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Grid connected dependent voltage and frequency controller for WECS with battery energy storage

[1]Kabita Manjari Samal
Gandhi Institute of Excellent Technocrats, Bhubaneswar, India
[2]Sanghamitra Behera
Sanjay Memorial Institute of Technology, Berhampur, Odisha, India

Abstract
Global environmental problems and climate change due to greenhouse gas emissions from fossil fuels showed the importance of renewable energy resources like hydro energy, geo thermal, ocean, hydrogen energy, bio energy & the most importantly Wind energy. Wind energy is gaining the most interest among a variety of renewable energy resources, but the disadvantage is that the wind generated power is always fluctuating due to its time varying nature and causing stability problem. This weak interconnection of wind generating source in the electrical network affects the power quality and reliability. The localized energy storages shall compensate the fluctuating power and support to strengthen the wind generator in the power system. The model contains an isolated asynchronous generator, wind turbine, PWM power converters and associated controllers, a DC-link capacitor and a battery storage system. SPWM signals have been generated by switching pulse generator for the three phase inverter which provides the function of a harmonic eliminator and load balancer. The complete system is modeled and simulated in MATLAB using the SIMULINK AND PSB (Power System Block set) Toolboxes. The simulated results are presented to demonstrate the capability of an isolated generating system driven by a wind turbine.

Keywords: *Isolated asynchronous generator, uncontrolled bridge rectifier, VSI, voltage and frequency controller (VFC), SPWM switching pulse generator, Grid and battery energy storage system..*

I. INTRODUCTION

The concern for environment due to the increasing use of fossil fuel and rapid depletion of these resources have led to the development of alternative sources of energy which are renewable and environment friendly. As a renewable source of energy wind power is one of the prominent source of energy. Wind power offers a feasible solution to distributed power generation for isolated communities where utility grids are not available. In such cases, stand-alone wind energy systems (i.e., systems not connected to the utility grid) can be considered as an effective way to provide continuous power to electrical loads [1]. 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 in order to store surplus power if wind power generated exceeds load demand.Wind electric generator converts kinetic energy available in wind to electrical energy by using rotor, gearbox and generator. The wind turbines installed so far in the country are predominantly of the fixed pitch 'stall' regulated design. However, the trend of recent installations is moving towards better aerodynamic design; use of lighter and larger blades; higher towers; direct drive; and variable speed gearless operation using advanced power electronics. Electronically operated wind turbines do not consume reactive power, which is a favorable factor towards maintaining a good power factor in the typically weak local grid networks. Different types of generators are being used with wind turbines. Small wind turbines are equipped with DC generators of up to a few kilowatts in capacity [2]. Modern wind turbine systems use three phase AC generators.

The common types of AC generator that are possible candidates in modern wind turbine systems are as follows:

- Squirrel-Cage rotor Induction Generator (SCIG),
- Wound-Rotor Induction Generator (WRIG),

- Doubly-Fed Induction Generator (DFIG),
- Synchronous Generator (With external field excitation),
- Permanent Magnet Synchronous Generator (PMSG).
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II. SYSTEM CONFIGURATIONS AND OPERATING PRINCIPLE

The controller consists of a three phase diode bridge rectifier connected to an inverter via a filter capacitor of 1mF & also to battery storage system. The inverter consists of three legs each containing one pair of IGBTs. With the use of diode rectifier to generate DC voltage we can aim to cut down its cost. However the pulse width modulated switch of the inverter gives a precise switching [3]. The schematic diagram of the proposed system with the imaginary wind turbine, the asynchronous machine, the excitation capacitor, the proposed power electronic controller with battery energy storage and the grid is as shown in fig.1. With this configuration an attempt has been made to simulate the control algorithm of the wind power generator scheme. The proposed controller has bi-directional power flow capability of reactive and active powers. So it controls the magnitude of the voltage under various wind speed condition

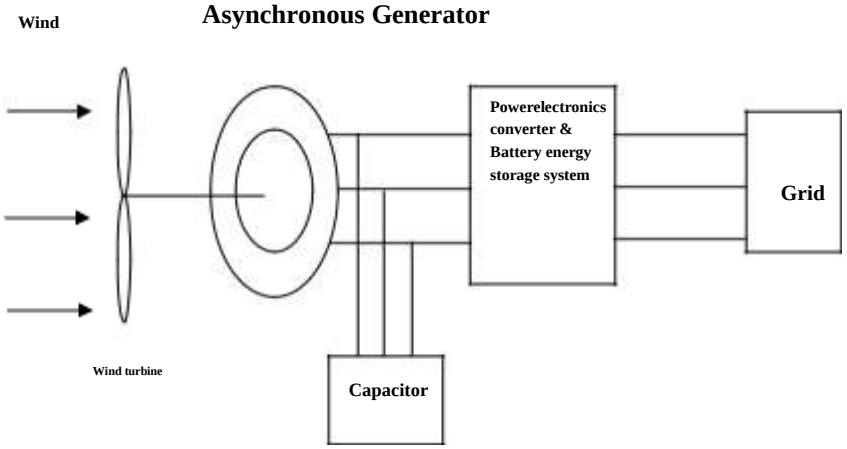

Figure 1. Block diagram of the complete system.

III. WIND ENERGY CONVERSION SYSTEM

Wind energy conversion system is summarized in three aspects

Wind turbine generator.

Power electronics converters & Battery storage system. Grid connectivity.

Wind turbine generators: Main features of various types of generators and their suitability in wind power generation are discussed below: [4]

Dc generator: Conventional dc generators are not favored due to their high cost, weight and maintenance problem due to commutator. However, permanent magnet (brushless and commutator less). DC machines are considered in small ratings (below 100kW) isolated systems.

Synchronous generator: They produce high quality output and are universally used for power generation in conventional plant. However they have very rigid requirement of maintaining constant shaft speed and any deviation from synchronous value immediately reflects in the generator frequency. Also precise rotor

speed control is required for synchronization. Requirement of DC current to excite rotor field which needs sliding carbon brush on the slip rings also posses limitation on its use. Machine ratings are limited to tens of kilowatts. Main advantage is that it generates active as well as reactive power.

Induction generator: Primary advantage of induction machine is the rugged, brushless construction, no need of separate DC field power. Compared to DC & synchronous machine they have low capital cost, low maintenance and better transient performance. Machine is available from very low to several megawatt ratings. Induction machine require AC excitation which is mainly reactive. The induction generators are self excited by shunt capacitors

Based on the generator drive two systems have been developed for WECS [4]

Fixed speed drive system: In this scheme constant speed is maintained at the shaft of generator by pitch control. A synchronous or induction generator is used to generate electrical energy. Induction generator is gaining more acceptability due to its ability to absorb small variations in shaft speed.

Variable speed drive system: In this scheme rotor speed is allowed to vary optimally with the wind speed to capture maximum power. As a result it can capture about one third more power per year as compared to fixed speed drive system. Modern variable speed drive scheme make use of power electronics converter for voltage and frequency control. The variable voltage and frequency output available from a generator (synchronous or induction) is first rectified to DC and then converted to fixed frequency & AC voltage using inverter. The harmonics are filtered out to get grid quality output before connecting to the grid. Apart from higher energy yield, use of power electronics offers remotely adjustable & controllable quality of power.

IV. CONCLUSION

In this paper we have developed constant power supply from a wind power plant (using squirrel-cage induction generator) to the grid using power electronics converter. We have also developed a battery energy storage system to store the extra power. This system is suitable for storing the energy using the Battery Energy Storage system (BES) for which we have used a thevenin equivalent of the battery model. The system is also suitably connected to the grid for feeding the generated power from the wind turbine/wind power generating system.

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