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Smoothing Of Power in Wind Generation Using Super Capacitor

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***Abstract*— The main theme of this project is smoothing of wind power using super capacitor due to variation in penetration of wind .The quality of wind power has become a major concern in stability of power grid because of wind speed oscillation power fluctuation a resulted a major problem. The paper studies advantages of integration of super capacitor to wind turbine system. The system is stimulated using MATLAB**

I. INTRODUCTION

Now a day we are experiencing an increasing demand for electrical energy. Many energy agencies have taken several proactive steps in-order to increasing the of renewable energy sources. Since they have more benefits than non-renewable. But renewable energy sources come with high initial cost. And even renewable energy sources faces many technical challenges, including power quality reliability, safety and protection load management grid interconnection and control, new regulation and grid operation economics Renewable energy source such as wind energy are available as long as there is wind. And this energy is abundant in nature and the power generation from this source is pollution free .The main problem faced in wind energy is the fluctuation in power due to variation in wind speed. Wind energy cannot be dispatched as same as other power sources. Here in this paper there is application of super capacitor in wind turbine which is used for variable speeds. Even application of super capacitor is increasing in industries.

II. SYSTEM CONFIGURATION

The configuration of wind turbine system is shown in the fig below. In this system wind turbine connected directly to permanent magnet synchronous generator. The wind turbine is directly connected to permanent magnet synchronous generator via gear box. Rectification is done for output of PMSG using PWM rectifier. Series connections of super capacitors are done with limited number. A boost inductor is used between the grid and inverter to filter out harmonics of the inverter.

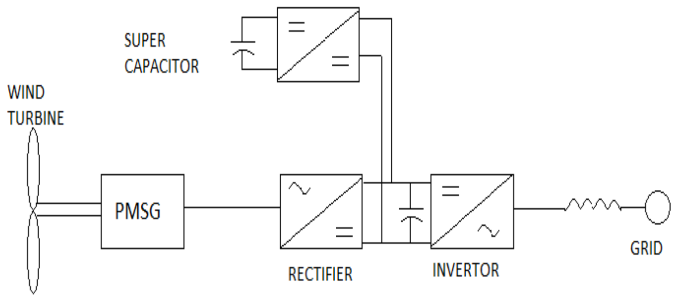

Fig 1. System configuration

III. DYANAMIC MODEL OF THE SYSTEM

The dynamic model of each part is described which is used to design the control algorithm

Wind model

There are various terminology used, V_{wind} is to define wind speed, V_{wa} is for average wind speed, V_{wn} is wind noise or for wind turbulence .A_r and A_g are defined for amplitude of wind ramp and gust. T_{sr},T_{sg},T_{er},and T_{eg} are defined for representing starting time of wind ramp and gust and ending time of wind ramp and gust. f is used for frequency ,h is for height of wind turbine, l is used noise or turbulence length and Z_o is of roughness of length. These parameters issued by the manufacturer and owners of the wind turbine.

$$V_{wind}=V_{wa}+V_{wr}+V_{wg}+V_{wn} \quad (1)$$

$$V_{wr}=\begin{Bmatrix} A\frac{(t-T_{sr})}{T(er-T_{sr})} & T_{SR}\leq t\leq T_{er} \\ 0 & otherwise \end{Bmatrix} \quad (2)$$

$$P_D(f)=l_{v_{wa}}[\ln(h|z_0)]^{-1}\left[1+1.5\frac{fl}{V_{wa}}\right]^{-5/3} \quad (3)$$

The expectation of this paper is smoothing the power fluctuation caused by wind gust and wind noise.

Wind turbine

Equations (5)-(8) are used to describe wind turbine model. Out power is defined in equation (5) and the coefficients of (5) are given in (6)-(8).

$$P=c(\beta,\lambda)\frac{\rho A}{2}V_{wind}^3 \quad (5)$$

$$c(\beta,\lambda)=c_1\left(\frac{c_2}{\lambda_2}-c_3\beta-c_4\right)e^{\frac{c_5}{\lambda_2}}+c_6\lambda \quad (6)$$

$$\frac{1}{\lambda_2}=\frac{1}{\lambda+0.08\beta}-\frac{0.035}{\beta^3+1} \quad (7)$$

Where p=1.2 kg/m^3 is of air density, area swept by turbine blades is A, tip-speed-ratio(TSR) λ is given by (8), β is pitch angle, c is used for performance coefficient of the turbine given by equation by (6), ω generator angular velocity. c_1-$c_6$are coefficients are dependent on wind turbine structures

PMSG

The d and q axes and flux direction of PMSG are as shown in fig2.Angle between the rotor d-axis and stator axis is θ

The following assumptions are considered

There is no damper winding saturation is negligible

Eddy-current and hysteresis losses is ignored

Power losses are considered constant

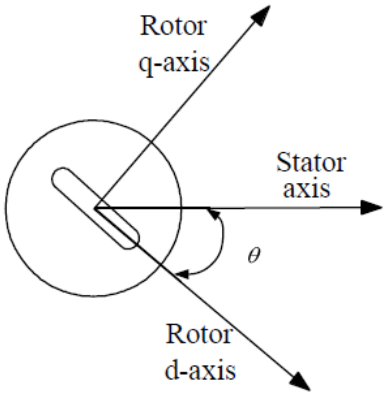

Fig 2.d-q axis of a typical rotating machine

$$\begin{bmatrix} i_{qs} \\ i_{ds} \\ \omega_s \end{bmatrix}=\begin{bmatrix} \frac{R_s}{L_{qs}} & -\omega_s\frac{L_{ds}}{L_{qs}} & -\frac{\lambda_m}{L_{qs}} \\ \omega_s\frac{L_{qs}}{L_{ds}} & \frac{R_s}{L_{ds}} & 0 \\ -\frac{1.5P^2}{4J}\lambda_f & \frac{1.5P^2}{4J} & -\frac{BP}{2J} \end{bmatrix}\begin{bmatrix} i_{qs} \\ i_{ds} \\ \omega_s \end{bmatrix} \quad (8)$$

$$+\begin{bmatrix} \frac{-1}{L_{qs}} & 0 & 0 \\ 0 & \frac{-1}{L_{ds}} & 0 \\ 0 & 0 & \frac{P}{2J} \end{bmatrix}\begin{bmatrix} V_{qs} \\ V_{ds} \\ T_m \end{bmatrix} \quad (9)$$

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R_s is the stator resistance, L_{ds} and L_{qs} are d-q axis inductance, P is the number of poles, and j is rotor inertia, V_{ds} is terminal voltage at stator d axis and V_{qs} is terminal voltage at stator q axis,i_{ds} is terminal current of stator d axis and i_{qs} is terminal current of stator q axis, input mechanical torque of wind turbine is T_m ,λ_m is the magnitude produced by permanent magnet

The electrical rotor speed is given by

$\omega_S = \frac{P}{2}\omega_m$

ω_m is the mechanical rotor speed

ENERGY STORAGE CONVERTOR

Circuit representation of energy storage device is as shown in the fig1, and fig3 shows the dynamic model for storage in which super capacitors and series inductance are present. Super capacitor and series inductance are transferred to the dc link. Capacitor side as shown in fig4.The duty ratio of switch S_1 is denoted by d

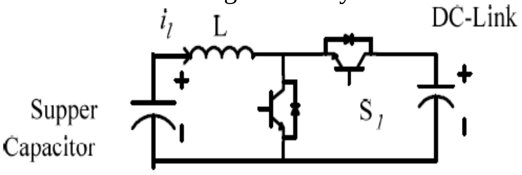


Figure 3. Circuit representation of energy storage.

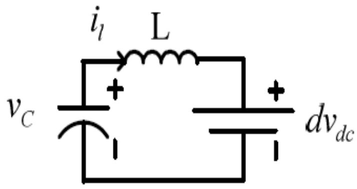
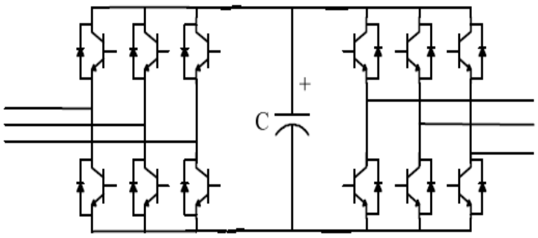


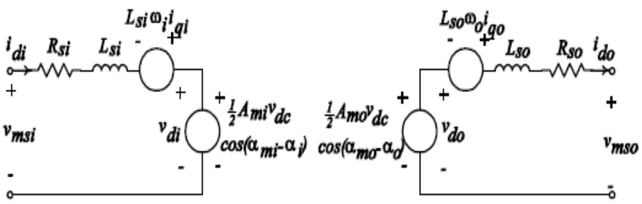
Figure 4. Dynamic model of the energy storage.

AC-DC-AC CONVERTOR

Back to back convertor of the wind energy system is represented by fig5.Here the convertor consists of six pulse voltage source convertor at the generator side, and six pulses convertor at the grid side. At generator side convertor changes the ac terminal voltage to dc voltage. And at load side dc voltage is converted to three phase voltage by the grid side convertor.



The dynamic model of back to back convertor of fig1 is shown in fig6.The dynamic model generated here of back to back convertor in d-q axes



(a)

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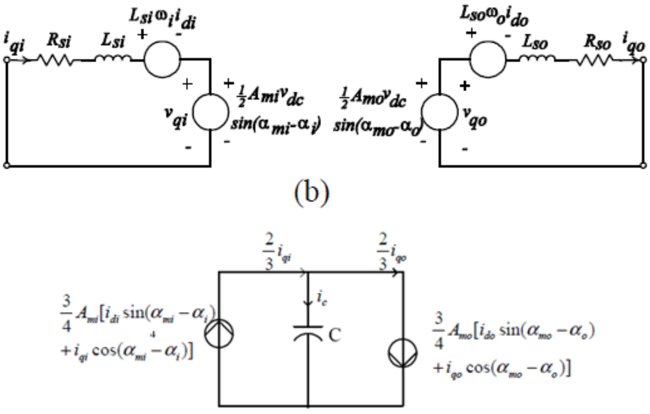

Figure 6. Dynamic model of the AC-DC-AC converter.

V_{smi} and V_{smo} used in the above figure are input and output voltage magnitudes. α_{mi} ,α_{mo} ,A_{mi}, A_{mo} are the magnitude and angle modulations of inverter and rectifier.α_i and $\alpha_o$are the angles phase a of input and output voltages. Equations (11)-(13) is of state space model of system.

$$\begin{bmatrix} V_{smi} \\ 0 \end{bmatrix} = \begin{bmatrix} R_{si} + L_{si}D & -L_{si}\omega_i \\ L_{si} & R_{si} + L_{si}D \end{bmatrix} \begin{bmatrix} i_{qi} \\ i_{di} \end{bmatrix} + \begin{bmatrix} \frac{1}{2}A_{mi}V_{dc}\cos(\alpha_{mi} - \alpha_i) \\ \frac{1}{2}A_{mi}V_{dc}\sin(\alpha_{mi} - \alpha_i \end{bmatrix} \quad (11)$$

$$\begin{bmatrix} -V_{mso} \\ 0 \end{bmatrix} = \begin{bmatrix} R_{so} + L_{so} & -L_{so}\omega_0 \\ L_{so}\omega_0 & R_{so} + L_{so}D \end{bmatrix} \begin{bmatrix} i_{qo} \\ i_{do} \end{bmatrix} + \begin{bmatrix} \frac{1}{2}A_{mo}V_{dc}\cos(\alpha_{mo} - \alpha_o) \\ \frac{1}{2}A_{mo}V_{dc}\sin(\alpha_{mo} - \alpha_o) \end{bmatrix} \quad (12)$$

$$C\frac{dv_{dc}}{dt} = \frac{2}{3}i_{di} - \frac{2}{3}i_{do} \quad (13)$$

IV. CONTROL ALGORITHM

There are five control parameters to control speed and flux of the generator. They are dc bus voltage the active power delivered to the grid and reactive power delivered to the grid .Here five separate loops are provided for the controls system. The super capacitor and its convertor are used to control the output power of the inverter. And they are used to regulate the output power delivered to grid. Wind turbine reference output power is compared with the incoming wind power of the generator and if output power is less than the reference then the stored energy is released from the super capacitor to compensate the lack of input power and if output power is more than the reference it is stored in super capacitor.

Maximum power of wind is achieved by keeping the TSR value to its optimal. And this can be done by adjusting the speed of wind turbine to its optimal value. Equation (14) gives optimal value of speed in order to achieve optimal value for TSR

$$\omega_{mopt} = \frac{\lambda_{opt} v_{wind}}{R} \quad (14)$$

Relationship between speed and other parameters is shown by equation

$$T_m = T_e + B\omega_m + j\frac{d\omega_m}{dt} \quad (15)$$

From equation (15) is known that electrical torque can be used control speed of the system. The relationship between generator electrical torque and other generator's parameter is given in equation (16).These equations holds good for all types of permanent magnet synchronous generators. $L_{ds} = L_{qs}$ in surface mounted PMSG ,the equation (10) obtained is derived from (17)

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$$T_e = \frac{3}{2}\left(\frac{p}{2}\right)\left(\lambda_{ds} i_{qs} - \lambda_{qs} i_{ds}\right) = \frac{1.5P}{2}\left(\lambda_f i_{ds} + (L_{ds} - L_{qs}) i_{ds} i_{qs}\right) \quad (16)$$

$$T_e = \frac{1.5P}{2}\lambda_f i_{ds} \quad (17)$$

By using park transformation equation (17) can be transformed

$$i_{qs} = |i_s| \sin(\alpha - \theta) \quad (18)$$

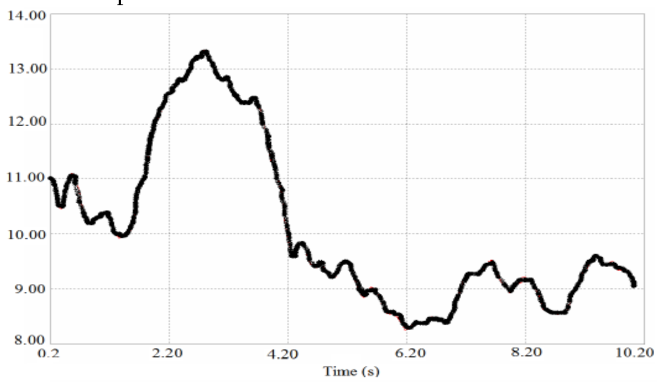
α is initial angle of the stator current. Equation (18) is known as the base for vector control of PMSG. I_{di} is used to prevent machine suffering from over voltage by controlling flux on d axis.

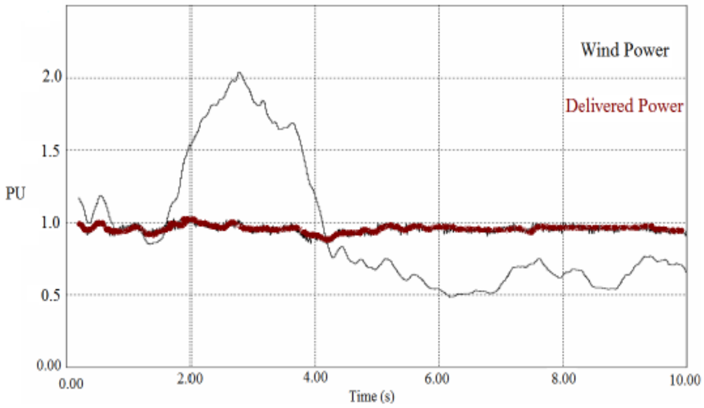
V. SIMULATION RESULTS

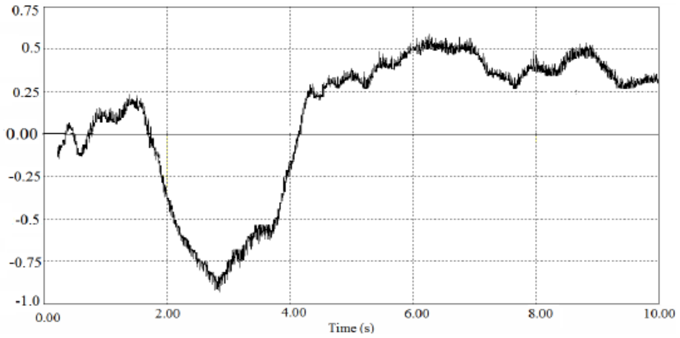
The given table below consist the parameters of the machine in PU

	10KW ratings	Remarks
R_s	.0918	(20^o C)
L_{ds}	.00195	Unsaturated
L_{qs}	.00195	

Figure 8-11 gives the simulation results. Wind speed variation during 10s is shown in fig8, average wind speed is 10.5m/s. And the average power of this is 0.9 PU. Output power of the wind turbine system is shown in figure9. Here oscillations are made smoothen and average power and input power are made equal. Super capacitor output power is shown in figure(10). Super capacitors stores extra wind power when power is negative and ,power is released by super capacitor when its positive.







VI. CONCLUSION

Here the application of supercapacitor in smoothing of wind turbine output power is achieved. Based on the dynamic of each part of wind turbine system control algorithm is developed and stimulated. From the results it will come to known the significance and improvement of wind turbine output power.

REFERENCES

[1] C. Luo, H. Banakar, B. Shen and B. T. Ooi, "Strategies to Smooth Wind Power Fluctuations of Wind Turbine Generator," IEEE Trans. Energy Convers., vol. 22, no 2, pp. 341 - 349, June 2007.

[2] C. Abbey and G. Joos, "Super capacitor Energy Storage for Wind Energy Applications," IEEE Trans. Industry Applications, vol. 43,no. 3, pp.769 – 776, May-june 2007.

[3] T. Ackermann, "Wind Power in Power Systems," John Wiley &Sons, 2005.

[4] R. Cardenas, R. Pena, J. Clare and G. Asher, "Power smoothing in a variable speed wind-diesel system," in Proc.34th Annual IEEEPower Electronics Specialist Conference, June 2003, pp. 754-759.

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