Anuradha S deshpande/ International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 6, November- December 2012, pp.1587-1592

WIND POWER SYSTEM AND BATTERY AS ENERGY STORAGE

Anuradha S deshpande
[a]Department of Electrical Engineering, Faculty of Technology & Engineering, Maharaja Sayajirao University of Baroda, Vadodara 390001,Gujarat, India

Abstract

Presented work has made an attempt to establish details of connectivity of Wind Farms with isolated installations. Paper has shown AC-DC-AC connectivity of wind farm through Rectifier inverter to an AC load. Mat Lab simulation results of wind farm connectivity to an AC load of lumped type is done. Developed work has focussed on necessity of energy storage during high wind situations so that use can be made during low wind conditions. Also energy storage device suitability during low wind conditions is obtained. Battery is used as energy storage device. Work explains connectivity to wind farms and importance of battery in its charging (high wind penetrations) and discharging (low wind penetrations) mode, without use of charge controller action but with different levels of SOC (State of Charge).Mat Lab simulation results for battery connectivity with SOC of 40% is established for lumped load. To summarize work high lights wind farm connectivity to AC load through energy storage device. Battery can supply successfully AC load during low wind conditions. Thus continuous power supply can be obtained through energy storage device like battery even during low wind conditions.

Key Words: Wind Farms, Energy Storage Device, State of Charge, Rectifier, Inverter, Battery.

I. INTRODUCTION

Modern power system are utilising both conventional and non-conventional sources of power. Conventional sources have their own merits but present trend for sustainable environment discourages their use due to ever soaring pollution levels introduced by them in to the atmosphere. Major gaseous pollutants contributed are NO_x, SO_x, and CO_2 in to the environment. Therefore need of renewable energy sources is realised.
Renewable energy sources have one major advantage that it is pollution free. Due to this tremendous use of renewable sources like wind, Solar has increased overnight. Lot of development in developed as well as under developed countries have taken place. Renewable energy sources are integrated in to the main system and have been successfully used in all countries. The problem associated with them is their excess availability during some period and their non availability during some part of the day; with the result that constant power supply cannot be ensured. In order to ensure continuous power supply, methods can be developed to store energy during excess availability and use it during weak periods.

Literature survey reveals work of [2], [3], and [5] who have discussed battery as energy storage device in integration with wind energy and have discussed BESS's size and capacity, charging/discharging cycles. Authors have developed theoretical base for all aspects of BESS. [1] has dealt with lead acid battery in respect of state of charge limits, life time, charge /discharge current limits. [4] has VRB as a battery source and developed VRB connection, suitability and modelling.[6] has talked about sizing and control methodologies, low cost flow battery based dispatch strategies. [7] has considered Li-ion batteries and obtained optimal control method for power smoothing to suppress wind power. Above literature survey results shows that no simulation results of voltage and current waveforms are obtained with respect to wind and BESS connectivity. Charging/Discharging phenomena through waveforms is not established. Wind and battery connectivity simulation is significant in establishing state of charge condition for the battery, its connectivity and disconnectivity. Present work has obtained simulation results of A) Wind supply to AC Lumped load) Wind supply to AC lumped load with battery connected in parallel to Wind. Results include waveforms of voltage with and without battery. The detailed development is formulated as under.

2.Wind Power System and Battery Power

2.1.1Power Balance Equation:

The wind generator connectivity in respect of load and battery system is as shown in figure.

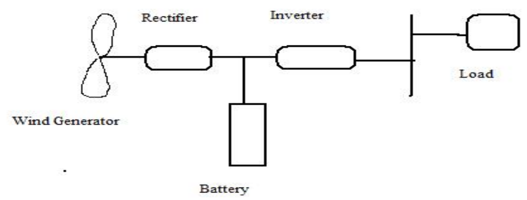

Fig 1 wind generator and batteryThe wind generator and battery power balance equation is as shown in figure.

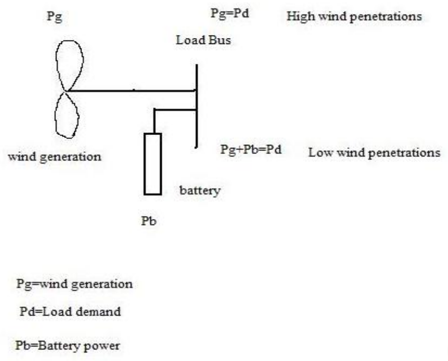

Fig 2 wind and battery power system

Utilities supply power to connected load satisfying

$P_g=P_d$, (1)

at all times, during high wind speeds. Wind energy is unsteady, so continuous availability of power can't be ensured during low wind speed. Therefore the problem is of unsteady nature of wind between the limits of high speed penetration and low wind speed penetration. Thus problem is of ensuring continuous availability of power supply irrespective of wind speed. This suggests a solution by storing power /energy in energy storage device during high wind penetrations and discharging during low wind penetration thus ensuring continuous availability of power. Energy storage can be obtained by connecting battery across wind supply to AC load. The concept is self explanatory as shown by figure.

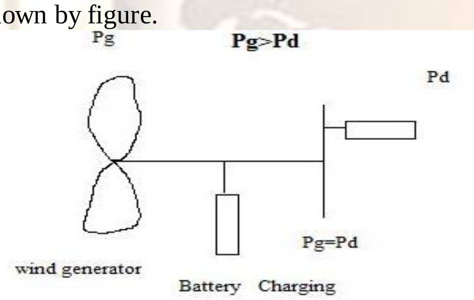

FIG3 Battery Charging Mode High wind penetration

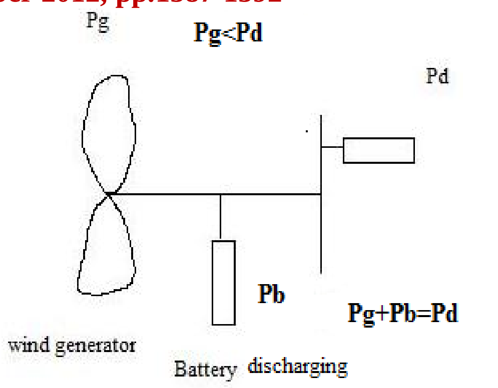

FIG4 Battery Discharging Mode(Low wind penetration)

2.2 Charging Mode of Battery: Fig 3

During high wind penetrations, power generated

Pg>Pd. (2)

Thus after satisfying (1), a power surplus is available which can be used to charge the batteries connected across the wind power system. Thus full utilization of high wind speed can be obtained, meeting load requirement and storing surplus in batteries.

2.3Discharging Mode of Battery: Fig 4

During low wind penetration, power generated

Pg<Pd. (3)

Thus it is short of supply in order to balance (1).

Thus Pg+Pb=Pd (4)

can be obtained by injecting power stored in battery as Pb in to the wind power system, thus collectively low wind generation Pg plus Pb can meet the requirement of load. Question there fore is of maintaining charging/discharging cycles, their state of charge level criteria to meet the required voltage, power etc.

3 Simulation of wind and battery power system:

3.1 Configuration details of parameters of wind generator to AC load:

3.1.1 Wind Generator characteristics:

a) Wind Turbine it is a variable speed pitch controlled wind turbine using a synchronous generator.

b) Number of wind turbines: 5

c) Generator Data for 1 wind turbine:

(i)Nominal power, L-L, f, [P_n(VA),V_n(V_{rms}),f_n(Hz)]:[2e6/0.9, 730 50];

(ii) Sample Time:[Ts]

(iii)Reactances[xd,xd',xd'',xq,xq',xq''](pu) : [1.305,0.296,0.252,0.474,0.243,0.18];

(iv)Time Constants[Tdo' Tdo'' Tq'](s): [4.49 0.0681 0.0513] ;

(v)Resistance R_s (pu): 0.006;

(vi)Inertia Constant, Friction factor and Pairs of poles: [H(s) F(pu) P]: [0.62 0.01 1]
(vii)Initial Conditions:[dw(%) th(deg) i_a i_b i_c(pu)pha,phb,phc(deg)V_f(pu)]: [0 0 0 0 0 0 0 0 1];
Turbine Data for 1 wind Turbine: (i)Nominal mechanical output power(W):2e6 ;
Wind speed at nominal speed and at C_{pmax}(must be between 6 m/s & 30 m/s): 11
Initial wind speed:11; Sample Time:[T_s]

3.1.2 PWM IGBT Inverter

It is a bridge of selected power electronics devices. Series RC snubber circuits are connected in parallel with each switch device. For most applications the internal inductance L_{on} of diodes and thyristors should be set to zero.
Parameters: a) Number of bridge arm:3, b)Snubber Resistance R_s (ohms):5000; c) Snubber Capacitance C_s (F): 0.0

Power Electronics Device: IGBT/Diodes

a) R_{on}(ohms): $1e^{-3}$; b) Forward voltages[device V_f(v), Diode V_{fd}(v)]: [0.0 0.0]; c) [T_f(s), T_t(s)]:[$1e^{-6}$, $2e^{-6}$]

3.1.3 Rectifier

a) Number of bridges:3; b) Snubber Resistance R_s (ohms):100; c) Snubber Capacitance C_s (F): $0.1e^{-6}$

Power Electronics Device: Diodes

a) R_{on} (ohms):$1e^{-3}$, b) L_{on} (H): 0; c) Forward voltage V_f (v): 0.8 ;

3.1.4 Load Characteristics: Three phase Parallel RL Load

a) configuration: star(grounded)/Delta, b)Nominal phase to phase voltage $V_n(V_{rms})$: 600
c) Nominal frequency f_n (Hz):50,
d) Active power P(MW):1,
e) Inductive reactive power Q_L(+ve Var):10000

3.1.5 Battery As Energy Storage Device

A generic battery that models most popular battery types.
Parameters: a)Type of battery: Nickel Metal Hydride; b)Nominal Voltage: 600V;
b) Initial State of Charge: 40%; d) Rated Capacity: 50Ah

Parameters based on battery type and nominal values: a) Maximum capacity (Ah): 53.8462
b) Fully charged voltage(V): 588.9831;
c) Nominal Discharge Current(A):10;
d) Internal resistance (ohms):0.1;
e) Capacity (Ah)@Nominal Voltage: 48.0769;
f)ExponentialZone[voltage(v),capacity(Ah)]: [542.3729 10]

4 Simulation Results:

4.1 Without Energy Storage Device

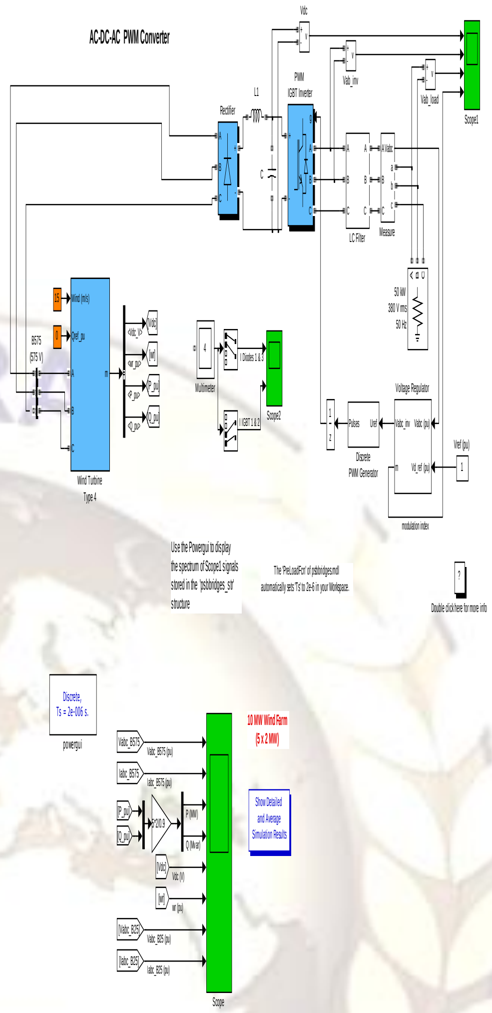

Fig 5 Wind system connected to load

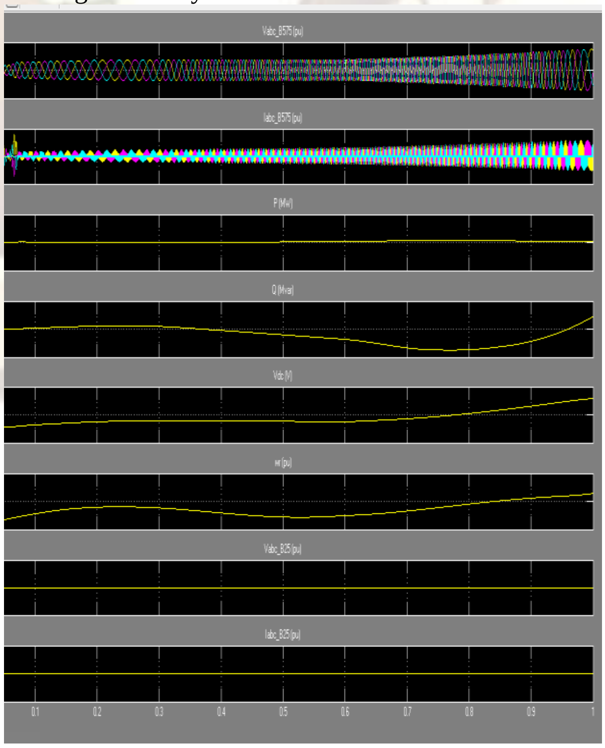

Fig 6 Waveforms of wind speed 11m/s

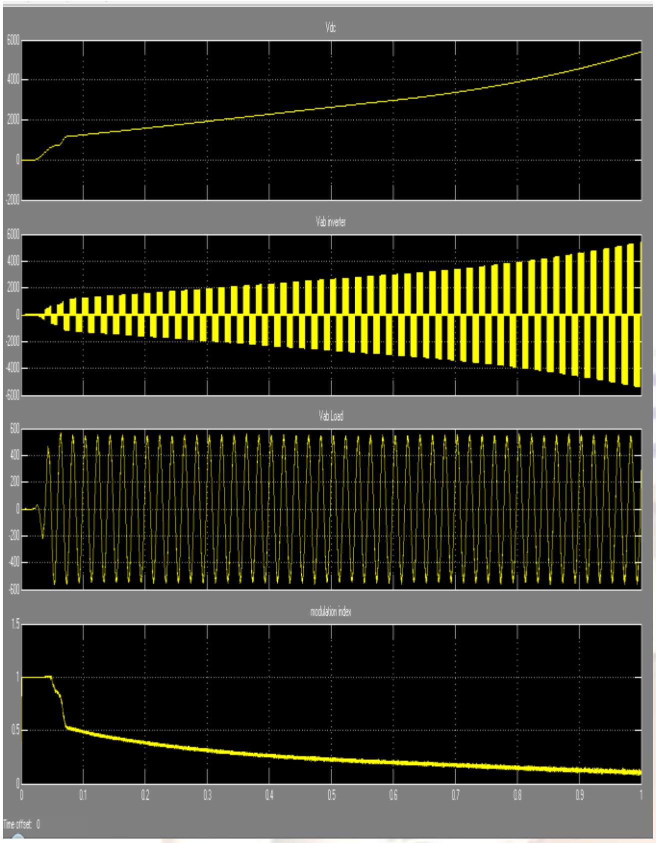

Fig 7 Waveform of load 50KW

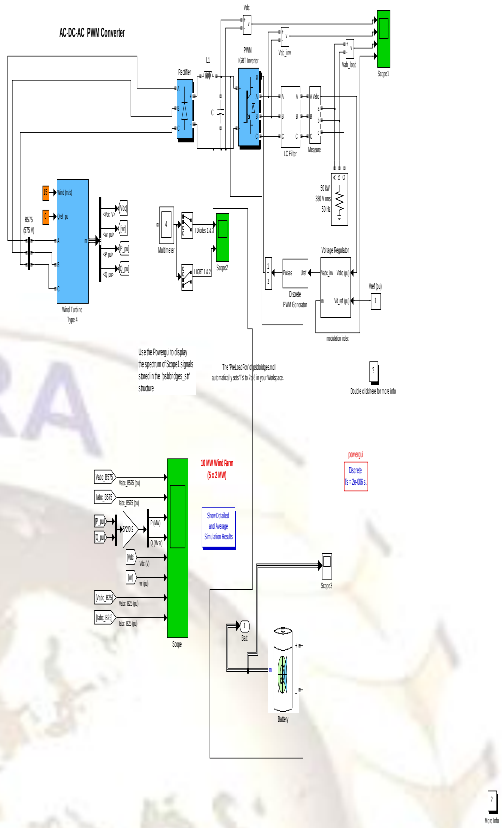

Fig 9 Wind system connected to load through converters and battery

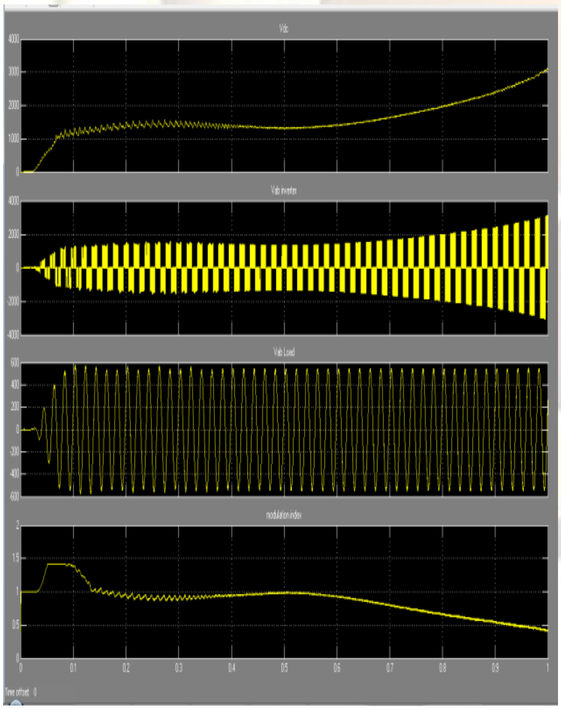

Fig 8 Waveform of load 1-5MW

3.2 With Energy Storage Device Battery

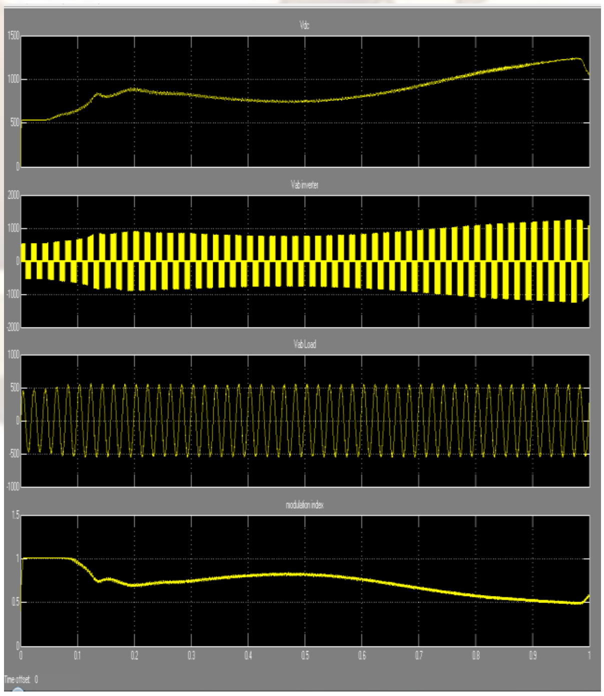

Fig 10 Waveforms of 40% battery SOC wind speed15m/s

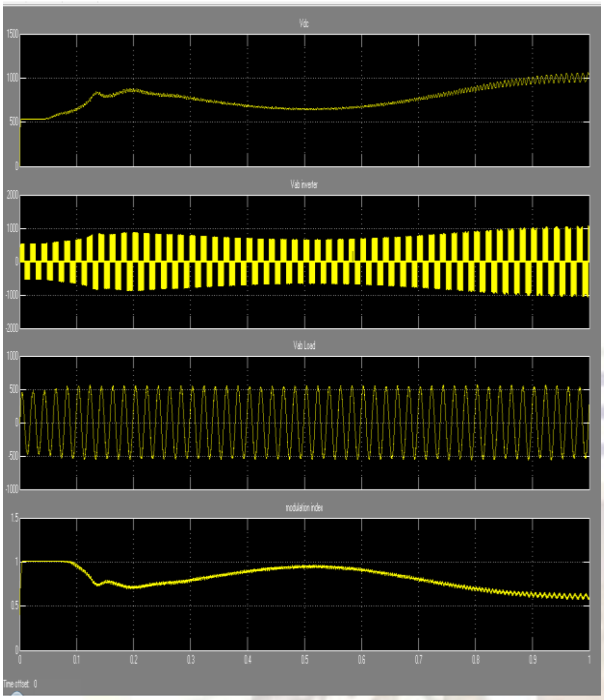

Fig 11 Wind and battery 40% SOC speed 6m/s

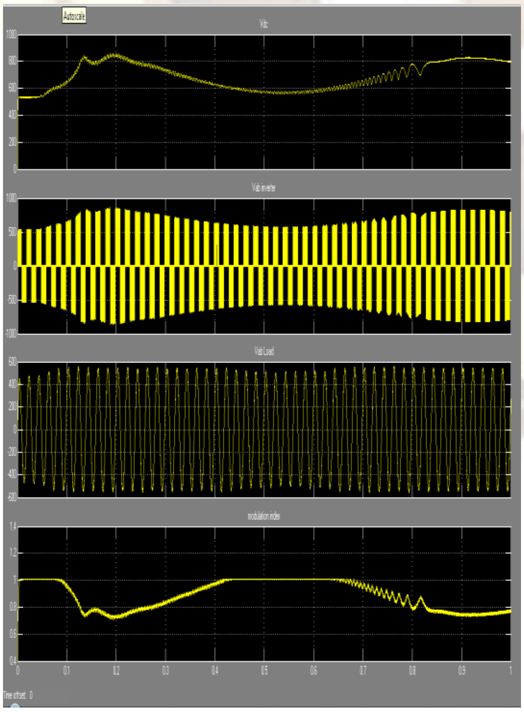

Fig 12 Wind and battery 40% SOC speed 0m/s

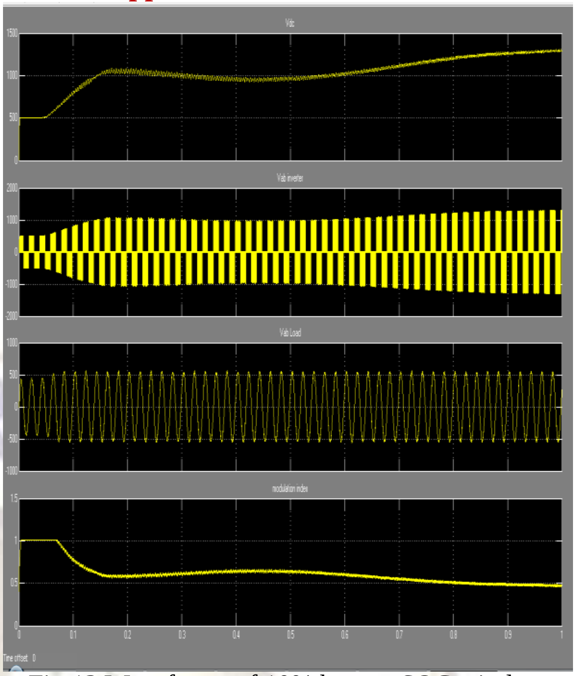

Fig 13 Waveforms of 10% battery SOC wind speed 15m/s

Rated voltage at the load has reduced in case of 10% SOC in comparison to 40% SOC.
Therefore Battery SOC has to be limited to up to 40% SOC for obtaining rated voltage.

4 Results and Analysis

- Wind generators can supply variable(unsteady) voltage during wind speed of 15m/s(1500V), 6m/s(1400V) and below 6m/s(1000v) with voltage across the load to be 600V. During wind speed of <6m/s, voltage across the load reduces to 500V.
- Connection of energy storage device battery during high wind penetrations charges the battery and during low wind penetration(<6m/s) discharges to the load, still maintaining a constant voltage of 600V across the load.
- Energy storage has maintained 600V across the load.

5 Conclusion

Wind power system can be made as steady power source with the help of energy storage during high wind penetration conditions. Energy storage device Generic battery can discharge to the load during low wind penetration conditions and maintain constant load voltage.

References

[1] Sercan Teleke, *Member*, *IEEE*, Mesut E. Baran, *Senior Member*, *IEEE*, Subhashish Bhattacharya, *Member*, *IEEE*, and Alex Q. Huang, Fellow, IEEE, Optimal Control of Battery Energy Storagefor Wind Farm Dispatching, IEEE Transactions on

Energy Conversion, vol. 25, no. 3, September 2010,787-794.

[2] Q. Li, S. S. Choi, Senior Member, IEEE Y.Yuan, Member, IEEE, and D. L. Yao, Student Member, IEEE, On the Determination of Battery Energy Storage Capacity and Short-Term Power Dispatch of a Wind Farm, IEEE Transactions on Sustainable Energy, vol. 2, no. 2, april 2011,148-158.

[3] Liang Liang, Li lianlin and Hui dong, An Optimal Energy Storage Capacity Calculation Method for 100MW Wind Farm, 2010 International Conference on Power System Technology,1-4.

[4] Wenliang Wang1, Baoming Ge1, Daqiang Bi2, and Dongsen Sun1, Grid-Connected Wind Farm Power Control using VRB-based Energy Storage System, 978-1-4244-5287-3/10/$26.00 ©2010 IEEE,3772-3777.

[5] KW Wee, SS Choi and DM Vilathgamuwa, Design of a Wind Turbine – Battery Energy StorageScheme to Achieve Power Dispatchability, 978-1-4244-7398-4/10/$26.00 ©2010 IEEE,1217-1222.

[6] Ted K. A. Brekken, Member, IEEE, Alex Yokochi, Annette von Jouanne, Fellow, IEEE, Zuan Z. Yen,Hannes Max Hapke, Member, IEEE, and Douglas A. Halamay, Student Member, IEEE, Optimal Energy Storage Sizing and Control for Wind Power Applications, IEEE Transactions on Sustainable Energy, vol. 2, no. 1, January 2011,69-77.

[7] Yun-Hyun Kim, Soo-Hong Kim, Chang-Jim Lim, Sang Hyun Kim,Byeong-Ki Kwon, Control Strategy of Energy Storage System for Power Stability in a Wind farm, 8th international conference on power Electronics – IEEE Asia May-30-June 3,2011, the shilla Jeju, Korea.