, and power signal feedback (PSF) control.

The TSR control method regulates the rotational velocity of the generator to maintain the tip speed ratio at an optimum value where the extracted power is maximum. This technique requires measuring or estimating both the wind speed and the turbine velocity, as well as knowledge of the turbine's optimum tip speed ratio to enable the system to extract the maximum possible power. Figure 3.3 illustrates the block diagram of a WECS with TSR control.

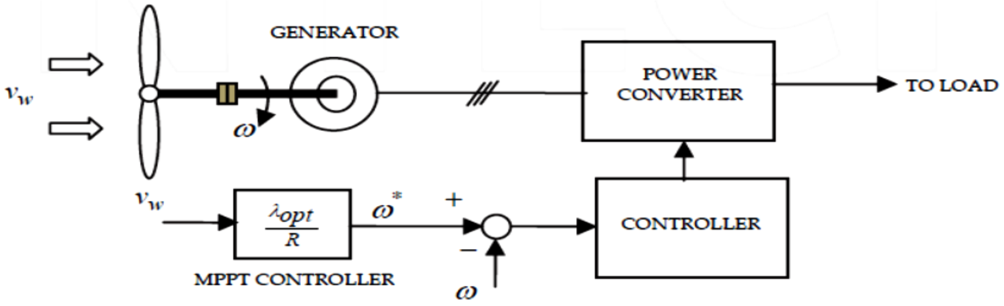

Fig 4 Tip speed ratio control of WECS

In PSF control, understanding the wind turbine's maximum power curve is essential, and the control mechanisms must track this curve. Obtaining the maximum power curves typically involves simulations or offline experiments conducted on individual wind turbines. In this technique, reference power is generated either using a recorded maximum power curve or by employing the mechanical power equation of the wind turbine, where wind speed or rotor speed serves as the input. Figure 3.4 illustrates the block diagram of a WECS with a Power Signal Feedback (PSF) controller for maximum power extraction.

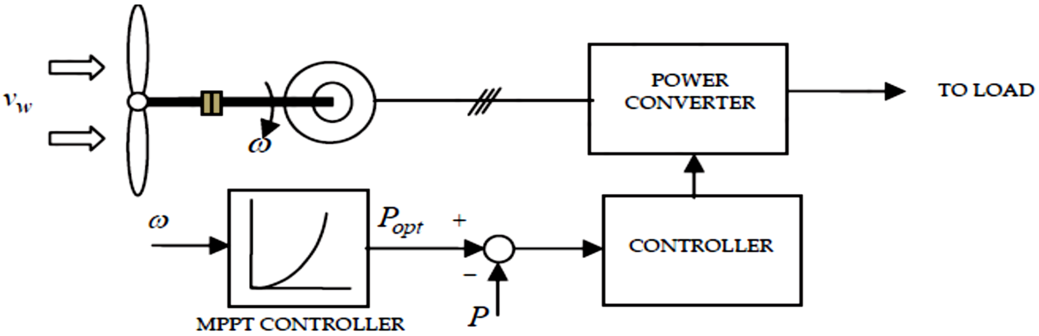

Fig 5 Power signal feedback control of WECS

SIMULATION MODELS AND RESULTS

The hybrid wind-battery system along with its control technique is developed in MATLAB/SIMULINK and is tested with various wind profiles. The result of the simulation experiments validates the improved performance of the system. The parameters that are used in MATLAB for design of model are shown in below tables.

PARAMETERS	VALUE(Units)
Rated power	4000W
Radius	2.3m
Cut-in speed	4m/s
Rated wind speed	10m/s
Inertia co-efficient	7kgm^2
Optimum tip speed ratio	7
Optimum power co-efficient	0.41

Table 4.1 Wind turbine system specifications

PARAMETERS	VALUE(Units)
rated power	5.4hp
Stator resistance	2.6ohm
Stator leakage inductance	4mH
Mutual inductance	240mH
Rotor resistance	2ohm
Excitation capacitance (at full load) connected in delta	15 micro farad

Table 4.2 Squirrel cage induction machine specifications

PARAMETERS	VALUE(Units)
Ampere hour rating	400Ah
Nominal voltage	48V
Fully charged voltage (no load)	55.2V
Charging rate	C/10

Table 4.3 Battery specifications

SIMULATION MODELS OF HYBRID WIND-BATTERY SYSTEM ALONG WITH CONTROL LOGIC:

Simulation models of the hybrid wind-battery system with control logic are conducted for three distinct wind profiles:

1. Gradual variation of wind speed
2. Step variation of wind speed
3. Arbitrary variation of wind speed

The simulation models of the hybrid wind system with various wind profiles are depicted in the figures below.

Simulation Model of Wind-Battery Hybrid System with Gradual Variation of Wind Speed:

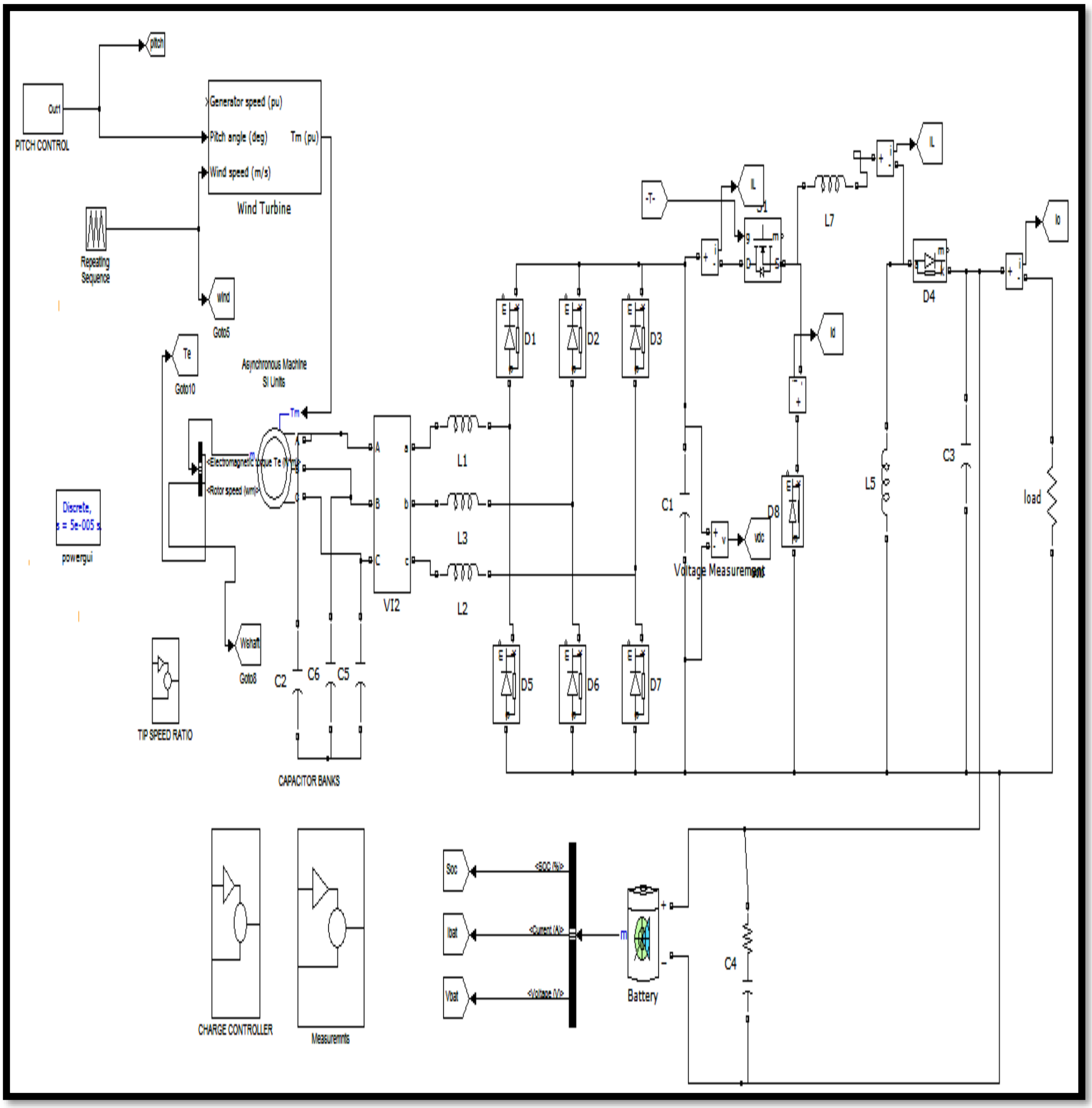

Fig 6 Simulation model of wind battery hybrid system with gradual variation of wind speed

SIMULATION RESULTS:

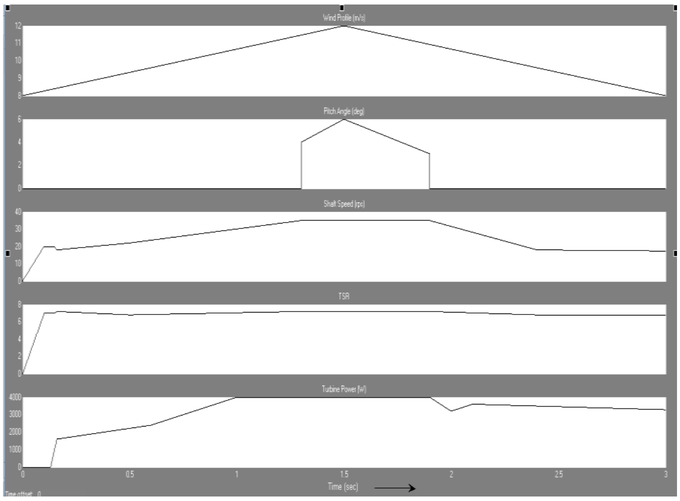

Fig. 4.4 (a) WT parameters under the influence of gradual variation of wind speed

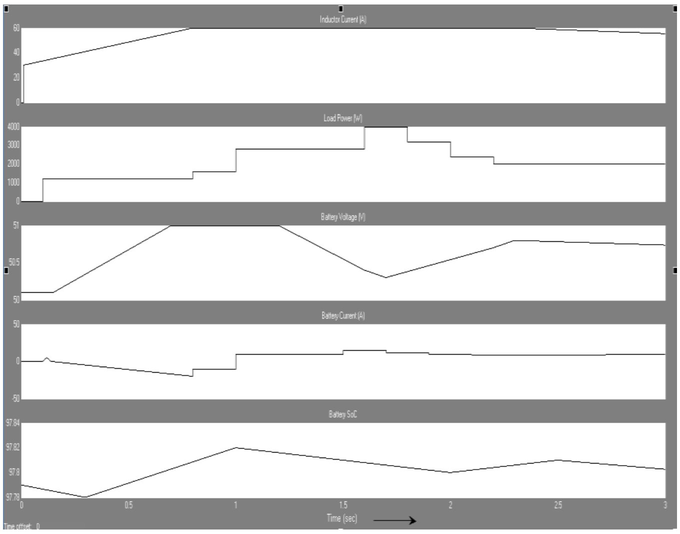

Fig.4.4 (b) Battery parameters under the influence of gradual variation of wind speed

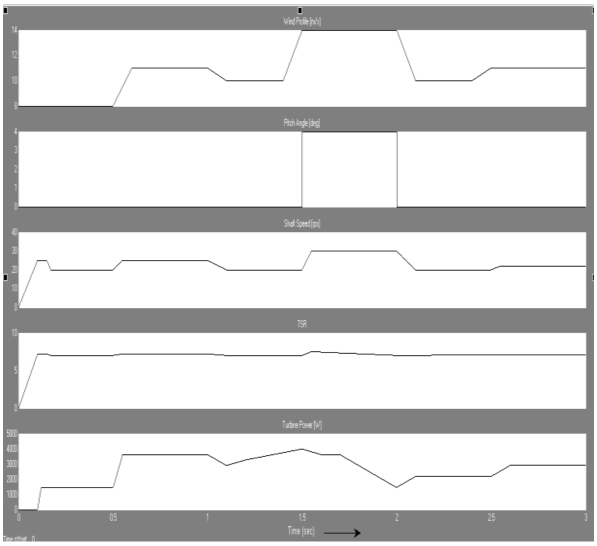

Fig. 4.5 (a) WT parameters under the influence of step variation of wind speed

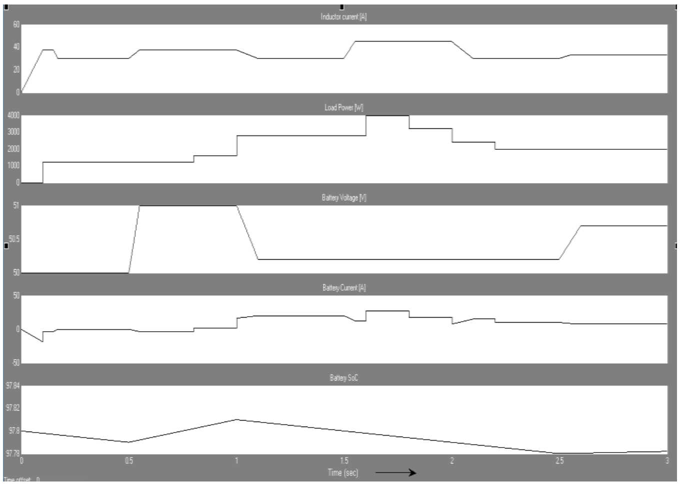

Fig. 4.5 (b) Battery parameters under the influence of step variation of wind speed

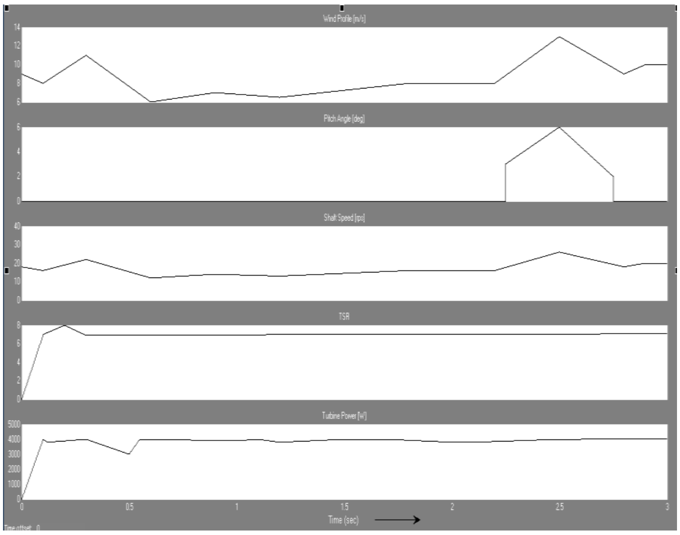

Fig. 4.6 (a) WT parameters under the influence of step variation of wind speed

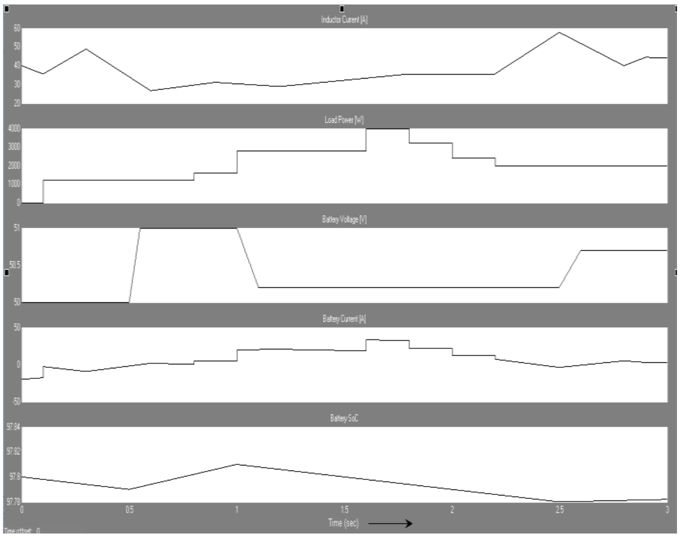

Fig. 4.6 (b) Battery parameters under the influence of arbitrary variation of wind speed

The hybrid system incorporates both the charge controller and pitch control strategy, which undergo simulation under various wind profiles to validate the system's efficiency. The system is connected to a load profile ranging from 0 to 4 kW in increments. Wind turbine parameters such as Tip Speed Ratio (TSR), shaft speed, output power, and blade pitch are scrutinized across different wind speed conditions, alongside the current profile of the converter, battery, and load. Priority is given to load demand over battery charging to ensure continuous power flow. The system's performance is assessed under wind profiles exhibiting gradual, step, and arbitrary variations. Observations encompass changes in pitch angle, shaft speed, TSR, turbine power, inductor current, load power, battery voltage, battery current, and battery State of Charge (SoC) across various wind profiles.

Based on the analysis presented in Figures 4.4 to 4.6:

- Pitch Angle: Elevates above rated wind speed and diminishes below rated wind speed.
- Shaft Speed: Corresponds to variations in wind speed.
- Tip Speed Ratio (TSR): Maintained at an optimal value using the MPPT technique, ensuring maximum power extraction.
- Turbine Power: Directly proportional to changes in wind speed.
- Inductor Current: Initially accumulates up to its rating and then gradually discharges.
- Load Power: Fluctuates between 0 to 4 kW.
- Battery Voltage and Current: Exhibit an inversely proportional relationship.
- Battery State of Charge: Declines during discharge and ascends during charging.

SUMMARY:

The hybrid system's capability to ensure uninterrupted power supply to the load is showcased through diverse control methodologies, encompassing charge control and pitch control. The effectiveness of these methodologies is verified through simulation using MATLAB/Simulink across varying load and wind scenarios.

CONCLUSION

This thesis effectively implements control strategies in a Wind Energy Conversion System (WECS) coupled with a battery bank to fulfill standalone load requirements. By conducting simulations and analyzing diverse wind profiles, it is affirmed that the integration of wind and battery energy storage systems, along with appropriate control strategies, guarantees efficient power distribution irrespective of wind conditions.

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