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Performance Evaluation of Grid Interconnected Wind Generator System

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Abstract - Recently various FACTS devices have been used for flexible power flow control, secure loading and damping of power system oscillation. Some of those are used also to improve transient and dynamic stability of wind power generation system (WPGS). It is proposed the STATCOM based on the voltage source converter (VSC) PWM technique to stabilize grid connected squirrel cage wind generator system. The study deals with the fuzzy logic based control of wind turbine driven by squirrel cage induction generator (SCIG) connected to grid. The proposed fuzzy logic controller (FLC) is used with nine rules to implement the control strategy for the induction generator. These state variables used for fuzzy logic controller design are the error signals from the model of the induction machine. The computer simulation results show the controller is satisfactory in operation of induction generator (IG) with the significant optimization in the reactive power output. In this work the static reactive compensator (STATCOM) based on voltage source converter (VSC) PWM Technique is presented to stabilize gird connected squirrel cage wind generator system. Simulation results clearly indicate that STATCOM equipped with the proposed fuzzy control gives better and faster performance than STATCOM with conventional controller.

Keyword *- Fuzzy Logic controller (FLC), Pitch Controller, PWM Voltage Source Converter (VSC), STATCOM, Wind Power Generation System (WPGS)*

1. Introduction

Since the installed wind energy capacity is growing continuously, the effect of interaction between the WPGS and grid cannot be neglected. Earlier, disconnection of wind turbine was not of the important consideration whenever there was a problem of supplying voltage. Today this concept has changed because loss of such a considerable part of the power production due to network disturbances can't be accepted any more as it results into in-stability of the power grid. Hence wind power plants (WPP) are forced to maintain the grid codes Due to its simple, rugged and maintenance free construction Induction generator (IG) are widely used as wind generator. IGs are connected directly to a power grid. For generation of active power IGs require reactive power to maintain air gap flux. This reactive power is provided by the grid. During disturbances when faults occurs the reactive power consumption of IGs increases. If grid is incapable to fulfill the reactive power requirements of IGs, it leads to tripping of wind turbines. This affects the voltage profile of the bus to which WPP is connected and results in grid instability.

So to maintain grid stability reactive power compensation is must whenever grid disturbances are considered. Recently voltage-source converters (VSC) or current-source inverters (CSI) based flexible AC transmission systems (FACTS) devices such as Static Var Compensator (SVC), Static Reactive Compensator (STATCOM), dynamic voltage restorer (DVR), solid state transfer switch (SSTS) and Unified Power Flow Controller

(UPFC) have been used for flexible power flow control, secure loading and damping of power system oscillation. Some of those are used also to improve transient and dynamic stability of WPGS. SVC is reported to improve the terminal voltage of induction generator by compensating the reactive power. But STATCOM has somewhat better performance compared to SVC for reactive power compensation. It is reported that STATCOM can recover terminal voltage of wound rotor induction generator after the fault clearance comparatively better than the capacitor banks. The proposed work considers STATCOM, based on voltage source converter (VSC) PWM technique to stabilize the grid connected squirrel cage wind generator system. The PI controller is replaced by the Fuzzy Logic Controller (FLC). STATCOM are popular flexible AC transmission systems (FACTS) devices which are very useful to simultaneously deliver reactive power and support bus voltage of a WPP. Both regulate voltage at terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, they

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generate reactive power (capacitive). When system voltage is high, they absorb reactive power (inductive). In this work, we propose the STATCOM, based on voltage source converter (VSC) PWM technique to stabilize grid connected squirrel cage wind generator system.

A simple control strategy of STATCOM is adopted. Moreover, a comparative analysis for steady state & transient condition has been made between the reactive compensations provided to induction generator with capacitor bank, induction generator with PI based STATCOM & induction generator with Fuzzy based STATCOM. Finally some simulation results are presented where transient stability of WPP is analyzed by using controllers system. Simulations have been done in MATLAB environment.

2. System Model

Fig. 1 shows the model system used for simulation of the transient stability of power system. Here, one 120 kV three phase programmable source is connected to infinite bus through a transformer (120/33 kV transformer) and a double circuit transmission line. One wind farm (Induction Generator, IG) is connected with the network via 25 km transmission line. The wind farm has 6 x 1.5 MW turbines thus the wind farm is having capacity of 9 MW.

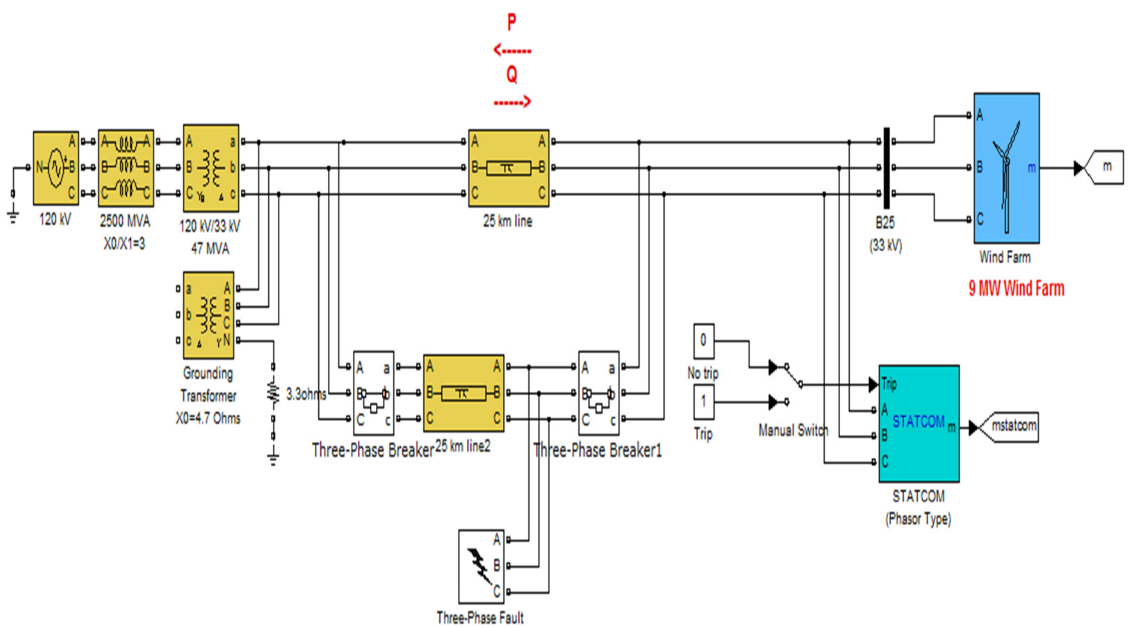

Fig 1. System Model with STATCOM

The fault is occurring on one of the circuits of double circuit transmission line in 33 KV grid. A 3 MVAR capacitor bank is connected internally for reactive power compensation at steady state for each of the wind turbine. The STATCOM is connected with 33 KV bus.

3. STATCOM Control Strategy

The Static Synchronous Compensator (STATCOM) is a shunt device of the Flexible AC Transmission Systems (FACTS) to control power flow and improve transient stability on power grids. The STATCOM regulates voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the STATCOM generates reactive power (STATCOM capacitive). When system voltage is high, it absorbs reactive power (STATCOM inductive). The variation of reactive power is performed by means of a Voltage-Sourced Converter (VSC) connected on the secondary side of a coupling transformer. The VSC uses forced-commutated power electronic devices (GTOs, IGBTs or IGCTs) to synthesize a voltage V2 from a DC voltage source. The principle of operation of the STATCOM is explained on the Fig 2 below showing the active and reactive power transfer between a source V1 and a source V2. In this Fig, V1 represents the system voltage to be controlled and V2 is the voltage generated by the VSC.

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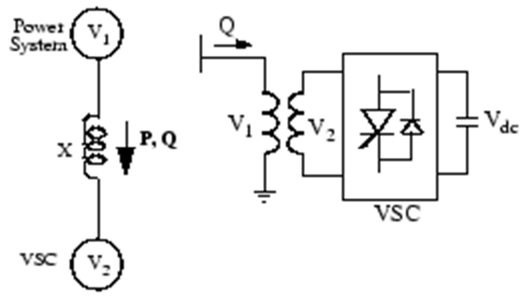

Fig 2. Single line diagram of STATCOM

$P = (V_1 V_2)\sin\delta / X$,
$Q = V_1(V_1 - V_2\cos\delta) / X$
Where,

V_1 Line to line voltage of source 1

V_2 Line to line voltage of source 2

X Reactance of interconnection transformer and filters

Δ Phase angle of V_1 with respect to V_2

4. Fuzzy Controller Design

In this work PI controller in AC Controller of STATCOM is replaced by FLC to modify the overall output. Fig 10 indicates the PI controller implemented in STATCOM.

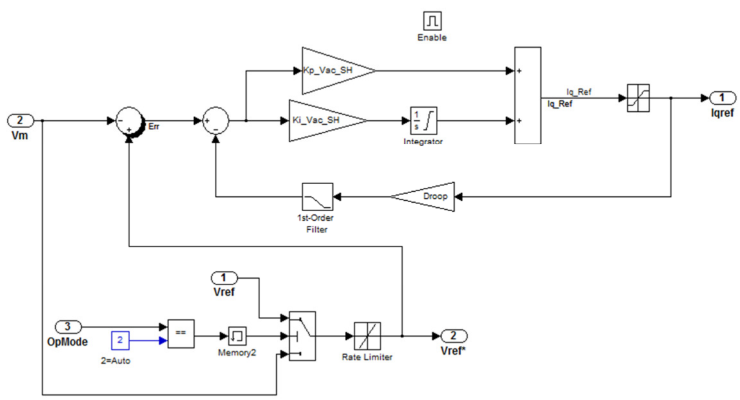

Fig 4. PI Controller connected in STATCOM

Fig 5 indicates the FLC connected in the STATCOM. Two inputs used FLC controller are the error signal & the change in the error signal of AC voltage regulator block inside the STATCOM.

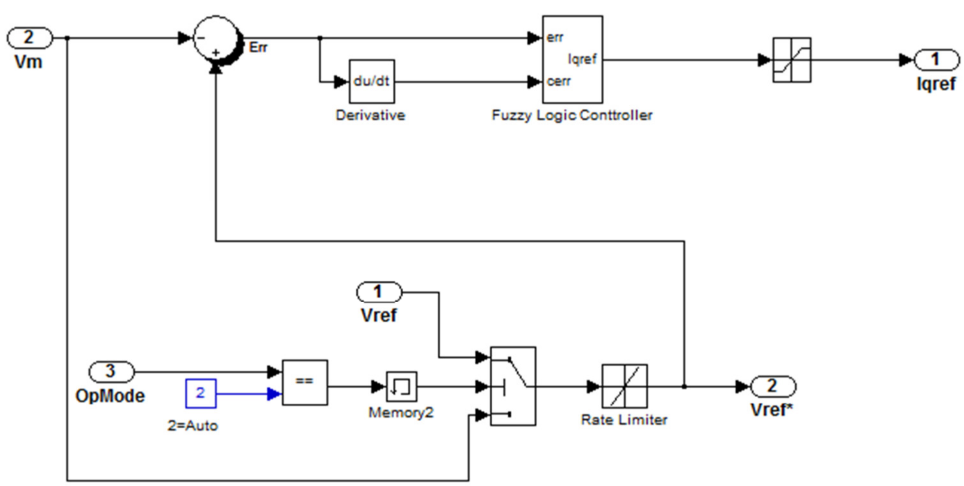

Fig 5. Fuzzy Logic Controller connected in STACOM

A. Fuzzification

To design the proposed FLC, the error signal, err(k), and change of error signal, cerr(k) are considered as the controller inputs. The Iqref , is considered as the controller output. For convenience, the output and inputs of the FLC are scaled with coefficients Ke , Kce , KIqref respectively. These scaling factors can be constants or variables and play an important role for FLC design in order to achieve a good response in both transient and steady states. In this work, these scaling factors are considered as constant for the simplicity of controller design, and are selected by trial and error. The values of are Ke , Kce , KIqref chosen 2, 10 and 0.5 respectively. The triangular membership functions with overlap are used for the input & output fuzzy sets as shown in Fig 7 The linguistic variables are represented by N (Negative), Z (Zero), and P (Positive) for input.

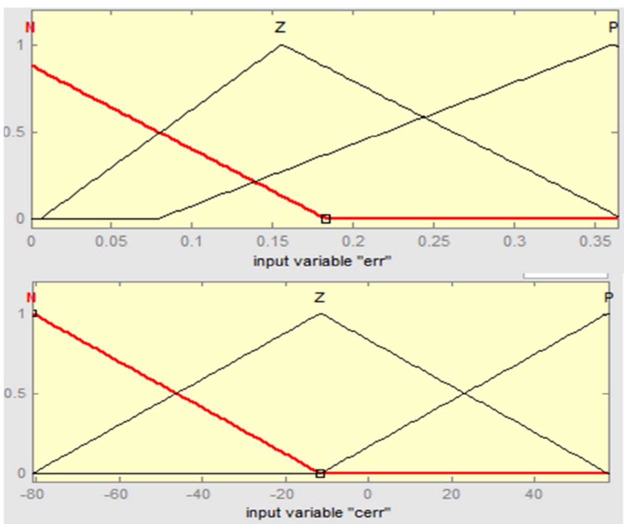

Fig 7. Fuzzy Set for input and their corresponding membership functions

The linguistic variables are represented by Lower Big (LB), Lower Medium-2 (LM2), Lower Medium-1(LM1), Lower Small (LS), Higher Big (HB), Higher Medium-2 (HM2), Higher Medium-1(HM1), and Higher Small (HS) for output.

Fuzzy Processing (Rule Base)

The fuzzy mapping of the input variables to the output is represented by IF-THEN rules of the following forms

IF (err = N) and (cerr = N)THEN (Iqref = LB)

IF (err = P) and (cerr = P)THEN (Iqref = HB)

The entire rule base is given in the Table-1 below. There are total nine rules used for achieving the desired performance of system.

Table 1: Fuzzy Rule Base

Iqref		***cerr***		
		N	**Z**	**P**
err	**N**	LB	LM2	LM1
	Z	LS	M	HS
	P	HM1	HM2	HB

B. De-fuzzificataaion

In this work, for the inference mechanism Mamdani's prod-probor method is used for inference mechanism. The center of gravity method is used for defuzzification to obtain Kp and Ki, which is given by following equation:

$$I_{qref} = \sum_{i=1}^{n} \frac{\mu_i C_i}{\mu_i}$$

Where,

n is the total number of rules,

µi is the membership grade for the i-th rule, and

Ci is the coordinate corresponding to respective output or consequent membership function.

C. Simulation Results under Steady State Condition

The model shown in the Fig 1 is simulated under steady state condition and the measurement at Bus B25 is taken. The fault block & breaker switching is disabled for steady state condition measurements.

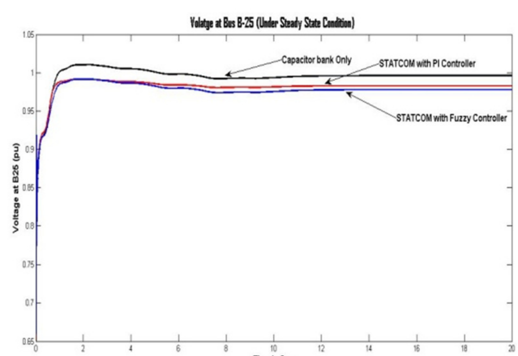

Fig 9. Voltage at Bus B-25 under steady state condition

Initially the simulation is carried for three different conditions (i.e for capacitor bank, STATCOM with PI, STATCOM with Fuzzy Controller) for the reactive power compensation of the wind farm and the voltage measurement is done at bus.From the simulation result it can be seen that the in all the three cases the voltage profile achieved is similar. The voltage at the B25 bus terminals is maintained to 1 p.u level approximately.

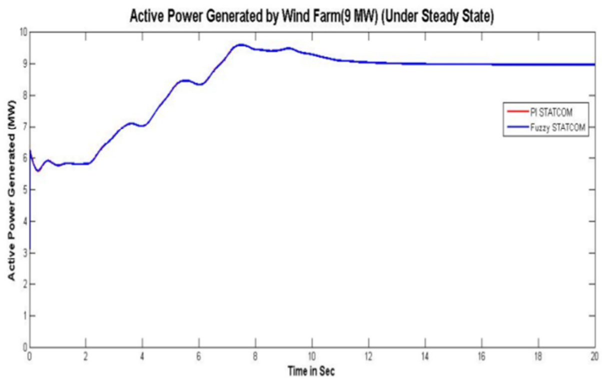

Fig 10. Active Power Demand under steady state condition

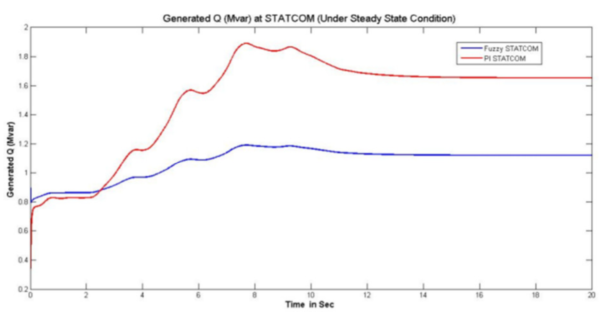

Fig 11. Reactive Power Demand under steady state condition

The simulation is carried for two different conditions (i.e for STATCOM with PI, STATCOM with Fuzzy Controller) for the reactive power compensation of the wind farm. The measurement for reactive power demand at the B-25 bus is done. From the simulation result it can be seen that the STATCOM with fuzzy controller is matching the reactive power demand of the Interconnection bus exactly similar to that of the STATCOM with PI Controller.

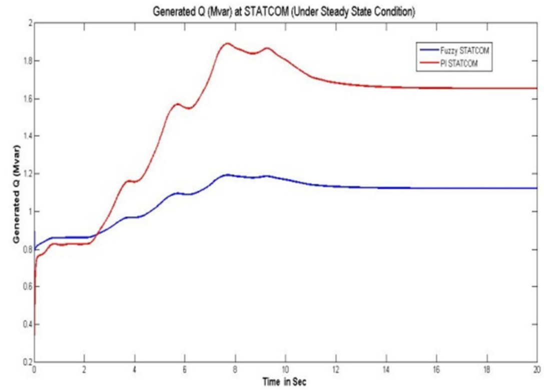

Fig 12. Generated Q (Mvar) at STATCOM under steady state condition

The simulation is carried for two different conditions (i.e for STATCOM with PI, STATCOM with Fuzzy Controller) for the reactive power compensation of the wind farm. Now the measurement for reactive power generated (Q) in Mvar is done. Now from the simulation result it can be seen that with maintaining the voltage profile & supporting the reactive power demand at the interconnecting the bus. The reactive power generated by t he STATCOM with fuzzy controller is comparatively less after 3sec & continuous to remain less after stabilization of system.

With the fuzzy controlled STATCOM the reactive power generation required for the active power generation of the Induction generator is optimized. The overshoot has been reduced from 1.8 Mvar to 1.2 Mvar during the starting & during the steady state it has been reduced from 1.7 Mvar to 1.2 Mvar.Considerable amount of reduction in the reactive power generated by the STATCOM is seen.

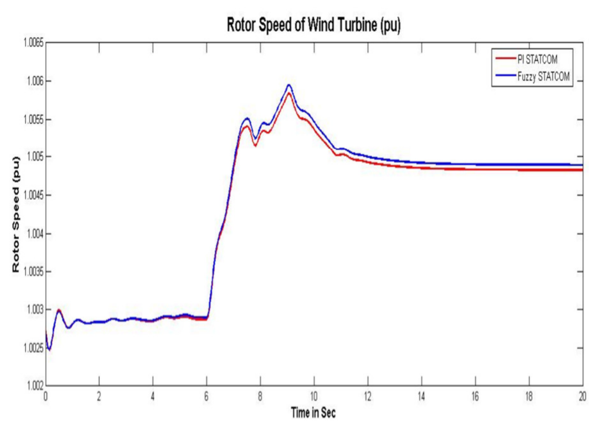

Fig 12. Rotor speed of wind turbine (in p.u) under steady state condition

The rotor angle during the operation is needs to be observed for the satisfactory active power generation of the Induction Generator. With the optimization of the reactive power generation in the STATCOM the rotor angle should be maintained same as in case of the previous case. Hence the simulation result for the rotor speed of wind turbine under steady state is plotted in the MatLab result shown in the fig above.

From the above simulation result it is seen that the rotor speed (in pu) with STATCOM with Fuzzy controller is approximately equal to the STATCOM with PI controller where as the voltage profile & the reactive power demand at the interconnecting bus (B-25) is unchanged.

5. Conclusion

In the above work for the wind power plant application the considered model has been simulated for STATCOM with PI & STATCOM with fuzzy controller both under steady state & various transient condition. The simulation results are tabulated in the Table 3. It can be concluded that the settling time & overshoot in Mvar generated at STATCOM is less in case of Fuzzy compared to PI controller. Even for the same active power generation the reactive power generation is optimized in case of fuzzy controlled based STATCOM as compared to PI based STATCOM. So it is recommended to connect the STATCOM with fuzzy controller for wind power plants having Induction generators. STATCOM for sure gives faster response, enhance stability & improve performance of grid interconnected Induction generator based wind system. Places where the switching capacitor banks are already installed. STATCOM can be installed. The reactive power compensation can be provided partially by capacitor & STATCOM to optimize the performance.

Reference

1) S. M. Muyeen, Mohammad Abdul Mannan, Mohd.Hasan Ali, Rion Takahashi, Toshiaki Murata, Junji Tamura,“ Stabilization of Grid connected Wind Generator by STATCOM", Power Electronics and Drives Systems, 2005. PEDS 2005. International Conference on Volume 2, Issue, 28-01 Nov.2005 (page 1584-1589).

2) M. Jazayeri , M. Fendereski , Semnan University, Semnan, Iran Islamic Azad University Science & Research Branch, Tehran, Iran “Stablization of Grid Connected Wind Generator During Power Network Disturbances By STATCOM” UPEC pp 1181-1186 Issue 2007 (page 1182-1186)

3) I. Erlich, Senior Member, IEEE, C. Feltes, F. Shewarega, Member, IEEE, and M. Wilch University Duisburg-Essen “Interaction of Large Offshore Wind Parks with
the Electrical Grid” DRPT 2008 6-9 April 2008 Nanjing China (page 2658-2663)

4) Mounes Alhajali, Brendan Fox, Jason Kennedy and D. John Morrow, Member, IEEE “Impact of Wind Variability on Weakly Interconnected Power Systems” 978-1-4244-6551-4/10 ©2010 IEEE, (page 1-6)

5) O. A. Mohammed, Fellow, IEEE, M. A. Nayeem, Student Member, IEEE and A. K. Kaviani, Student Member IEEE," A Laboratory Based Microgrid and Distributed Generation Infrastructure for Studying Connectivity Issues to Operational Power Systems”. 978-1-4244-6551-4/10/ ©2010 IEEE,(page 1-6)

6) Prechanon Kumkratug , Faculty of Engineering at Si Racha, Kasetsart University, 199 M.6, Tungsukhla, Si Racha, Chonburi, 20230, Thailand “STATCOM Stabilizer based on Fuzzy Logic Control for Damping Power Oscillation” American Journal of Applied Sciences 8 (10): 1041-1044, 2011, ISSN 1546-9239 © 2011 Science Publication Pg No.1041-1044

7) Leonel de Magalhães Carvalho, Student Member, IEEE, Mauro Augusto da Rosa, Member, IEEE, Armando Martins Leite da Silva, Fellow, IEEE, and Vladimiro Miranda, Fellow, IEEE, "Probabilistic Analysis for Maximizing the Grid Integration of Wind Power Generation," IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 27, NO. 4, NOVEMBER 2012 (page 2323-2330)