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Application of STATCOM to Enhance the LVRT Capability of DFIG Based Wind Turbine Generating System

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Abstract: This paper present application of STATCOM to enhance the LVRT (Low Voltage Ride-Through) capability of DFIG (Doubly-Fed Induction Generator) based wind turbine generators. Two different controlled techniques are applied for STATCOM controller. 1) Decoupled Current controlled technique 2) Hysteresis current controlled technique. Simulation results, are carried out for both the controlled techniques and based on that performance comparison is done. Three phase fault is simulated at PCC bus. Among various controlled techniques of STATCOM these two are widely used for small and large power requirement.

Key Words: DFIG, LVRT, STATCOM, HCC, wind turbines.

I. INTRODUCTION

With increasing energy demand to meet this demand renewable energy sources are the only option. Environmental pollution is a big issue today. Renewable energy sources are providing good option. Penetration of wind energy is increasing day by day. Renewable sources are like wind, solar, bio-mass, tidal, hydro power is widely used sources of energy. With integration wind energy in power system, minimize environmental problems. The challenges faced by wind power generation are voltage fluctuation, power quality issues, voltage regulation. These problems largely affect on the distribution network, where power quality and continuity of supply is more important.

Now a day's individual wind generation unit capacity is increased to 2 MW. Fix Speed Wind Turbines (FSWT) were used previously. Induction generators were used in FSWT. Variable Speed Wind Turbine (VSWT) were took place and slip ring induction generator were used. DFIG replaced slip ring induction generators [5]. LVRT capability is defined as *"Ability of wind turbine to remain connected to the grid without tripping for a specific period of time at the point of connection [3]"*.

Doubly-Fed Induction Generator (DFIG) has Stator and Rotor terminals. The stator is directly connected to the grid and Rotor is connected with two back-to-back convertors. Between two convertors RSC and GSC DC-link capacitor is connected [5]. Power converters are designed to carry 30% of generator rated power. GSC (Grid Side Convertor) is used to maintain voltage and frequency at grid side.RSC (Rotor Side Convertor) [3] is used to control active and reactive power. Among various FACTS devices STATCOM has faster dynamic control [4]. STATCOM (Static Synchronous Compensator) and SVC (Static Synchronous Compensator) are most used FACTS devices. STATCOM is a parallel compensating device. STATCOM passes following advantages.

1. STATCOM provides reactive support during a fault.
2. STATCOM Maintain unity power factor at source side.
3. Faster dynamic response.

II. DECOUPLED CURRENT CONTROL TECHNIQUE

2.1 Overall Control Scheme of STATCOM Connected With DFIG

Fig.1 shows the overall control scheme of STATCOM is connected at PCC [2]. Here DFIG generate power and fed to the grid using step-up transformer [6]. Three phase fault is creating at PCC. During fault period STATCOM is connected parallel at PCC and after removal of fault STATCOM will be disconnected from the grid. STATCOM inject reactive power at PCC and DFIG will remain connected to the grid.

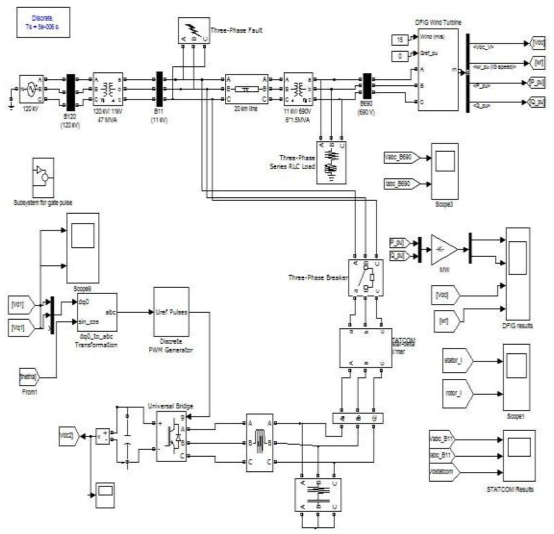

Fig.1 MATLAB Simulink Model of Overall Control Scheme of STATCOM Connected With DFIG

This technique is widely used for high power applications. This method requires measurement of three phase voltage and current. Two component id and iq are controlled using four cascaded pi controllers [6]. One pi controller maintains DC-link voltage constant, another pi controller control PCC voltage. The reference signal is generated from the output of these two pi controller [6]. The reference signal is compared with direct and quadrature axis component of the current, after inverse park transformation these signals is given to the gate pulse of the inverter. Injected real and reactive power is given by following equation.

$$p = V_d I_d + V_q I_q$$

$$q = V_q I_d - V_d I_q$$

Vq=0 hence Id represent active power injection and Iq represent reactive power injection by STATCOM [7]. System voltage remains constant.PLL (Phase Locked Loop) is used to synchronies control output with transformed component id and iq[6].

Fig.1 shows the control scheme of STATCOM connected parallel at PCC with DFIG.STATCOM inject reactive power during fault period and maintain voltage at PCC [2]. Initially circuit breaker is open and breaker close during fault duration and STATCOM will be connected [9]. Parallel RC filter and series inductor are used to filter the output of inverter and absorb dc component from output. DC-link voltage and inductance value are determined by following equation [9]. Modulation index m is 1.

$$Vdc = 2\sqrt{2}V_{ll} / \sqrt{3}\text{m}$$

$$Lf = \sqrt{3}mVdc / \{12 * a * fs * icrpp\}$$

$$icrpp = \text{ripple current}$$

$$fs = \text{switching frequency}$$

$$V_{ll} = \text{Ac line output voltage of STATCOM}$$

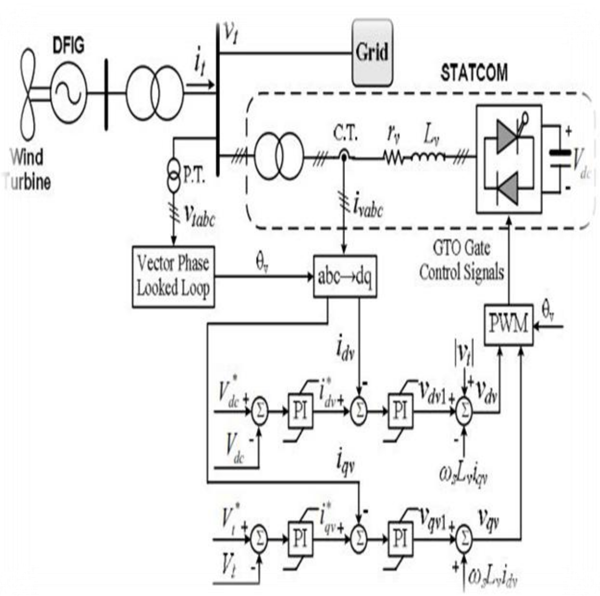

Fig.2 control Scheme of STATCOM connected at PCC

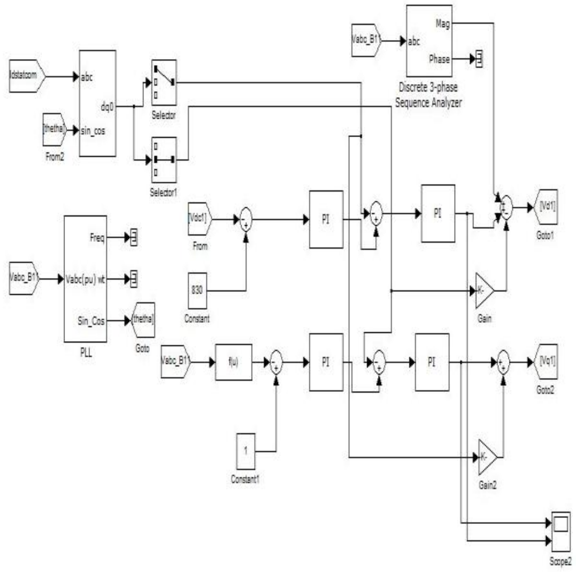

Fig.3 control Scheme of STATCOM in MATLAB Simulink

2.2. DFIG Fault results without implementation of STATCOM

Fig.4 shows the DFIG behavior during a fault. A fault occurred in between duration.3s to.4s, during this time voltage goes down and current increase rapidly [1]. Dc-link voltage gets disturbed, active power gets reduced and DFIG draw more reactive power from the grid [2], rotor speed increase during fault period. STATCOM will be connected at 0.3 to 0.4s and improves voltage level to its normal value of 1 p.u.

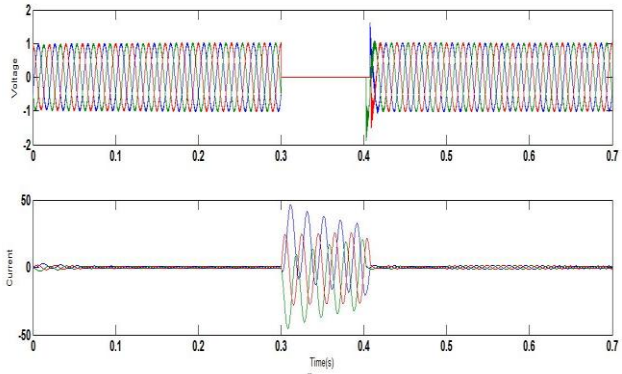

Fig.4. Voltage and current waveform at 11kv bus during fault

From Fig.4 voltage goes very down up to 85% and LVRT (Low Voltage Reid-Through) capability will prove a continuous operation of DFIG even if voltage is down to 85%.Current is very high during fault period it is 20 to 30 times higher than normal current. During fault period active power dropdown and system demand more reactive power from the source. The reactive power requirement is fulfilled by STATCOM [1].

Dc-link voltage will fluctuate during fault period. The rotor will rotate with higher speed. When a fault occurs in a high current will flow from the stator. Stator and rotor are mutually coupled with each other hence high amount of current will flow from the rotor. Convertors are rated to

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handle sleep times power of rated power so convertors will damage from high current. Crowbar protection is provided to protect convertors from high power [2]. DC Crowbar is used to provide protection to DC-link capacitor while AC Crowbar protection is to bypass Rotor Side Convertor (RSC).

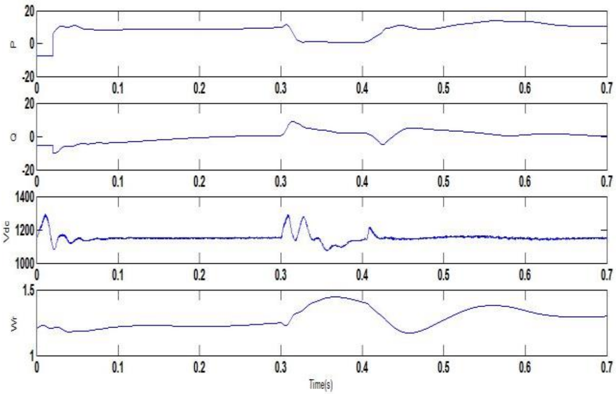

Fig.5 Active and reactive power, DC-link voltage and rotor speed current during a fault

2.3. DFIG fault result with implementation of STATCOM

STATCOM provide reactive power support during a grid fault, hence the voltage gets stabilized and DFIG will not disconnect and continue to supply load [1]. STATCOM maintain DC-link voltage constant and active power to rated its rated value [7].

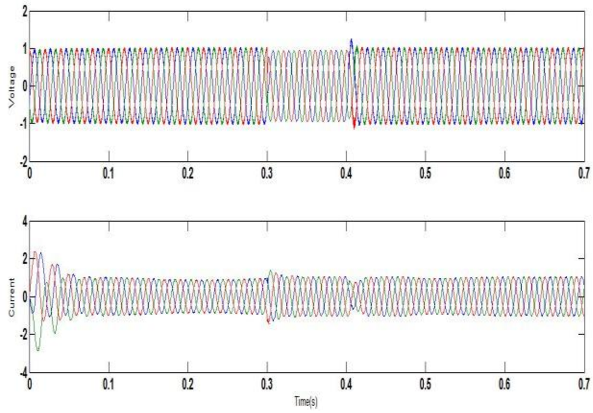

Fig.6 Voltage and current waveform at 11kv bus

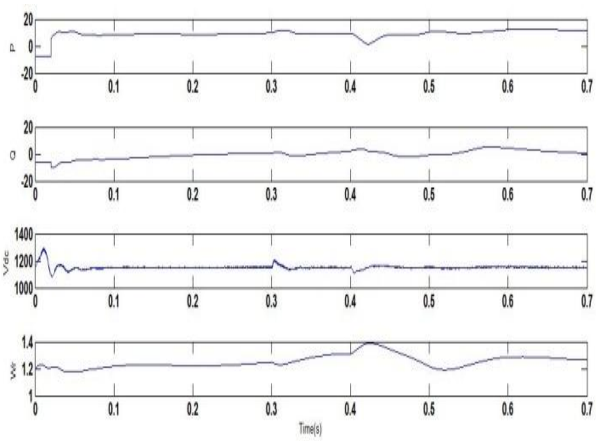

Fig.7 Active and reactive power, DC-link voltage and rotor speed current during a fault

2.4 Specifications

Parameter	Generator (DFIG)	STATCOM
Power	1.5 MW	3MVAR
Transformer voltage	690V/11KV	415V/11KV
Capacitor voltage	1150V	700V
Rated Wind speed	15m/s	---
DC- link capacitance	10PF	10000 μF
Frequency	50HZ	50HZ
Stator current	1811.25 Amp	---
Rotor current	603.73 Amp	---

III. HYSTERESIS CONTROL TECHNIQUE

3.1 Hysteresis current controller

Fig.8 shows the control scheme of STATCOM using HCC (Hysteresis Current Control) technique. The hysteresis current control technique is used for low power applications [6]. Hysteresis current control technique injects less harmonic contents in the network.

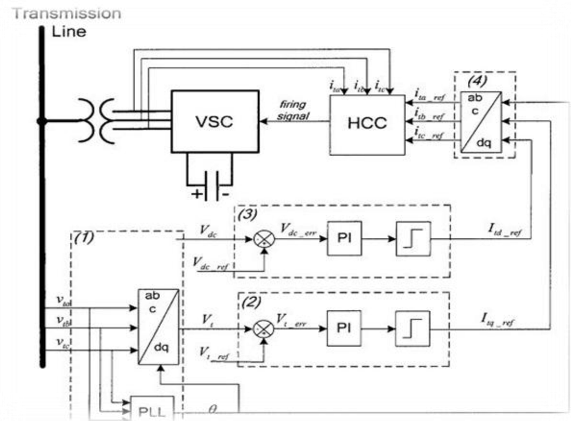

Fig.8 Block diagram of the control scheme of STATCOM

HCC technique has simple control technique and it is cheaper. Here two pi controllers are used [8]. One pi is used to regulate PCC bus voltage and maintain a voltage within permissible limits. Second one uses to maintain DC-link voltage constant across the capacitor

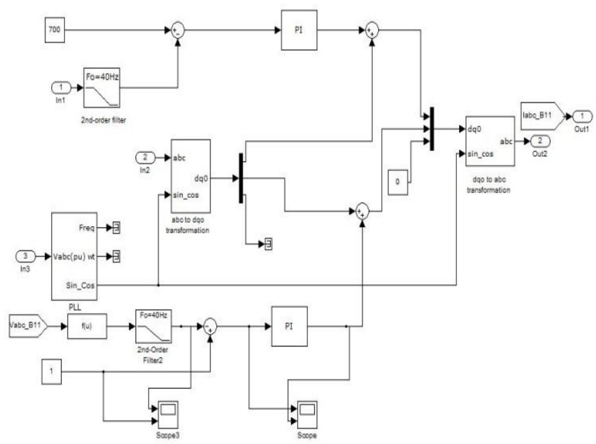

Fig.9 Control Scheme of STATCOM in MATLAB Simulink

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Input of pi id and iq is given by park transformation. Input will be compared with the reference value and it will generate an error signal. This error signal is given to the input of inverse park transformation and then HCC. Fig.10 shows the Hysteresis current controller.

The reference signal is generated from the control scheme of STATCOM and it is compared with the actual three phase current [6]. All three phases will compared individually and error signal is given to relay. Six Switches of inverter will trigger according to the output of the relay. Input signal to the lower switch in each leg will inverted by not gate.

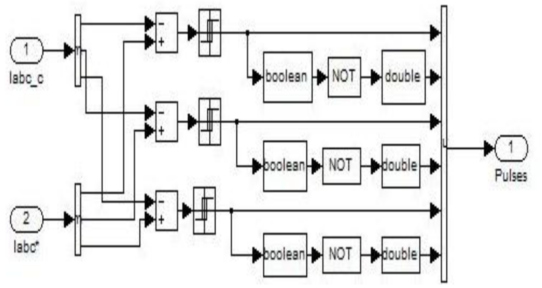

Fig.10 Hysteresis current Controller

3.2 DFIG Fault results with the implementation of STATCOM using HCC (Hysteresis Current Controller)

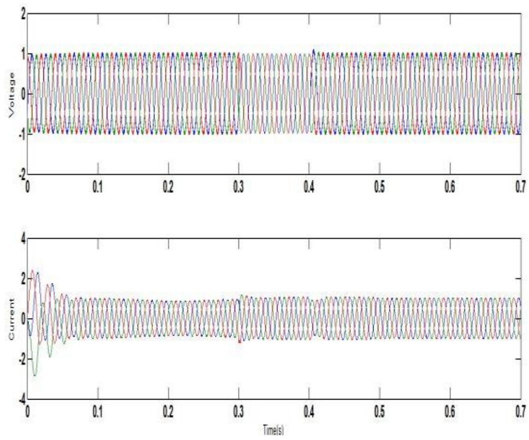

Fig.11 Voltage and Current Waveform at 11kv bus (fault duration 0.3s to 0.4s)

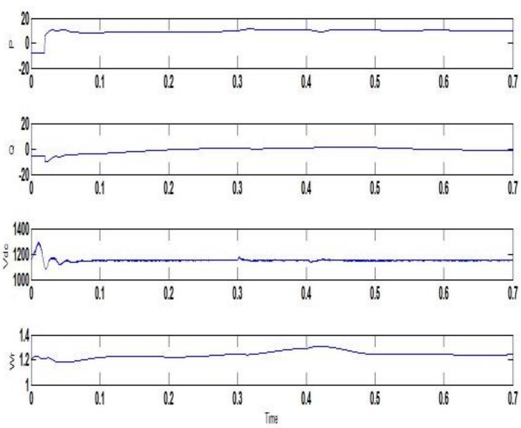

Fig.12 Active and reactive power, DC-link voltage and rotor speed current during fault, with STATCOM implementation with HCC technique.

With the implementation of SATCOM we can maintain voltage levels at PCC to 1 p.u. Value and harmonic content are less with this method of controlling of STATCOM. Current is also got reduce and gets stable as shown in fig. 11. Active power will drop down and system demand more reactive power [8].

3.3 Comparison between Decoupled current control and Hysteresis current control For STATCOM connected with DFIG

Decoupled current control and Hysteresis current control are two most used techniques for low and high power applications.

- For low power application hysteresis current controlled technique is widely used and for high power application Decoupled current control controlled technique is preferable.
- HCC controls the output current of STATCOM current injected to bus, thus fast dynamic response is achieved.
- HCC has Simple, controlled strategy compare with Decoupled current control technique.
- HCC injects fewer harmonic compared with Decoupled control technique

IV. CONCLUSION

Doubly-Fed induction generator is fault sensitive. DFIG remain connected to the grid even if voltage drops to 85% of its rated value. STATCOM provide Low Voltage Ride-Through capability to DFIG. Three phase Fault is simulated for two different control technique of STATCOM Decoupled current control technique and Hysteresis current controlled technique (HCC). Hysteresis current control technique is simple control technique and injects less harmonic content in the system. Hysteresis is widely used for low power applications. STATCOM enhance LVRT capability of DFIG during fourth period of 0.1s and recovers system voltage to its normal value at the point of common coupling (PCC).

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