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Improvement of Power Quality Considering Voltage Stability in Grid Connected System by FACTS Devices

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Abstract - Recently the wind power generation has attracted special interest and many wind power stations are being in service in the world. In the wind turbine that mostly uses induction generators, tend to drain large amounts of Vars from the grid, potentially causing low voltage and may be voltage stability problems for the utility owner, especially in the case of large load variation on distribution feeder. Voltage-source converter based various FACTS devices have been used for flexible power flow control, secure loading and damping of power system oscillations. Some of those are used also to improve transient and dynamic stability of the wind power generation (WPGS).

Keywords - *PWM Voltage Source Converter (VSC); STATCOM, PI Controller, Wind Power Generation System (WPGS)*

I. INTRODUCTION

One way of generating electricity from renewable sources is to use wind turbines that convert the energy contained in flowing air into electricity. The main advantages of electricity generation from renewable sources are the absence of harmful emission and in principle infinite availability of the prime mover that is converted into electricity [1]. Due to clean and economical energy generation, a huge number of wind farms are going to be connected with existing network in the near future. Induction generator (IG) is widely used as wind generator due to its simple, rugged and maintenance free construction [2]. An Induction generator connected with a wind turbine to generate electricity is the sink of reactive power. Therefore, the compensation of reactive power is necessary in order to maintain the rated voltage on the network to which the wind farm is connected. Voltage instability problems and collapse typically occur on power system that is not able to meet the demand of reactive power, for considering heavy loads and fault conditions. When the wind farms are connected to a weak network, the voltage stability is one of the most important factors that affect the wind farm's stable operation [1]. Both normal and fault condition operation of wind farms can be optimized by using FACTS devices such as SVCs (static Var Compensator) and STATCOMs (Static Synchronous Compensator) [3]. STATCOM provides shunt compensation in a way similar to the SVC, but utilizes a VSC rather than shunt capacitors and reactors. A STATCOM can control voltage magnitude and, to a small extent, the phase angle in a very short time, and therefore has the ability to improve the system damping as well as the voltage profile of the system [4]. This paper demonstrate the performance of static synchronous compensator (STATCOM) based on voltage source converter (VSC) PWM technique to stabilize grid connected squirrel cage wind generator system under various system conditions. The dramatic increase in the penetration level of wind power generation into power system as a serious power source has received considerable attention. One of the major concerns related to the high level penetration of the integrated wind turbines is the impact on the power system stability. As the penetration level of wind power in power systems increases, the overall performance of the system will increasingly be affected by the inherent characteristics of wind power generators.

II. DYNAMIC STABILITY OF GENERATOR AND CONTROL

Dynamic stability of generator and control

The impact of the wind power on the stability and transient behaviour of the power systems :

During a short circuit fault, the short circuit current will result in voltage drop at the wind turbine terminal. Due to the voltage dip, the output electrical power and the electromagnetic torque of the wind turbine are significantly reduced, while the mechanical torque may be still applied on the turbine. Consequently, the turbine and generator system will accelerate due to the unbalanced torque.

After the clearance of the fault, the voltage of the power system tends to recover, however, the reactive power is required to recover the air-gap flux of the wind power generator. This could cause an inrush current to be drawn by the wind turbine from the power system, which in turn causes a voltage drop in the power system and at the wind turbine terminal

Model System and Initial Conditions

The model system used for simulation of the transient stability of power system is shown in Fig.1. The System configuration considered for investigation consists of one synchronous generator (100 MVA hydro-generators, SG) is connected to infinite bus through a transformer and double circuit transmission line. One Wind farm (Induction Generator 50 MVA, IG) is connected with the network via a transformer and transmission line. Though a wind power station is composed of many generators practically, it is considered to be composed of a single generator with total power capacity in this paper. There is a local transmission line with one circuit between the main transmission line and a transformer. Initial conditions are calculated in PSCAD/EMTDC in which the synchronous generator is treated as P/V specified generator and the induction generator is treated as a P/V/Q specified one. The specified values are shown in fig.1. A capacitor bank has been used for reactive power compensation at steady state. The value of capacitor C is chosen so that the power factor of the WPGS becomes unity. Table 1 and Table 2 show parameters and initial conditions of each generator. A double squirrel-cage induction machine model, which is represented by a steady state equivalent circuit shown in fig.2. (Where *s* is the slip) Main flux saturation of the induction generator is considered in the simulation. Fig.3 shows the saturation characteristic of the main flux Ψ*m* with respect to the magnetization X*mu* I*mu*, where X*mu* denotes the unsaturated magnetizing reactance and I*m* denotes the magnetizing current.

AVR and governor control systems are considered in the Synchronous generator model shown in fig.4

The mathematical relation for the mechanical power extraction from the wind can be expressed as follows.

$$Pw = 0.5\rho \Pi R^2 V_w^3 C_p(\lambda, \beta)$$

Where, *Pw* is the extracted power from the wind, ρ is the air density [Kg/m^3]. R is the blade radius[m]. V_w is the wind speed [m/s] and C_p is the power coefficient which is a function of both tip speed ratio, λ and blade pitch angle, β [deg].

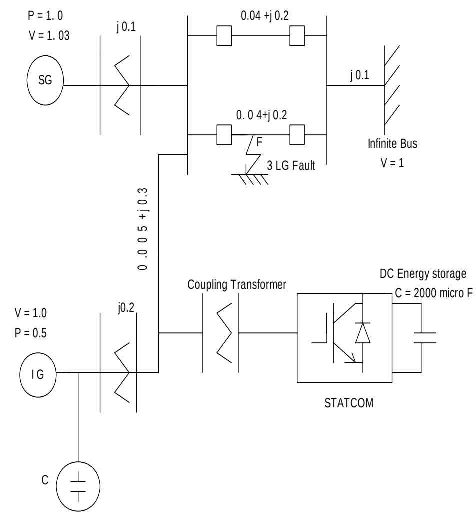


Fig. 1 : Model System (100MVA, 50Hz)

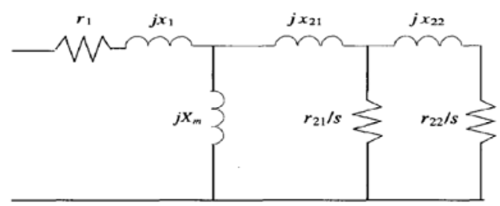


Fig.2 Steady state equivalent circuit.

Table 1. Parameters of generators.

SG		H (sec)	2.5
MVA	100		
r_a (pu)	0.003	IG	
x_a (pu)	0.13	MW	50
X_d (pu)	1.2	r_1 (pu)	0.01
X_q (pu)	0.7	x_1 (pu)	0.1
X'_d (pu)	0.3	X_{mu} (pu)	3.5
X''_d (pu)	0.22	r_{21} (pu)	0.035
X''_q (pu)	0.25	x_{21} (pu)	0.030
T'_{do} (sec)	5.0	r_{22} (pu)	0.014
T''_d (sec)	0.04	x_{22} (pu)	0.098
T''_q (sec)	0.05	H (sec)	1.5

Table 2. Initial conditions of each generator.

	SG	IG
P	1.00	0.50
V	1.03	1.00
Q	0.32	0.00 (0.26)[*1]
E_{fd}	1.79	-
δ	51.2 deg	-
slip	0.00	-1.11%

(*1) reactive power demand of IG.

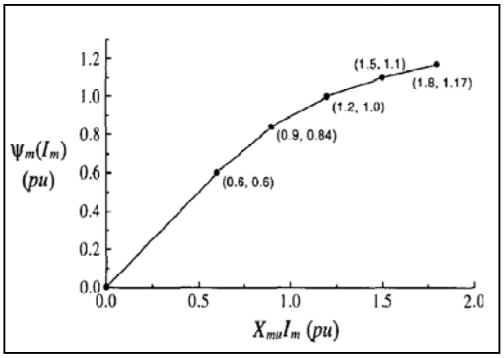


Fig.3 Saturation characteristic of induction machine.

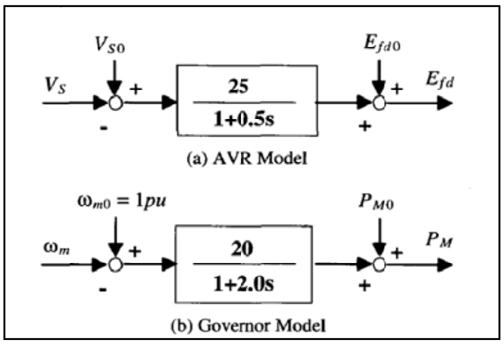


Fig.4 Control System Models of Synchronous Generator.

The torque developed by the wind turbine can be expressed as follows

$$T_w = K_T C_T V_w^2$$

Where K_T is constant determined by the density of the air and the radius of the windmill, C_T denotes the windmill torque coefficient, and V_w denotes the wind speed.

The windmill torque coefficient, C_T can be expressed approximately by using the blade pitch angle of windmill β [deg], and angular speed rate of windmill, λ as follows

$$C_T = (C_1 \beta + C_2) \lambda + (C_3 \beta + C_4)$$

Where $C_{1,2,3,4}$ are the constants [5]

III. STATCOM CONTROL STRATEGY BASED ON PI CONTROLLER

The voltage recovery after the fault clearance of a fault may be assisted by dynamic slip control and pitch control in a wound rotor induction generator wind turbine. It has been shown that the pitch control could help to rebuild the voltage and maintain power system stability efficiently.

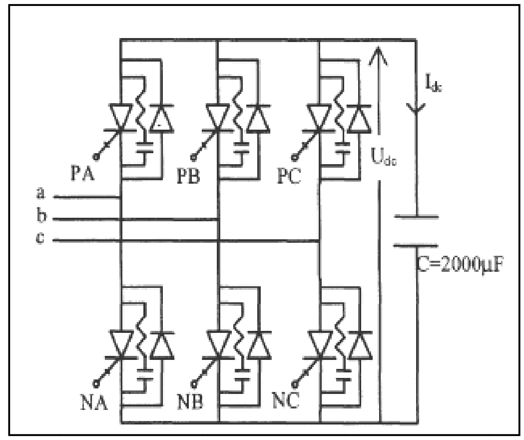


Fig. 5 : Schematic Diagram of STATCOM switching circuit.

A simple control strategy of STATCOM is adopted where only measurement of rms voltage at the wind generator terminal is needed i.e. there is no need of reactive power measurement. STATCOM is used to regulate voltage at IG terminal end under disturbances. An error signal 'e' is obtained by comparing reference voltage with the rms voltage of IG terminal. PI controller progresses the error signal and generates the required angle δ to drive the error to zero. i.e. the induction generator terminal voltage is brought back to reference voltage. In the PWM generators, the sinusoidal reference signal is phase modulated by means of angle δ.The modulated signal is compared against a triangular carrier signal in order to generate the switching signals for the GTO switched VSC. High switching frequencies is used to improve the efficiency of the converter, without incurring significant switching losses.

PI Controller Design

The classical PI Controller has extensive application in industrial control. The structure of continuous time PI controller is used as shown in fig.6, where e (error signal of terminal voltage of IG) is the input and δ is the output of the PI controller.

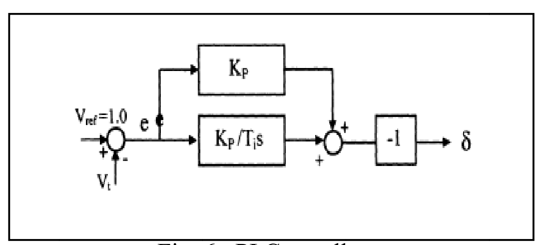
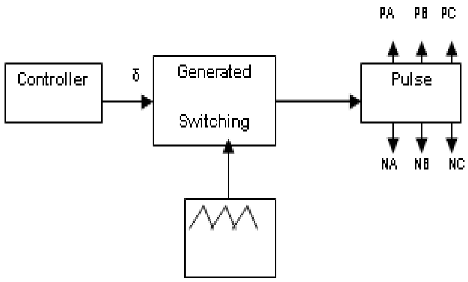


Fig. 6 : PI Controller

Kp & Ti represent the proportional gain and integration time constant respectively. The values of Kp & Ti are chosen as10.0 and 0.01respectively.



IV. SIMULATION ANALYSIS

For simulation purpose a 3LG fault is considered to occur at point F as shown in above Fig.1. The fault occurs at 0.1sec, the circuit breaker (CB) on the faulted line is opened at 0.2 sec and at 1.0 sec the circuit breakers are closed. The simulation time step and total simulation time are chosen 0.00005sec and 10sec respectively. Simulations have been done by PSCAD/EMTDC [2].In this system, steady state and transient performance of STATCOM connected WPGS are demonstrated. The reactive power is needed to supply from the network to the stator winding of the induction generator to establish the rotating magnetic field of he stator. At steady state capacitor bank is inserted at IG terminal to compensate the reactive power. When STATCOM is connected with WPGS then the capacitor value is decreased by 25%. The rest of the reactive power is supplied by the STATCOM. The analysis of transient performance of STATCOM connected WPGS system is done and response of terminal voltage, rotor speed are as shown in fig.7 & Fig.8 respectively. It is clear that using STATCOM with 25% decreased capacitor bank can make the IG stable after occurrence of the fault. But only with capacitor bank at rated value, IG is unstable. So STATCOM can improve the transient performance of WPGS. It is noticeable that he PI Controller improves the transient performance of STATCOM connected (Wind power generation system (WPGS).When wind speed is above the rated speed, the PI controller is used to maintain the output power of wind generator at rated level.

V. CONCLUSION

Reactive power consumption and poor voltage regulation under varying speed are the major drawbacks of the induction generators, but the development of static power converters has facilitated the control of output voltage of induction generator. The FACTS device increase power handling capacity of the line and improves transient stability as well as damping performance of the power system. The static synchronous compensator (STATCOM) consists of shunt connected voltage source converter through coupling transformer with the transmission line. STATCOM can control voltage magnitude and to a small extent , the phase angle in a very short time and therefore has ability to improve the system damping as well as voltage profile of the system. Besides this, it can enhance the transient performance of WPGS as well as entire power by certain percentage when severe network disturbances occur in the power system[2].It is clearly presented that, Wind Power Generation System connected with PI controller equipped STATCOM is transiently more stable. So, it is recommended to connect STATCOM with Wind Power Generation System as it can improve both Steady State as well as transient response of the entire Power System.

VI. SIMULATION RESULTS

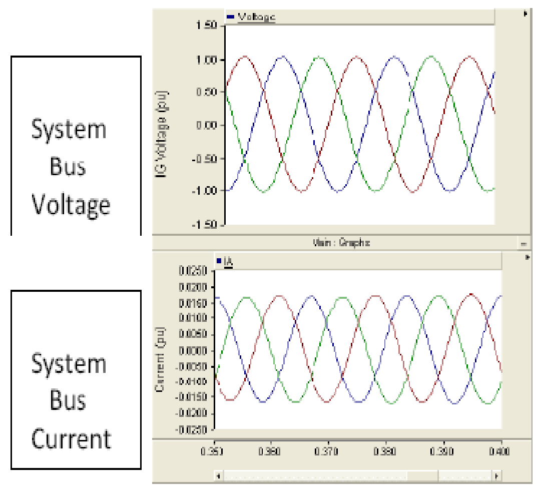


Fig. System without Fault

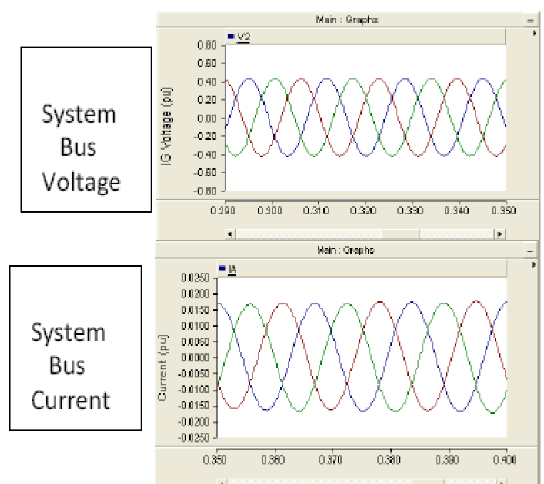


Fig. System With IG

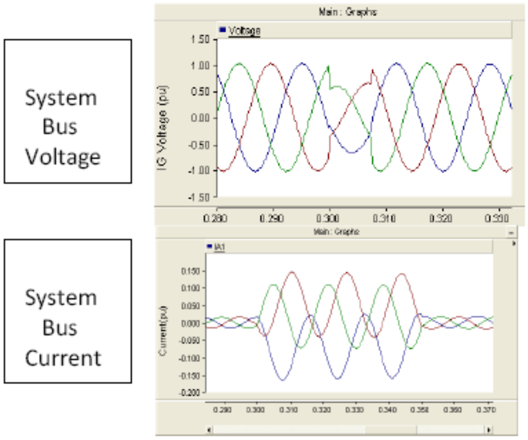


Fig. System with 3LG Fault

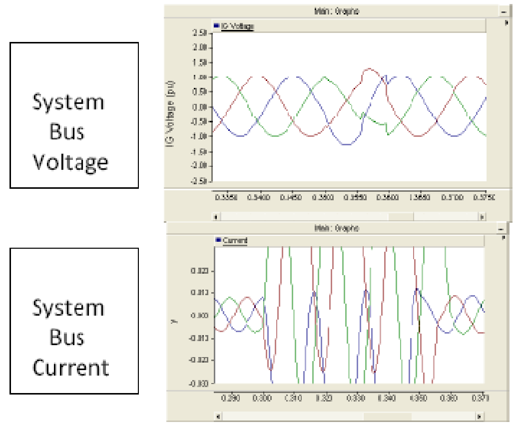


Fig. System With IG & Fault including STATCOM

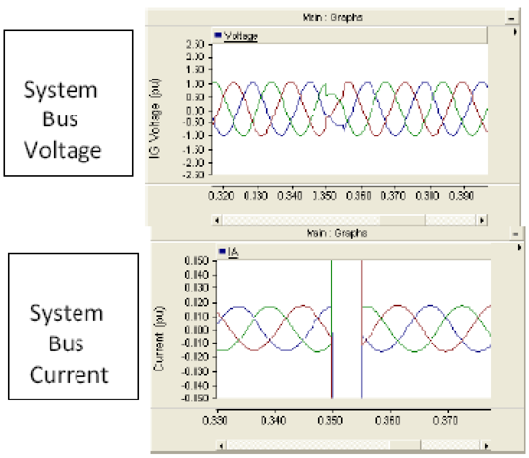


Fig. System With IG & 3LG Fault

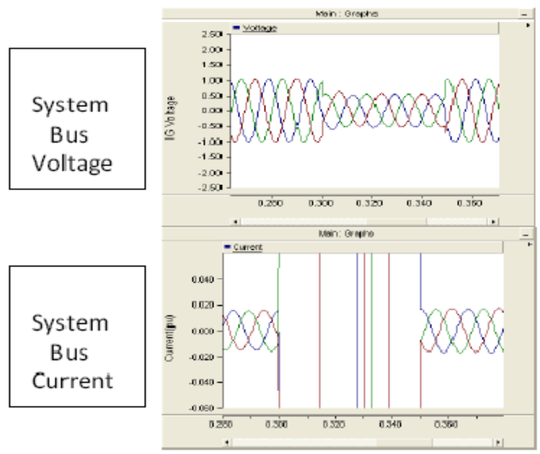


Fig. System With IG & Capacitor bank & Fault

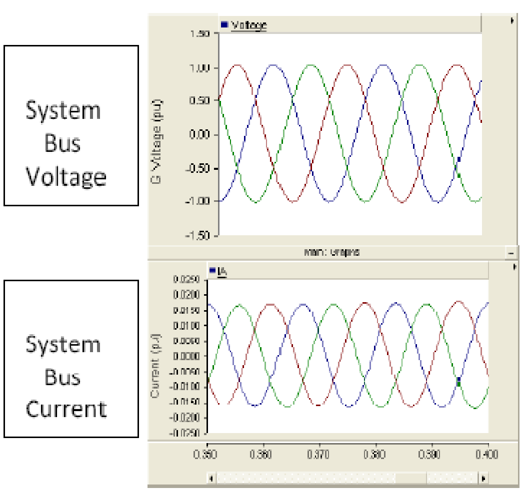


Fig. System With IG & Capacitor bank

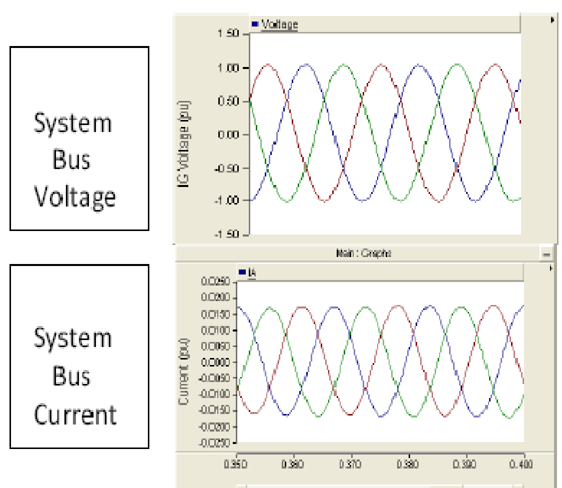


Fig. System With IG & STATCOM only

REFERENCES

[1] *V. Salehi, S. Afahrnia, S. Kahrobaee, "Improvement of Voltage stability in Wind Farm Connection to distribution Network Using FACTS Devices" IEEE 2006, pp.4242-4247*

[2] *S.M.Muyeen, Mohammad Abdul Mannan, Mohd. Hasan Ali, Rion Takahashi, Teshiaki Murata, Junji Tamura, "Stabilization of Grid Connected Wind Generator by STATCOM" IEEE PEDS 2005, pp .1584-1589*

[3] *Haiza Gaztanaga,Ion Etxeberria-Otadui, Dan Ocnasu, "Real- Time Analysis of the transient Response Improvement of Fixed- Speed Wind Farms by Using a Reduced-Scale Statcom Prototype." IEEE transactions onPower Systems, Vol22,No.2, May 2007.*

[4] *V.K.Chandrakar and A.G.Kothari, "Fuzzy-based Static Synchronous Compensator (STATCOM) for improving transient stability performance" International Journal of Energy Technology and Policy, Vol. 5, No. 6, 2007, pp.692-707*

[5] *Junji Tamura, IEEE member, Tetsuya Yamazaki, Kitami Institute of Technology, JAPAN, "Transient Stability Simulation of Power System Including Wind Generator by PSCAD/EMTDC " 2001 IEEE Porto Power Tech Conference 10th ,13th September, Porto, Portugal.*

[6] *Claudio L. Souza et. Al., " Power System Transient Stability Analysis Including Synchronous and Induction Generator", IEEE porto Power tech Proceedings Vol.2,pp.6,2001*

[7] *N.G.Hingorani, L.Gyugyi, "Understanding FACTS: Concepts & Technology of Flexible AC transmission Systems", IEEE power engineering society, IEEEpress, Delhi 2001*

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