OPERATION OF DOUBLY FED INDUCTION GENERATOR WITH INTEGRATED ACTIVE FILTER CAPABILITIES USING GRID SIDE CONVERTER AND PV

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Abstract—This paper presents doubly fed induction generator based wind energy conversion system which deals with the operation doubly fed induction generator (DFIG) with an integrated active filter capabilities using grid side converter. Both converters rotor side converter (RSC) and grid side converter (GSC) are used to extract maximum power and supplying harmonics in addition to its slip power transfer respectively. Grid side converter is working as an active filter when wind turbine is stalling condition. Both control algorithms are presented in detail. The proposed system is simulated using MATLAB/Simulink.


I. INTRODUCTION

Energy demand and environmental pollution are major concern in daily life. With increase in population energy demand has increased. But conventional energy sources are limited in nature. Therefore, there is need for renewable energy sources because they are and unlimited in nature. While considering the cost, wind energy is most preferred. Since 1990, Most of wind turbine manufactures made constant speed wind turbine with power level below 1.5 MW with squirrel cage induction generator and capacitor banks. Late of 1991 wind turbine manufactures have changed to variable speed wind turbine power levels from 1.5 MW[3]. Wind turbines are used to convert kinetic energy into electric energy. By observing wind turbine characteristics, to obtain maximum power wind turbine is run at variable speed. Doubly fed induction generator is preferred out of variable speed wind turbine because of their simplicity and lower cost. Also DFIG has high energy output. Doubly fed induction generator can be run at sub synchronous and super synchronous speed[4]. Maximum power [MPPT] can be extracted by using RSC. Maximum power point tracking is used to extract maximum power which can be obtained by varying wind speed. Peak power point tracking algorithm is based wind turbine characteristics. In first machine is run at a speed, and output power is measured based that speed. After that wind speed is increased and corresponding power is measured. Then change in power is corresponding to the change in wind speed. This procedure is repeated when maximum power is obtained In the initial days reactive power control and harmonics compensation are achieved by using RSC. Due to this harmonics are injected into the rotor windings. This causes losses in the machine. Later, the reactive power control and harmonics compensation are achieved by using GSC. So harmonics are not entered into the machine.

After that combination of RSC and GSC are used for reactive power control and harmonics compensation.

Initial day’s direct current control technique is used to compensate harmonics. Later indirect current control technique is used to compensate the harmonics. In this work GSC is used to compensate harmonics. RSC is used to control reactive power. GSC is working as an active filter when wind turbine is stalling condition.

Here hysteresis current controller is used to control GSC. Two type controller is used at RSC i) Hysteresis controller ii) PWM controller. Also in this paper we discuss about PV is integrated with DC link.

II. SYSTEM DESCRIPTION
Fig. 1 shows proposed system of DFIG based wind energy conversion system. In this stator is directly connected to grid and rotor is connected to grid via converters, RSC and GSC. A dc link is connected between these converters.

A non linear load is connected at the point of common coupling. RSC is used to extract maximum power (MPPT) and GSC is used to compensate harmonics and maintain dc link voltage constant. Harmonics created by the nonlinear load is eliminated by GSC therefore stator and grid currents are harmonic free. Grid currents are calculated by subtracting load current from the summation of stator current and grid side converter current.

III. SIMULATION MODEL

Fig.2 Simulation model of the proposed system

IV. DESIGN OF DFIG BASED WIND ENERGY CONVERSION SYSTEM.

a) DC link voltage

Selection of DC link voltage is depends on PCC voltage and rotor voltage. But rotor voltage is slip times rotor voltage. Here stator – rotor turns ratio is 2:1. Therefore rotor voltage is lower than stator voltage. Hence for the selection of DC link voltage we consider only PCC voltage. PCC voltage is 230 V and DC link voltage can be calculated as per the equation [1]

\[ V_{dc} \geq \frac{2\sqrt{2}}{\sqrt{3} \times m} \times V_{ab} \]

Where \( V_{ab} \) - PCC voltage
\( m \) - Modulation Index

b) VSC rating

Here the system is operating speed is between 0.7-1.3, because slip is 0.3. Rotor active power is slip times stator reactive power. Therefore rotor reactive power is calculated as

\[ Q_r = S_{max} \times Q_s = 0.3 \times 2 \times 1000 = 600 \text{ VAR} \]

V. CONTROL STRATEGIES

a) Control of RSC

Rotor side converter is used to extract maximum power which can be achieved from MPPT. Direct reference rotor current is selected to obtain maximum power at a particular wind speed. This particular wind speed is obtained by MPPT. Two type controller used at the RSC. First is hysteresis controller is used. After that PWM is used. Direct axis reference current is selected to obtain that particular speed by using the equation

\[ i_{dr}^*(k) = i_{dr}^*(k-1) + k_{pd} (\omega_{er}(k) - \omega_{er}(k-1)) + k_{id} \omega_{er}(k-1) + k_{id} \omega_{er} \]

Where \( \omega_{er} \) - Speed error
\( k_{pd} \) - Proportional constants of the speed controller
\( k_{id} \) - Integral constants of the speed controller
ROTOR SIDE CONVERTER WITH PWM CONTROLLER

PWM signals are generated by comparing three phase reference rotor voltages and triangular carrier wave with fixed switching frequency. In this model PV is integrated with DC link to control the rotor side converter.

b) SIMULATION MODEL OF ROTOR SIDE CONVERTER WITH HYSTERESIS CONTROLLER

Fig. 3 Simulation model of rotor side converter with PWM controller

Fig. 4 Simulation model of rotor side converter with hysteresis controller

VII. MPPT PROGRAM

Maximum power point tracking is used to extract maximum power which can be obtained by varying wind speed. Peak power point tracking algorithm [2] is based wind turbine characteristics. In first machine is run at a speed, and output power is measured based that speed. After that wind speed is increased and corresponding power is measured. Then change in power is correspond to the change in wind speed. This procedure is repeated when maximum power is obtained.

```
function w_ref = mppt(P,T,w)
persistent w_old P_old delw_old
if isempty(P_old), P_old = 0; end
if isempty(delw_old), delw_old = 0; end
if isempty(w_old), w_old = 0; end
P1=P+P;
T1=T;
w1=w;
Pband=0.1;
K1=2.6;
delP=P1-P_old;
%delT=T1-delw_old;
delw=delP*K1;
if (delw_old==0)
    S=sign(delP);
else
    S=sign(delP)*sign(delw_old);
end
delw=S*abs(delw);
if (abs(delP)<Pband)
    w_ref=P_old
else
    w_ref= w_old + delw;
end
```

b) Control of GSC

GSC is used to eliminate harmonics produced by the nonlinear load. Here we use hysteresis controller and indirect current control is to make grid current balanced. Grid current is calculated by subtracting load current from the summation of stator current and GSC current. Here GSC is working as filter when wind speed is zero. Then active power is zero and reactive power is zero. GSC is working as active filter by supplying harmonics to eliminate harmonics produced by nonlinear load.

Fig. 5 Simulation model of grid side converter with hysteresis controller
VIII. PV MODELLING

Here DC link is integrated with PV. For that PV generates current which is function of cell voltage, conductance and module temperature. In this no of solar cell is 72 and the short circuit current is calculated from the module temperature. Photons generated by the current at given irradiance is calculated by the equation

\[ I_{ph} = G \times I_{sc}; \]

IX. SIMULATION RESULTS

Fig 7 shows active power fed to grid when wind speed is 12 m/s and DFIG runs at speed of 1400 rpm

Fig 8 Shows nonlinear current when wind speed is 12 m/s and nonlinear load is connected at the point of common coupling.

Fig 9 shows three phase rotor current when rotor runs at speed 1500rpm

Fig 10 shows the dc voltage when DC link system is integrated with PV

Fig 11Grid current when wind speed 12 m/s. Grid current can be calculated by subtracting load current from the summation of stator current and GSC current.
Fig 11 Grid current when wind speed 12 m/s

X. CONCLUSION

GSC control is used to eliminate harmonics produced by non linear load. RSC is used to extract maximum power by MPPT. GSC is works as an active filter when wind turbine is stalling condition. PV module is used to reduce transients. The system is simulated in MATLAB/Simulink.

REFERENCES

[1] N K Swami Naidu and Bhim Singh "Doubly fed induction generator for wind energy conversion systems with an integrated active filter capabilities” IEEE transactions on industrial informatics Vol.11, No.4, August 2015.

