Control Scheme for a Stand-Alone Wind Energy Conversion System

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Abstract- Energy demand across the world is increasing and the resources are becoming scarce. The major source of power is from the conventional sources only. Some of the conventional sources of energies like thermal energy is produced from the fossil fuel coal which are depleting and is only limited to 2030. Renewable sources of energies are Solar, Wind, Biomass, etc hold bright prospect for the future. Wind industry has made rapid strides in the recent years. In order to ensure continuous supply of power suitable storage technology is used as backup. In this paper, the sustainability of a 4-kW hybrid of wind and battery system is investigated for meeting the requirements of a 3-kW stand-alone dc load representing a base telecom station. A charge controller for battery bank based on turbine maximum power point tracking and battery state of charge is developed to ensure controlled charging and discharging of battery. The mechanical safety of the WECS is assured by means of pitch control technique. Both the control schemes are integrated and the efficacy is validated by testing it with various load and wind profiles in MATLAB/SIMULNIK.

Keywords: Maximum power point tracking (MPPT), pitch control, state of charge (SoC), and wind energy conversion system (WECS) regulator.

I. INTRODUCTION

Energy is the considered to be the pivotal input for development. At present owing to the depletion of available conventional resources and concern regarding environmental degradation, the renewable sources are being utilized to meet the ever increasing energy demand. Due to a relatively low cost of electricity production wind energy is considered to be one of the potential sources of clean energy for the future. But the nature of wind flow is stochastic. So rigorous testing is to be carried out in laboratory to develop efficient control strategy for wind energy conversion system (WECS). The study of WECS and the associated controllers are, thus, becoming more and more significant with each passing day.

The discontinuous battery charging current causes harmonic heating of the battery. The terminal voltage instead of state of charge (SoC) is used for changeover from current mode to voltage mode. Also the MPPT implementation is highly parameter dependant and will be affected by variation of these parameters with operating conditions. Moreover, as the wind speed exceeds its rated value, the WT power and speed needs to be regulated for ensuring mechanical and electrical safety. This is achieved by changing the pitch angle to the required value. Several pitch control techniques are explained

Renewable energy sources including wind power offer a feasible solution to distributed power generation for isolated communities where utility grids are not available. In such cases, stand-alone wind energy systems can be considered as an effective way to provide continuous power to electrical loads. One of the most promising applications of renewable energy generation lies in the development of power supply systems for remote communities that lack an economically feasible means of connecting to the main electrical grid. For isolated settlements located far from a utility grid, one practical approach to self-sufficient power generation involves using a wind turbine with battery storage to create a stand-alone system. Stand-alone wind energy systems often include batteries, because the available wind does not always produce the required quantities of power. If wind power exceeds the load demand, the surplus can be stored in the batteries [1]. The function of an electrical generator is providing a means for energy conversion between the mechanical torque from the wind rotor turbine, as the prime mover, and the local load or the electric grid. For the installation of wind energy MNRE scheme (The Ministry of New & Renewable energy) has introduced to aware more and more people about this technology, government also gives incentives in order to promote wind energy.

Wind is air in motion; this is actually derived from solar energy. About 2% of total solar flux that reaches the earth’s surface is transformed into wind energy due to uneven heating of atmosphere. This kinetic energy of wind is used to gain the rotational motion of wind turbine which is coupled with an electrical generator to supply over a region acting as standalone or supplying power to a grid.

An actual WECS (Wind energy conversion system) be considered as follow [1] which can be used in two different ways: Isolated standalone systemd Grid connected system

Figure 1 shows Isolated Standalone system which is used to provide energy to small scale industries or towns located in remote areas.

![Fig. 1. Standalone wind energy system.](image-url)
II. LITERATURE SURVEY

Title: Wind turbine driven self excited induction generator.
Authors: S. C. Tripathy, M. Kalantar, and N. D. Rao,

Modeling as well as controlling of self Excited Induction Generator (SEIG) which is connected by Wind Turbine. The AC capacitors are used to build up the process of an isolated induction generator starts from charge in the capacitors or from a remnant magnetic field in the core. Same process is done at the time of isolated induction generator is excited by inverter/rectifier system. A closed loop voltage control scheme using a PWM Voltage Source Converter (VSC), dc link capacitor and a P-I voltage controller is proposed. This scheme generates constant voltage and variable frequency using the converter which also acts as a reactive power compensator. In the growing applications and environmental conditions, various types of technologies are introduced to delivering the power to the grid. The main objective of the project is to track and extract maximum power to the grid connected wind energy conversion system.

The voltage developed in the induction generator due to the residual magnetism. The terminal voltage will build up from small value to a rated value over a period of several seconds When the slip becomes negative, the output power and developed torque changes from positive to negative, which indicates the motor has become a generator.

Three phase diode bridge rectifier is used to convert variable magnitude, variable frequency voltage at the induction generator terminal into DC voltage The current ripples and voltage ripples are reduced Here the model is designed using the components like SEIG, PWM Inverter, Capacitors, Diodes, Rectifiers, and three phase load offered. In the literature survey the wind turbine is discussed based energy generation, active and reactive power generations as well as harmonics.

Title: “Advancements in power electronics and drives in interface with growing renewable energy resources,”

The whole world is now concentrating on advancing their pool of renewable energy resources. Immense growth has happened in the field of renewable energy and the energy harvesting methods in the past decade. It is estimated that there is still a huge potential of growth remaining in the field of renewable energy resources in the coming years. Generation of renewable energy at the source end to the transmission of the energy to the utility end is done at various interstates coupled with power electronic equipments and systems. Applications of power electronics are expanding at a high pace in industrial power generation, utility, grid integration, and transmission environments due to the advancements in technology and reduction in cost and size of the components and systems. There are numerous multistage converters and inverters topologies being developed for processing and delivering the gigawatt level of renewable power being produced. This paper highlights the growth of power electronics starting from semiconductor type switching devices to various multistage topologies which will extensively contribute to the development and growth of renewable energy resources around the globe.

Title: “Review of storage schemes for wind energy systems”

Wind Energy is a fast developing source of energy since 1996. Despite its advantages, this energy could never be a primary source of electric power to be integrated into the grid even in high wind areas, such as Great Plains, due to its intermittent behaviour. This intermittency will generate intermittent power to grid, which leads to instability, unreliability and power quality problem onto the grid system. One of the widely accepted methods to overcome this problem is by coupling the wind turbine with the energy storage system. This paper reviews the ability of four different types of the energy storage system to mitigate the power fluctuated into the grid, especially during low wind speed.

Energy shortage, global warming issues, emission of GHG demand development of renewable energies resources to play their role, from which wind energy is one of the auspicious renewable energy source due to its clean and environmental friendly features. Wind energy has some technical issues that affect the power quality of the systemwhile integrating it with power grid.

III. RELATED WORK

A detailed comparison between asynchronous and synchronous generators for wind farm application is made in [4]. The major advantage of asynchronous machine is that the variable speed operation allows extracting maximum power from WECS and reducing the torque fluctuations [5]. Induction generator with a lower unit cost, inherent robustness, and operational simplicity is considered as the most viable option as wind turbine generator (WTG) for off grid applications [6].

However, the induction generator requires capacitor banks for excitation at isolated locations. The excitation phenomenon of self-excited induction generator (SEIG) is explained in [5]–[7]. The power output of the SEIG depends on the wind flow which by nature is erratic. Both amplitude and frequency of the SEIG voltage vary with wind speed. Such arbitrarily varying voltage when interfaced directly with the load can give rise to flicker and instability at the load end. So, the WECS are integrated with the load by power electronic converters in order to ensure a regulated load voltage [8].

IV. PROPOSED WORK

A hybrid wind-battery system is considered to meet the load demand of a stand-alone base telecom station (BTS). The BTS load requirement is modeled as a dc load which requires a nominal regulated voltage of 50 V. The WECS is interfaced with the stand-alone dc load by means of ac–dc–
dc power converter to regulate the load voltage at the desired level, that MPPT schemes with and without battery charging mode control and pitch control technique have been implemented independently for stand-alone wind energy applications.

The proposed control scheme utilizes the turbine maximum power tracking technique with the battery SoC limit logic to charge the battery in a controlled manner. Unlike the MPPT logic used here actually forces the turbine to operate at optimum TSR and hence is parameter independent. The battery charging current is always continuous with very low ripple thus avoiding harmonic heating. The changeover between the modes for battery charging is affected based on the actual value of the SoC. Further it also provides protection against turbine over speed, over loading, and over voltage at the rectifier output by using pitch control.

Advantages Of Proposed Technique
- Efficient to ensure continuous power flow to the load
- Maximum power is extracted from WECS at all windspeeds to meet the load requirement
- He pitch control logic guarantees that the rectifier voltage does not lead to an overvoltage situation.
- Overall efficiency is improved.

IV METHODOLOGY
The wind flow is erratic in nature. Therefore, a WECS is integrated with the load by means of an ac-dc converter to avoid voltage flicker and harmonic generation. The control scheme for a stand-alone hybrid wind-battery system includes the charge controller circuit for battery banks and pitch control logic to ensure WT operation within the rated value. The control logic ensures effective control of the WECS against all possible disturbances. To implement the MPPT logic, the actual tip speed ratio (TSR) of turbine is compared with the optimum value.

The error is tuned by a PI controller to generate the battery current demand as long as the battery SoC is below the CC mode limit. Beyond this point, the SoC control logic tries to maintain constant battery charging voltage. This in turn reduces the battery current demand and thus prevents the battery bank from overcharging. The buck converter inductor current command is generated in the intermediate control loop.

Module Description
Wind energy conversion system (WECS).

The generators used for the wind energy conversion system mostly of either doubly fed induction generator (DFIG) or permanent magnet synchronous generator (PMSG) type. DFIG have windings on both stationary and rotating parts, where both windings transfer significant power between shaft and grid. In DFIG the converters have to process only about 25-30 percent of total generated power (rotor power connected to grid through converter) and the rest being fed to grid directly from stator. Whereas, converter used in PMSG has to process 100 percent power generated, where 100 percent refers to the standard WECS equipment with three stage gear box in DFIG. Majority of wind turbine manufacturers utilize DFIG for their WECS due to the advantage in terms of cost, weight and size. But the reliability associated with gearbox, the slip rings and brushes in DFIG is unsuitable for certain applications. PMSG does not need a gear box and hence, it has high efficiency with less maintenance. The PMSG drives achieve very high torque at low speeds with less noise and require no external excitation. In the present trend WECS with multibrid concept is interesting and offers the same advantage for large systems in future. Multibrid is a technology where generator, gearbox, main shaft and shaft bearing are all integrated within a common housing. This concept allows reduce in weight and size of generators combined with the gear box technology. The generators with multibrid concept become cheaper and more reliable than that of the standard one, but it loses its efficiency.

Wind Energy Conversion System (WECS): The equipment that converts and then stores or transfers energy from the wind into usable forms of energy and includes, but not limited to, base, blade, foundation, generator, nacelle, rotor, wind tower, transformer, turbine, vane, wind farm collection system, meteorological towers, communications facilities, electrical cabling or other components related to the system. self-excited induction generator (SEIG).

The energy demand around the world increases the great opposition facing the nuclear energy in some countries have spur researchers attentions for renewable energy. The self excited induction generator is a very popular machine used in isolated areas to generate electrical energy because of its low price, mechanical simplicity, robust structure. When capacitors are connected across the stator terminals of an induction machine, and driven at a given speed, the voltage will be induced from a remnant magnetic flux in the core. The induced emf and current in the stator windings will continue to rise until steady state is attained. This behavior is influenced by the Magnetic saturation of the machine. At this operating point the voltage and current will continue to oscillate at a given peak value and frequency. However, its major disadvantage is the inability to control the terminal voltage under variable load and speed conditions.

The objective of this work is divided into two parts: in the first part we present the experimental curve of variation speed and capacitance with the SIEG connected to load and no load in order to show the behavior of our machine, The relationship between magnetizing inductance (Lm) and phase voltage for induction machine was obtained experimentally, and in the second part we are more interested in the control of the DC bus voltage in order to provide an essentially constant terminal DC voltage in spite of the presence of disturbances such as step change in rotor speed and application of sudden AC load for supplied an isolated DC load.

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The output of a solar module is characterized by a performance curve of voltage versus current, called the I-V curve. See Figure 1. The maximum power point of a solar module is the point along the I-V curve that corresponds to the maximum output power possible for the module. This value can be determined by finding the maximum area under the current versus voltage curve.

There are commercially available MPPTs which are typically used for home solutions and buildings. These are not designed to withstand the harsh, fast-changing environmental conditions of solar car racing. Design of the customized MPPT will ensure that the system operates as closely to the Maximum Power Point (MPP) while being subjected to the varying lighting and temperature. The inputs of the MPPT consisted of the photovoltaic voltage and current outputs. The adjusted voltage and current output of the MPPT charges the power supply. See Figure 2.

A microcontroller was utilized to regulate the integrated circuits (ICs) and calculate the maximum power point, given the output from the solar array. Hardware and software integration was necessary for the completion of this component.

Many factors influenced the component selection and the design of the MPPT.

• In terms of optimal functionality, the theory of power conservation needed to be applied. The input and output voltage and current were calculated such that the power into and out of the MPPT was equal.
• To protect the photovoltaic array from damage, protection diodes were employed.
• Two 48V lead acid battery banks were utilized. Only one battery bank will be charged at a time. (The other will be employed to run other components of the car).
• In order to trickle charge the batteries, a voltage exceeding 48V must be fed to the bank. In this design, 50V was chosen to charge the power supply.

• To prevent damage and overcharging of the power supply, a FET was employed.

IV. RESULTS

AC to DC Conversion (Rectifier)

A rectifier is an electrical device composed of one or more diodes that converts alternating current (AC) to direct current (DC). A diode is like a one-way valve that allows an electrical current to flow in one direction. This process is called rectification. A rectifier can take the shape of several different physical forms such as solid-state diodes, vacuum tube diodes, mercury arc valves, silicon-controlled rectifiers and various other silicon-based semiconductor switches.

DC to DC Conversion (chopper)

A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc. In this circuit the transistor turning ON will put voltage Vin on one end of the inductor. This voltage will tend to cause the inductor current to rise. When the transistor is OFF, the current will continue flowing through the inductor but now flowing through the diode. We initially assume that the current through the inductor does not reach zero, thus the voltage at Vx will now be only the voltage across the conducting diode during the full OFF time. The average voltage at Vx will depend on the average ON time of the transistor providing the inductor current is continuous.
IV. CONCLUSION

In this paper, a hybrid wind-battery system is chosen to supply the desired load power. To mitigate the random characteristics of wind flow the WECS is interfaced with the load by suitable controllers. The control logic implemented in the hybrid set up includes the charge control of battery bank using MPPT and pitch control of the WT for assuring electrical and mechanical safety. The charge controller tracks the maximum power available to charge the battery bank in a controlled manner. The hybrid wind-battery system along with its control logic is developed in MATLAB/SIMULINK and is tested with various wind profiles. The outcome of the simulation experiments validates the improved performance of the system.

REFERENCE


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