Battery Energy Storage System Addressing the Power Quality Issue in Grid Connected Wind Energy Conversion System

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Abstract— Renewable Energy Sources (RES) are readily available for replacement of conventional energy around the world in the form of Solar Energy, Wind Energy, Bio energy, etc. However, due to the fluctuating and intermittent characteristics of wind energy, it is difficult to predict the output power from wind and it requiring additional fast grid balancing services as fast up and down power ramps. Unbalance between power generation and power demand leading to variation in voltage & frequency. Utilization of Energy Storage (ES) systems as Battery Energy Storage System (BESS) is smoothen the power output from the grid connected with Wind Energy Conversion (WECS). BESS provide the grid regulation, ancillary services and enable the large scale integration of WECS units to allow a high penetration of wind power in the grid. BESS utilize the excess amount of wind power when it is highly available to non-available or less penetration time.

This paper focus the BESS for large scale grid connected Wind Energy Conversion System (WECS) to save the excess power available and providing the ancillary services as maintaining the Power Quality (PQ). The sizing of BESS based on the power output, discharge duration, response time, energy density, lifetime and self discharge of the battery. The behaviour of grid connected WECS are studied and their impacts on voltage and frequency in 110 / 11 kV substation without BESS and with BESS. Modelling and simulation is carried out using DIgSILENT Power Factory simulation software. Real time data's are used for modelled the Wind Turbine (WT), transformer, transmission line, capacitor bank are built in available model in Dig Silent and data's used for simulation are taken from the National Institute of Wind Energy (NIWE) website, wind density map of India, Southern Regional Load Dispatch Center (SRLDC) website and manufactures catalogue. The primary control is used to vary the active and reactive power of all sources to obtain the voltage and frequency regulation while secondary control used to maximize the power capture from the WECS. Controls have been employed for battery inverters to vary the output active/reactive power to maintain the voltage regulation in terminals. BESS is controlling the injecting or absorbing the active power. Two cases were considered as without BESS and with BESS. BESS improves the voltage profile during the fault.

Keywords- Wind energy; battery energy storage; power quality; renewable energy

I. INTRODUCTION

Electric power is the one which is necessary for day today activities like cooking, cooling, air conditioning, entertainment, agriculture, industrial development etc. The economic growth of the country is mainly depends on electric power [7]. This power is mainly generated from conventional energy sources like coal, nuclear, diesel etc. Due to increase of population, standard of human living, industrial growth, the usage of energy consumption is keeps increasing and the availability of fossil fuels decreasing. Renewable Energy (RE) sources are alternative for fossil fuels. RE can replace the fossil fuels in energy requirement in electric power generation, heating, refrigeration, air conditioning etc. India is a second world populist country has the installed capacity of 308.8 GW and renewable energy is 46.3 GW on Nov 2016 [3]. India is planning to increase the installed capacity of RE to 175 GW by the year of 2022. However intermittent characteristics of RE sources like wind shall fluctuate the power output from Wind Turbine Generator (WTG). When the large scale WTG is connected with grid, Power Quality (PQ) problem also associated with this. Energy storage system improves the grid regulation by smoothening the power output from WTG, time shift for generated RE to meet the load, peak shaving of demand, increase the reliable of large scale RE grid connected system and off grid system without diesel backup. Ministry of New and Renewable Energy Sources (MNRE), Government of India (GoI) engage the Energy Storage (ES) for grid connected RE system to maximize the utilization of RE during excessively available and un available time [2].

This paper focusing the Battery Energy Storage System (BESS) for grid connected large scale WECS to improve the voltage profile.

II. PQ PROBLEMS IN GRID CONNECTED WECS

Intermittent characteristics of the wind velocity (below the cut in speed and above the cut out speed) resulting to disconnection of WTG from the grid. When the tip of the WTG is reaches the cut in speed again WTG is connected to the grid. Due to multiple connection and disconnection of WTG from the grid creating the PQ problems in grid connected WECSS. Type 1 & type 2 WTGs are creating voltage sag due to reactive power drawl, transients due to switching of capacitor banks etc during the connection to the grid and creating voltage swell during disconnected from the grid. Type 3 & type 4 WTGs are using the power electronics based converters for interconnection to the grid. It generating the harmonics, DC injection and voltage flicker to the grid. The major PQ event in grid connected WECS is voltage sag. Voltage profile in the grid can be maintained during fault by Low Voltage Ride Through (LVRT) characteristics of the WTG by injecting the reactive power to the grid with proportional to the voltage.

III. BATTERY ENERGY STORAGE SYSTEM

BESS can store the excess amount of power from the RE when demand is low and wind penetration is high. It facilitates the reuse of stored energy in the battery to higher demand and lower wind penetration times. This supporting fast response to variations in the wind power output and balancing the power generation VS demand. When the output power from the WTG is fluctuating, BESS gives both real and reactive power support to the grid & maintain the grid voltage profile. BESS reduce the voltage sags caused by faults or switching of large loads in the system and reduces the peaks power generation. In other words it store the energy during lesser demand time and delivering during the higher demand to reduce the peak power generation.

The selection of BESS for grid connected WECS is based on battery capacity, rate of charge and discharge, open circuit voltage, State of Charge (SOC), depth of discharge, self discharge, nominal cell voltage, battery life time, no of cycles of charge and discharge, efficiency of the converter and discharge time. Lithium ion (Li – Ion) batteries are selected for this analysis due to better energy to weight ratio, lesser self discharge when it is in ideal condition and not affected from memory effect.

The equations for charging of batteries are shown in Eqn 1.

$$E(t+1) = E(t) + \Delta t P_t^{Ec} \eta_c \quad (1)$$

The equations for discharging of batteries are shown in Eqn 2.

$$E(t+1) = E(t) - \frac{\Delta t P_t^{Ed}}{\eta_d} \quad (2)$$

Where

$E(t)$ is energy stored in the battery in t

Δt is duration of the interval

P_t^{Ed} is power discharge by the battery during the time t

P_t^{Ec} is battery during in the time t

η_c is charging efficiency

η_d is discharging efficiency

The minimum rating of BESS value is obtained from the Eqn 3.

$$E_{\min}^{BESS} = \left(\frac{E_{\min}^{dis}}{\eta_d},\ E_{\min}^{char} * \eta_c \right) \quad (2)$$

Where

$E_{\min}^{BESS}$ is minimum value of BESS rating

$E_{\min}^{dis}$ is minimum energy supplied by BESS during the discharge

$E_{\min}^{char}$ is minimum energy charged the BESS during charging

η_c is charging efficiency

η_d is discharging efficiency

IV. MODELLING OF WECS

A 110 / 11 kV Sub Station (SS) is considered for the analysis with 11.5 MW of WTG installed capacity, connected load in the SS is 10 MVA and capacitor bank connected in the SS is 1.587 MVAr. The details of WTG is listed in table 1.

TABLE I. DETAILS OF WTG INSTALLED CAPACITY

S. No	Customer	Capacity in MW
1	A	5 (20*250 kW)
2	B	2 (8*250 kW)
3	C	4.5 (9*500 kW)
Total		11.5

The modelling and simulation is performed in DIgSILENT power factory. The Single Line Diagram (SLD) of SS with aggregated WTG, load, BESS is shown in figure 1.

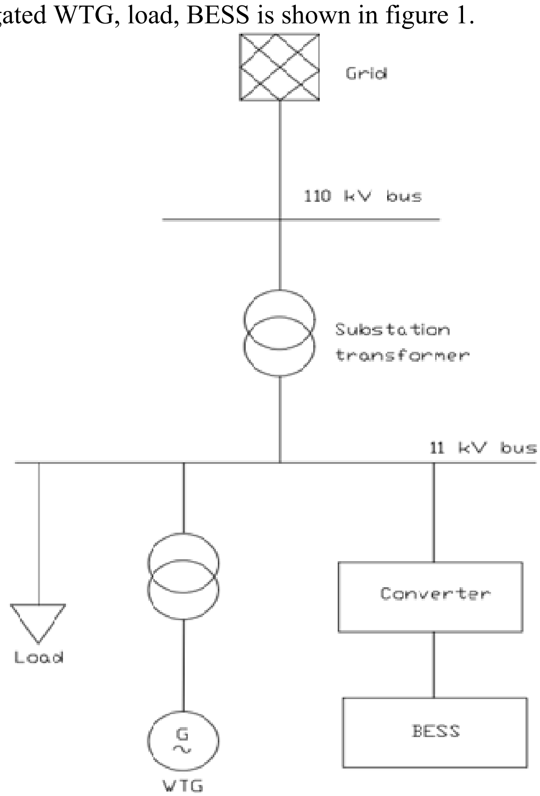

Figure 1: SLD

V. SIMULATION RESULTS

The electrical fault is crated at 2 sec and lasting for 100 milli seconds. The voltage profile at 11 kV bus without BESS is shown in figure 2.

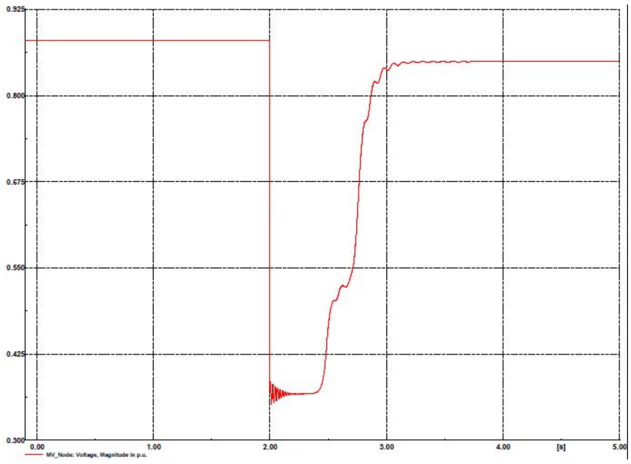

Figure 2: Voltage at 11 kV bus without BESS

During the fault, voltage profile at 11 kV bus is reduced to 0.4 pu.

The voltage profile at 11 kV bus with BESS is shown in figure 3.

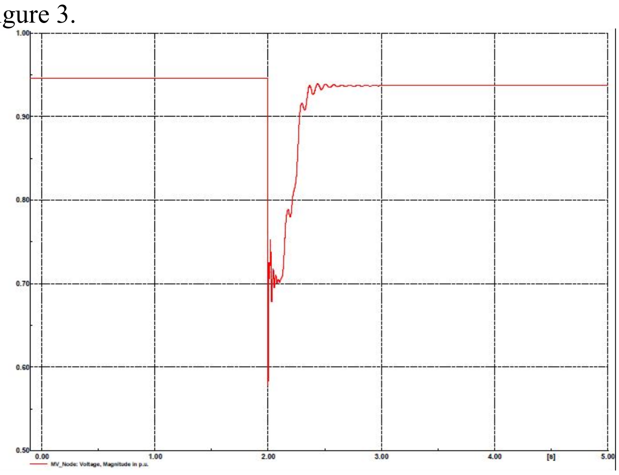

Figure 3: Voltage at 11 kV bus with BESS

During the fault, with BESS voltage profile at 11 kV bus improved from o.4 pu to 0.7 pu.

VI. CONCLUSION

This paper discuss the BESS for grid connected WECS. BESS can store the excess power from RE sources during higher penetration time and discharge during lesser penetration time. The variation in power output from the WTG is smoothed BESS by supplying both real and reactive power. BESS improves the voltage profile from 0.4 pu to 0.7 pu during the fault.

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BIOGRAPHICAL INFORMATION

P. Sivaraman was born in Vellalur, Madurai district, Tamilnadu. He completed schooling in Govt. Higher Secondary School, Vellalur, B.E. in Electrical and Electronics Engineering from PGP College of Engineering and Technology, Namakkal and M.E. in Power Systems Engineering from M. Kumarasamy College of Engineering (autonomous), Karur affiliated to Anna University, Chennai. Presently, he is working as an Electrical Engineer, Power System in TECh Engineering Services, Bengaluru. He has three years of experience in power quality & trouble shooting analysis, power system & power evacuation studies and arc flash studies. His areas of interest include Cost effective electronic products, Power quality, Smart grid, Distributed generation and Renewable energy systems.

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