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CONTROL STRATEGY OF ENERGY STORAGE SYSTEM FOR THE GRID INTEGRATION OF WIND POWER GENERATION

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Abstract

Energy storage system is becoming more important now a days. This study proposes a battery storage for the grid integrated wind power generation system. Energy storage and variable Renewable Energy (RE) generation have an important role, making them complementary. Storage system can store RE generation output during off-peak hours and supply power to the grid during peak hours. This reduced the pressure on the Conventional Energy sources. The advanced control strategy for the overall system is designed. In this paper a simultaneous power management between wind and grid by using a battery is proposed. Simulations are done in MATLAB to demonstrate the effectiveness of the system.

Keywords: *MATLAB, HESS, WPG, Buck Boost*

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1. INTRODUCTION

The present days energy crisis and environmental pollution put pressure on us to rely on alternative energy sources namely non-conventional energy sources such as photovoltaic and wind power generation. For sustainable future these energy source are important. Storage feature plays a significant role in successful integration of RE electricity generation into the electric grid. It enables reliable integration of Renewable Energy system whose output is fluctuating. The integration of energy storage with renewable energy sources helps us to solve the fluctuations in the power output. This helps in minimizing the power fluctuations. For practical application, we must consider both economical and technical performance characteristics.

Besides the use of renewable energy sources, innovative concepts should be used such that it helps in the simple, quick, reliable and inexpensive representation of the system. Due to continuous variation of generation and loads all over the power system more flexible concept of decentralization of power conversion is essential. We need to design a system that are adaptable to the existing system’s nature. And their power output can be adjusted freely for the smooth operation of the system by using suitable power conditioning system. Recent developments in power electronics and energy storage techniques make it a better solution for many power applications.

In AC system storage of electrical energy cannot be done in electrical form, whereas it has to be converted and stored kinetically, electromagnetically, electrochemically or in the form of potential energy. Here battery is controlled via DC/AC converter . The battery can handle long-term variations in the system. Power transferred between energy storage devices require appropriate current and voltage conversion for better efficiency and safety operation of the system, thus power electronic converters are adopted to properly control the power flow. This reduces the use of conventional energy sources where the cost of installation is high and requires large area. By using this scheme we can satisfy load demands by controlling charging and discharging of storage device. There are several energy storage options, such as Battery, SMES, Fuel-cells etc. Most common type batteries for storages are Lithium-ion type, Lead acid type etc.

The strategy used for the operation of energy storage systems are designed for different applications. The main aim of recent researches is to control wind farms and online Energy Storage Systems. But Grid integration is possible only when certains rules prescribed by the electricity authorities are followed. Else power quality of the system will get affected. However in present days the use of non-linear loads connected to power systems are increasing, which results in degradation of power quality of the system mainly due to the harmonics and power factor problems. Now a days variable speed wind power generation systems are increasing. As a result the penetration of wind generated into the grid will be increased.

The paper is formulated in the following manner. Section 2 introduce about the topology and model of the Energy Storage System (ESS). Section 3 describes the design of wind generating System. Section 4 explains the device level and system level control scheme. Section 5 mention about simulation results. Conclusion about the following system is derived in section

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2. TOPOLOGY AND MODEL OF THE PROPOSED ESS

In this model a wind power generating system is the renewable energy source. The battery can handle long-term variations of power. To transfer power between energy storage devices, they require appropriate current and voltage conversion devices for safety of the system and better efficiency. This is achieved by using suitable power electronic converters. The converter has two parts -The DC/AC converter can control the grid side and a DC/DC converter controls the power flow between energy storage devices. These converters are operated together for transferring better quality of power to the grid. Wind power generating system is directly connected to grid. By using suitable power conditioning device power is transferred between battery and grid. The basic block diagram for the system is shown in Fig 1. The defined direction of power flow of wind generation, grid and battery is shown in the

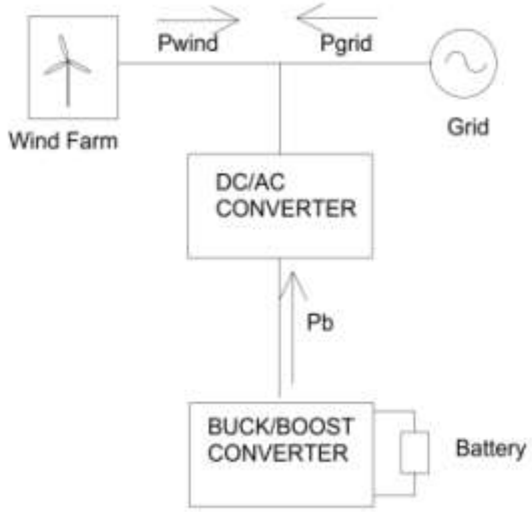

Fig 1: Basic Block diagram

The power balance equation is represented as:

$$P_{wind} + P_b + P_{grid} = 0 \qquad \ldots\ldots \ (1)$$

The equations of the system for discharging state is given as:

$$L_1 \cdot \frac{di_{L1}}{dt} = u_b - (1-d_1)u_0 \qquad \ldots\ldots \ (2)$$

$$C_2 \cdot \frac{du_o}{dt} = i_o - (1-d_1)i_{L1} \qquad \ldots\ldots \ (3)$$

The equations of the system for charging state is given as:

$$L_1 \cdot \frac{di_{L1}}{dt} = u_b - d_1 u_0 \qquad \ldots\ldots \ (4)$$

$$C_2 \cdot \frac{du_o}{dt} = i_o - d_1 i_{L1} \qquad \ldots\ldots \ (5)$$

where P_{wind} is the power generated by the wind power generating system, P_b is the power transferred by the battery to the DC bus via DC/AC converter, respectively, P_{grid} is the power from the grid to DC bus, u_o is the DC link voltage and d_1 is the duty ratio of the battery buck- boost converter circuit. The detailed topology is shown in Fig.2. VSC (Voltage Source Converter) provides the continuous control of voltage, it has wide application in not only keeping energy balance but also maintaining frequency or voltage stability.

Here a battery buck boost converter controls the power transferred by battery. During off-peak hours battery is charged through the converter through DC link. This state is called charging mode of battery buck-boost converter. In this state switch S_1 of battery buck boost converter is kept turned OFF. There is charging state and a standby state in this mode of operation. During charging state S_4 is turned ON. Then battery charges through C_2-S_2-L_1. In stand-by state S_2 is OFF and inductor current forms a closed loop through L_1-C_1-D_1. During Peak hours battery supplement the excess demand by supplying those power from battery. This state is called discharging mode of battery buck-boost converter. In this mode there are two states, discharging and stand-by state. In this mode S_2 is OFF all times. During discharging state switch S_3 is switched off and battery discharge through L_1-D_2. During stand-by state S_3 is turned ON and inductor current forms a closed loop through L_1-S_1-$C_{1.}$

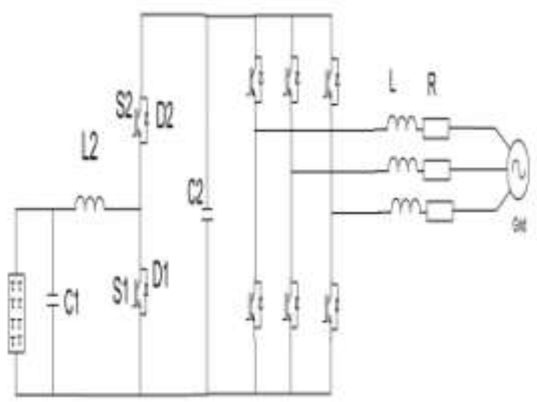

Fig 2: Detailed Configuration

Assume all switching devices have ideal characteristics and line resistance R has a very small, power loss can be neglected.

3. WIND MODELLING

Wind power is an eco-friendly source of energy and a renewable energy source. For modeling wind power generating system we need to know certain parameters and

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criteria. Firstly, the Wind power is proportional to the cube of wind speed. The mechanical power output of turbine is

$$P_m = c_p(\lambda, \beta)\frac{\rho A}{2}v_{wind}^3 \quad \ldots\ldots\ldots. (6)$$

P_m = Mechanical output of turbine
c_p = Performance coefficient of turbine
ρ = Air Density (kg/m^3)
V_{wind} = wind speed (m/s)
A = Turbine swept area (m^2)
β = Blade pitch angle (deg)
λ= Tip speed ratio of the rotor blade tip speed to wind speed

$$c_p(\lambda, \beta) = c_1\left(\frac{c_2}{\lambda_i} - c_3\beta - c_4\right)e^{-c_5/\lambda_i} + c_6\lambda \quad \ldots.. (7)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3} \quad \ldots\ldots\ldots (8)$$

Here the rotor used is of Squirrel –Cage type.

Table 1: Wind model parameters

PARAMETERS	VALUE
Power	10kW
Wind Speed	12m/s
Inertia Constant, H_s	0.91kg-m^2
Friction Factor, F	0.18
Pole Pair, p	2
Switching Frequency	10kHz
Pitch Angle, β	0^0
Air density, ρ	1.225 kg/m^3
Tip Speed ratio, λ	6.16
Radius of Rotor, r	3.5m

4. CONTROL STRATEGY

System level Control Strategy: The control strategies consist of two levels. Firstly, by monitoring the operation state of the wind farm, grid and ES elements, the respective power demand from battery can be calculated. The device level responds to the power demand of the system level and regulates the power flow between the system and devices. The device control diagram is as shown below:

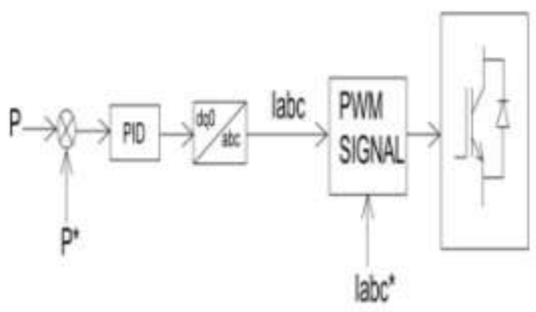

Fig 3: Control strategy

Device level Control strategy: Device level control strategy is used to control the power output from battery by controlling switches S_1 and S_2 of Fig 2

Table 2: PID controller values for Device Level Controller

Proportional gain for VSI Converter control , K_{pc}	10
Integral gain for VSI Converter control , K_{ic}	100
Proportional gain for Battery Converter control , K_{pb}	0.01
Integral gain for Battery Converter control , K_{ib}	0.05

For controlling switch S_1 and S_2 we first compare battery voltage with our reference voltage 217.5V. If this error value (say 'k') is positive this is used for control switch S_2 else it is used for S_1. Next condition we need to check is whether the DC link voltage is greater than or less than 800V. So we need to compare DC link voltage to the reference voltage. If this error value (say 'l') is negative it is used for controlling switch S_2 else it is used for controlling switch S_1

5. RESULT

A simulation model of single wind power generation system incorporated with a single battery storage unit is done in the paper. A variable load is applied. The power waveforms of wind power generating system is shown in Fig 5. Fig 6 shows the grid power and battery power output is shown in Fig 7 respectively. The DC link voltage is maintained at 800V as shown in Fig 8. The Voltage output of battery is maintained at 217.5V is given in Fig 9.

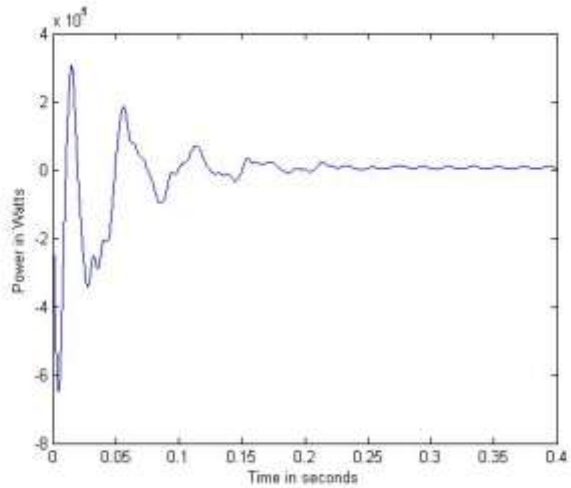

Fig 4: Wind power output

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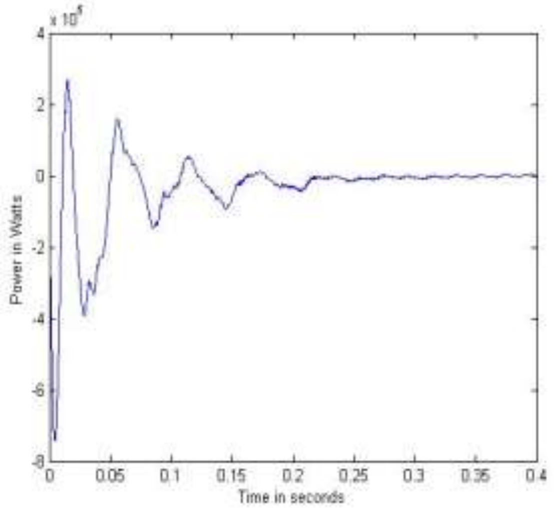

Fig 6: Grid power

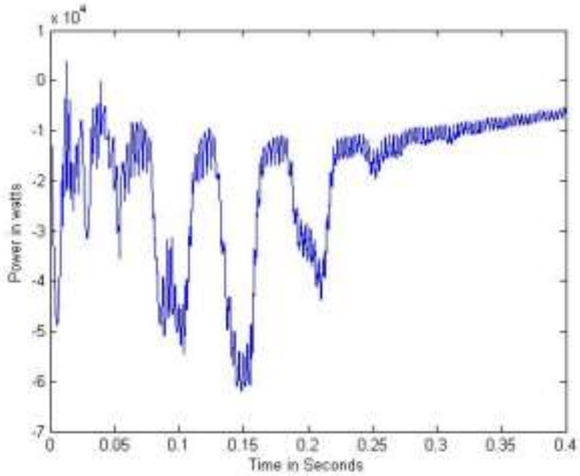

Fig 7: Battery power

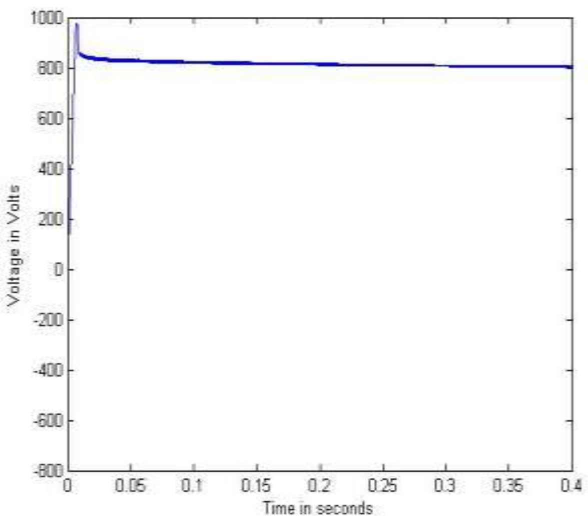

Fig 8: DC link voltage

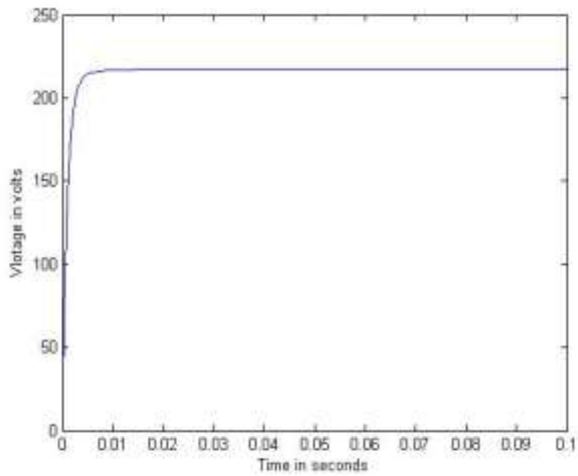

Fig 9: Battery output voltage

6. CONCLUSION

In this paper a battery storage system supporting the grid integrated wind power generating system is proposed. The power output of photovoltaic and wind power generating system are fluctuating in nature, because of the randomness and intermittence of wind energy. These fluctuations adversely affect the grid when they are working in on-grid mode. Recently, the incorporation of energy storage with wind power generating system has become one of best solutions to solve the power fluctuation problems. So here we are able to balance the power.

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