Voltage and Frequency Controller for Isolated Wind Energy Conversion System

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Abstract— This paper deals with voltage and frequency controller for wind generating system with linear, nonlinear, dynamic load and we will see the result for varying wind speed also. The proposed system is modelled and simulated in MATLAB R2009 using Simulink. The controller that controls both voltage and frequency of an asynchronous generator along with its improvement of power quality. The proposed controller has bidirectional active and reactive power flow capability along with battery energy storage system by which it controls the system voltage and frequency with variation of consumer load. Given system is also beneficial for harmonic elimination as well as load balancing also. By using the simulation techniques as well as some mathematical modelling we have some results of different loads at different condition in tabular form.

Key words: Battery Energy Storage System, Excitation Capacitor, Isolated Asynchronous Generator, Linear, on Linear Dynamic Load, Active and Reactive Power Controller, Wind Energy Conversion System

I. INTRODUCTION

Energy is available in two different alternatives, non-renewable (coal, fuel, natural gas) and renewable energy (RE) (solar, wind, hydro, wave) sources. Especially, after the industrial revolution, in the 19th century, first coal and then fuel oil are used as primary energy sources for the needs of modern communities. Towards the end of 20th and beginning of the 21st centuries, interest has risen in new and renewable energy sources especially wind energy for the electricity generation. Wind energy is welcomed by the society, practical, economical and environmentally friendly alternative. After the 1973 oil crisis, the RE sources started to appear in the agenda and hence the wind energy gained significant interest. Faced with energy crises in 1973, western countries began to search for their own clean and (RE) sources (wind, solar, biomass, etc.) which are effective but they must inevitably compete against the conventional energy sources. In this competition, energy sources with huge and renewable raw materials have the advantage in the long run. Atmospheric environment is polluted due to thermoelectric power plants, and petroleum materials since the industrial revolution. The pollution crises are the catalysts for the search and development of RE sources.

Continuing to use fossil fuels is bound to pollute the atmosphere, and consequently, unwanted greenhouse emissions and climate change effects will come to dominate every part of the earth. Currently the fastest developing energy source technology is the wind energy. Because wind energy is renewable and environment friendly, systems that convert wind energy to the electricity have developed rapidly. Wind energy is an alternative clear energy source compared to the fossil fuels that pollute the lower layer of atmosphere. It is, therefore, advisable to exploit clean energy resources for many nations in the world to try to keep their environment friendly. Wind energy is widely used in many countries such as the USA, Germany, Spain, Denmark and India. It seems that the wind power is esteemed in these countries as the most perspective branch of the electric power industry.

II. CONFIGURATION OF ISOLATED WIND ENERGY SYSTEM

A. System Configuration

The complete off grid stand alone system with asynchronous generator, wind turbine, excitation capacitor, balanced/ unbalanced, linear/non-linear/dynamic consumer loads and proposed controller. The proposed controller includes three-phase insulated gate bipolar junction transistor (IGBT) based voltage source converter (VSC) along with a battery at its dc link. The controller is connected at the point of common coupling (PCC) through the inter-facing inductor. The excitation capacitor is selected to generate the rated voltage at no-load while additional demand of reactive power is met by the controller.

1) Excitation Capacitor Bank:

Autonomous induction generators are cheap, simple and robust. However, while they are capable to generate active power, they are unable to produce the reactive power needed for their own excitation. The classical solution to this problem is to connect capacitors across its stator terminals of the externally driven three-phase squirrel cage induction machine Due to the three-phase capacitor bank connected to the induction generator an emf is induced in the machine windings due to the self-excitation provided by the capacitors. The magnetizing requirement of the machine is supplied by these capacitors. For self-excitation to occur, the following two conditions must be satisfied

1) The rotor of the machine should have sufficient residual magnetism.
2) The three-phase capacitor bank should be of sufficient value.

2) Battery Energy Storage System:

The proposed voltage and frequency controller is realized using IGBT (Insulated Gate Bipolar Junction Transistor) based voltage source converter (VSC) along with battery energy storage system (BESS) at its DC link. The proposed controller is having bidirectional flow capability of reactive and active powers because of which it can control the magnitude and frequency of the generated voltage under different electrical and mechanical dynamic conditions. Accordingly the principle of frequency regulation for generating constant frequency at fixed speed, the total generated power should be consumed by the applied load (consumer load battery) otherwise additional generated power might be stored in the revolving component of the machine and it increases the machine speed which in turns increases the system frequency. On the other hand when there is variation in wind speeds and corresponding variation in the machine speed, the battery and consumer loads absorb such amount of power by which desired frequency of the generated voltage can be achieved. In proposed control scheme, the frequency controller is used for extracting active component of the source current. When there is deficiency in the generated power, the battery supplies the additional required load demand through process of discharging and maintains the constant frequency along with providing the functions of load leveling. While there is an excess generated power it starts charging and consumes additional generated power which is not consumed by the consumer loads.

3) Capacitor Bank:

The main drawback of the autonomous squirrel cage induction generator having a three-phase capacitor bank is the lack of ability to control the terminal voltage and frequency under non-constant load and speed conditions. Therefore, capacitor excited induction generators have poor voltage and frequency stability. To regulate the voltage of an autonomous induction generator with changing load and speed, the capacitors may be replaced or supplemented with an active external source of reactive power. Such a so-called solid-state synchronous voltage source is based on a dc-ac converter (or inverter), which is able to generate leading or lagging reactive power. Thus, inverters can be used as reactive power compensators for squirrel cage induction generatorThe amplitude of active power component of the source current is estimated by dividing the difference of filtered load power and output of PI frequency controller to the amplitude of the terminal voltage. Multiplication of with in-phase unit templates yields the in-phase component of reference source currents

B. Control Scheme

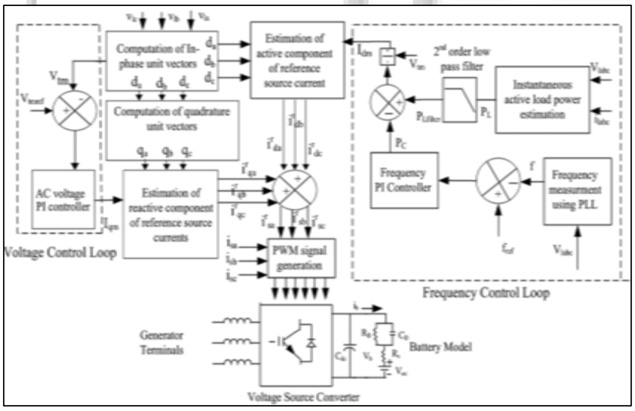

Fig. 1: Control Scheme

Fig. 4.1 demonstrates the control strategy of the proposed controller which is based on the generation of reference source currents. Reference source currents are having two components one is reactive component for controlling the magnitude of the generated voltage and other one is the active component for regulating the frequency of the generated voltage. The amplitude of active power component of the source current is estimated by dividing the difference of filtered load power and output of PI frequency controller to the amplitude of the terminal voltage. Multiplication of with in-phase unit templates yields the in-phase component of reference source currents. These templates are, three phase sinusoidal functions which are derived by dividing the ac voltages by their amplitude. To generate the reactive component of reference source currents another set of unit templates is derived from in-phase unit template and which are 90 leading from the corresponding voltages. The multiplication of these templates and output of PI (Proportional–Integral) terminal voltage controller gives the reactive component of reference source currents .The sum of instantaneous reactive and active Components of currents gives the total reference source currents and these are compared with the sensed source currents. The amplified current error signals are compared with fixed frequency (10 kHz) triangular carrier wave to generate the PWM switching signals for the devices of VSC

III. SIMULINK MODEL

From now on, the simulation can be done with power system block set. The available blocks set are modeled by professionals. There are an asynchronous machine, 3-pahse V-I measurement blocks, main load (which have two type we use 3-phase series RL load, and second is asynchronous machine as dynamic load), Wind turbine and our voltage and frequency controller.

The voltage and frequency controller of a wind turbine driven isolated asynchronous generator. The proposed voltage and frequency controller consists of an insulated gate bipolar junction transistor based voltage source converter along-with battery energy storage system at its dc link. The proposed controller is having bidirectional active and reactive powers flow capability by which it controls the system voltage and frequency with variation of consumer loads and the speed of the wind turbine. The proposed electro-mechanical system along with its controller is modeled and simulated in MATLAB using Simulink and power system block-set toolboxes. Performance of the proposed controller is presented to demonstrate voltage and frequency control of a wind turbine driven isolated asynchronous generator.

There are two models usung RL load and dynamic load. Models give different performances under different types of loads. Results are also classified according to load nature

IV. SIMULINK MODEL OF RL LOAD

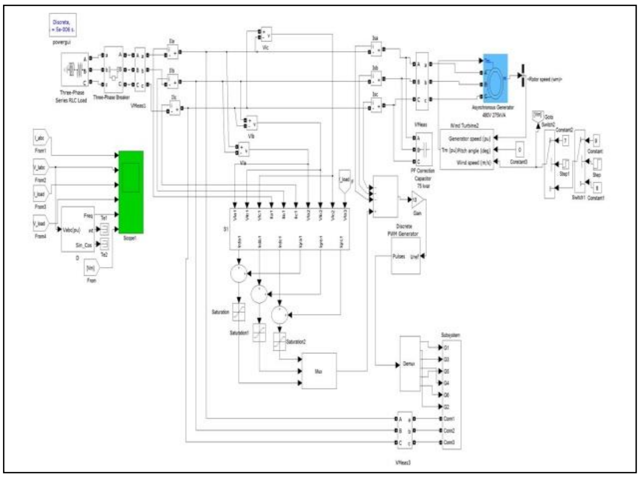

Fig. 2: Simulation model of the system using series RL load

V. SIMULINK MODEL OF DYNAMIC LOAD

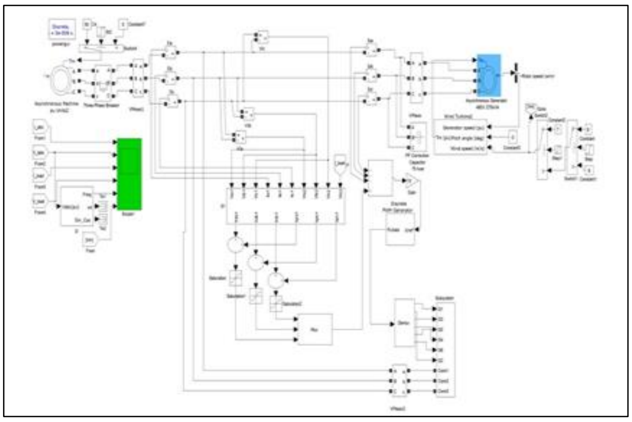

Fig. 4: Simulation Model using Dynamic Load

VI. RESULTS

A. Using Series RL Load

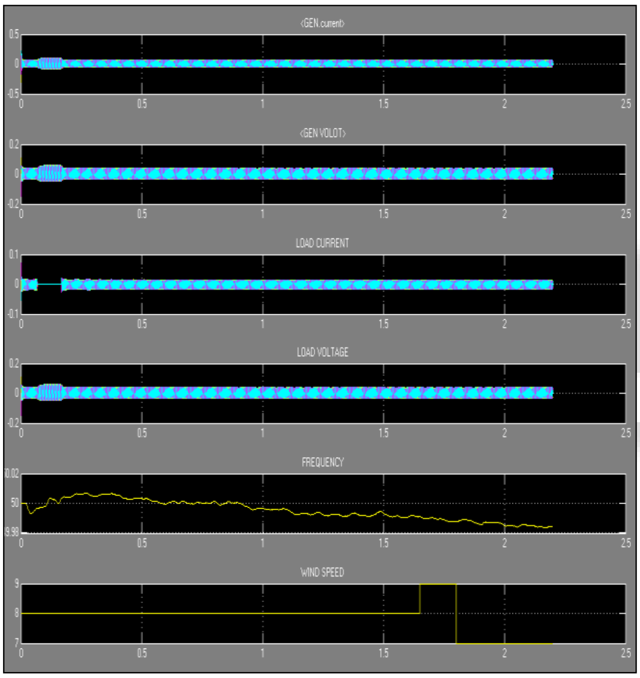

Fig. 3: Simulation Result for RL load

It has been observed that the proposed controller has been found to regulate the magnitude and frequency of the generated voltage constant in isolated wind power application. In the present model by comparing the system voltage with our reference voltage we compute the reactive component of reference current and compare the system frequency with reference frequency to generate active component of reference current then combining both reference current and compare with system current we generate pulse for working of our controller. If the system generate extra power battery store extra power and give it back to load when system generate less power than load requirement

B. Using Asynchronous Motor as Load

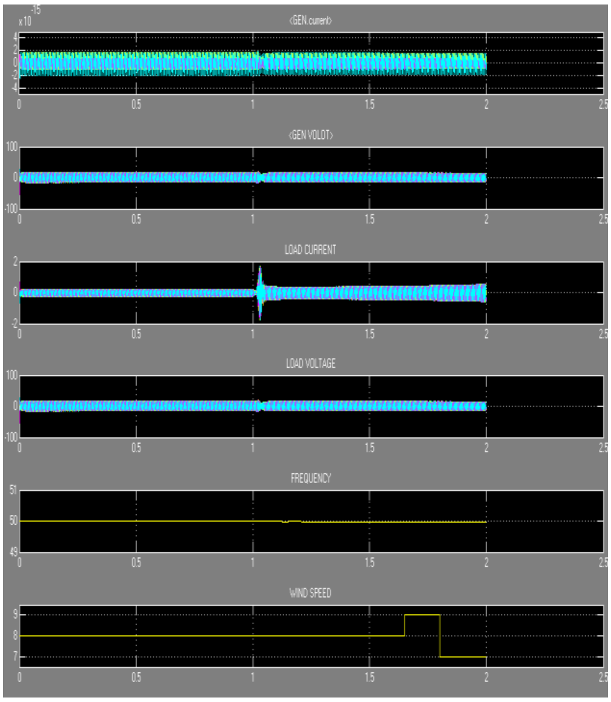

Fig. 5: Simulation Result for Asynchronous motor load

VII. CONCLUSION

This paper present the voltage and frequency control of self excited isolated asynchronous generator. For this we construct a bidirectional current controlled voltage source converter using a battery bank. The performance of the proposed controller has been demonstrated for an isolated wind energy conversion system. Simulation results have verified the performance of the controller under different electrical (varying consumer loads) and mechanical dynamic conditions (varying wind speed). It has been observed that the proposed controller has been found to regulate the magnitude and frequency of the generated voltage constant in isolated wind power application. In the present model by comparing the system voltage with our reference voltage we compute the reactive component of reference current and compare the system frequency with reference frequency to generate active component of reference current then combining both reference current and compare with system current we generate pulse for working of our controller. If the system generate extra power battery store extra power and give it back to load when system generate less power than load requirement

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