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Power Quality Improvement in Grid Connected DFIG-Wind System using ANFIS

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ABSTRACT

This paper proposes a concept of ANFIS based DFIG controller to variable speed wind turbine system for power smoothening. Power fluctuations due to the unpredictable nature of the wind are eliminated by introducing battery energy storage system in the dc link between two back-to-back connected voltage source converters. The design of BESS is presented for feeding regulated power to the grid irrespective of the wind speeds. The control algorithm of the grid-side converter is implemented with ANFIS for feeding regulated power to the grid. Rotor-side converter is controlled for achieving MPPT and unity power factor operation at the stator terminals. And also to improve the efficiency of WECS an MPPT controller is proposed in this paper. The ANFIS based DFIG system is to be implement in MATLAB.

Key Words: *Grid Control, micro-grid, wind power generation, ANFIS.*

INTRODUCTION

Over the past few years, the growth in the use of nonlinear loads has caused many power quality problems like high current harmonics, low power factor and excessive neutral current. Nonlinear loads appear to be current sources injecting harmonic currents into the supply network through the utility's Point of Common Coupling (PCC). This results in distorted voltage drop across the source impedance, which causes voltage distortion at the PCC. Other customers at the same PCC will receive distorted supply voltage, which may cause overheating of power factor correction capacitors, motors, transformers and cables, and mal-operation of some protection devices [12].

The Distributed Energy Resources are one of the power generations systems in small scale range such as renewable energy resources examples of photovoltaic cell, wind energy generation system or hydro energy. Placing the microgrid concept near to the load centers have the advantage of improving efficiency by reducing the transmission line losses or voltage drops.

By increasing the domestic and commercial appliances and increasing demand of critical or sensitive loads causes the growing electricity consumption. In this paper a micro grid concept based single stage AC-DC converter is proposed for reducing processes of multiple reverse conversions in an individual ac or dc grid and to facilitate the connection of various renewable sources and loads to power system. The coordination control scheme such as maximum power point tracking converters are proposed for obtaining maximum power from the renewable energy sources under variations in input or any demand conditions [1]-[9]. This type of microgrid systems are even generated electrical power under normal abnormal conditions such as if it is solar it operate at room temperature or if it generates energy at normal speed i.e in plain surface area. However, power electronic based converters are proposed in this paper for controlling purpose.

Generally, harmonics and reactive power are two of the serious problems associated with the grid. They are caused by nonlinear loads, including saturated transformers, arc furnaces, and semiconductor switches. The presence of harmonics and reactive power in the grid is harmful, because it will cause additional power losses and malfunctions of the grid components [1]–[5]. To prevent the inflow of harmonic and reactive currents and to improve the operating ability of the transmission systems, a kind of Flexible AC Transmission System (FACTS) has been proposed [6]–[10]. The static var compensator (SVC) is an important component of FACTS.

GRID INTERFACING SYSTEM

In the present scenario, the integration of grid with the renewable energy sources such as photovoltaic system is the most important application. These advantages include the favorable incentives in many countries that impact straightforwardly on the commercial acceptance of grid connected PV systems. This condition imposes the necessity of having good quality designing tools and a way to accurately predict the dynamic performance of three-phase grid-connected PV systems under different operating conditions in order to make a sound decision on whether or not to incorporate this technology into the electric utility grid.

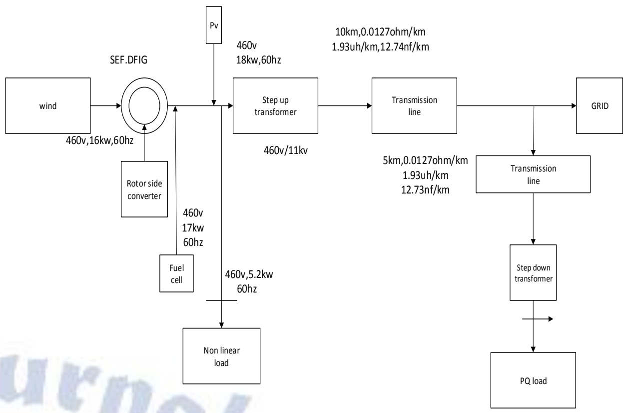

Fig 1 Microgrid power system

Wind Energy System:

The generation of electrical power is obtained mainly in two ways i.e one is conventional source and other is non- conventional energy sources. The generation of electricity using non-renewable resources such as coal, natural gas, oil and so on, shows great impact on the environment by production of pollution from their general gases. Hence, by considering all these conditions the generation of electricity is obtained from the renewable energy sources.

Basically, out of all renewable energy sources the wind turbine plays an important role for generating electricity. And also from economical point of view the wind turbine has low maintainece cost because it needs no fuel so that it is pollution free. Mostly, in present world 50-60 percent [13] of energy is generated from wind turbine as compared with all other renewable energy sources.

The typical layout of wind power generation as shown below.

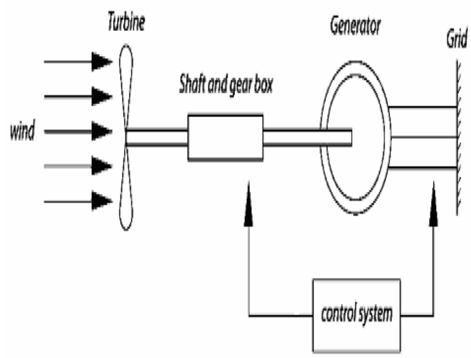

Fig.2 basic schematic diagram of wind turbine

The wind turbine converters wind energy to electrical energy and the generator mechanical shaft power is obtained by the following expression:

$$P_m = 0.5\rho A C_p v^3$$

Wind-Turbine based doubly fed Induction Generator:

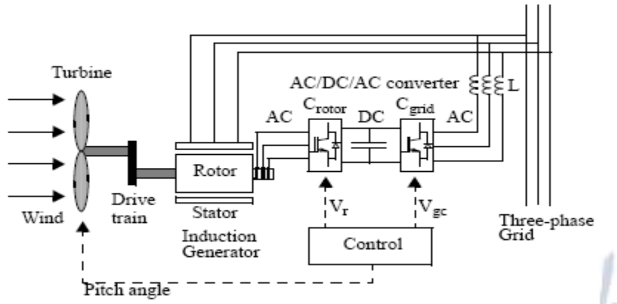

Fig 3: DFIG Connected to Wind Turbine

With the help of induction generator conversion of electrical energy from generated mechanical power from the wind blades and by the stator it is connected to the grid and the rotor converter terminals. Rotor voltage command signal Vr and grid command signal Vgc and the pitch angle command are generated by the control techniques and the and respectively in order for controlling wind turbine power, the DC bus voltage between the rotor and stator converters and the voltage at the grid terminals.

CLOSED LOOP CONTROL DIAGRAM FOR ROTOR SIDE CONTROLLER:

In the RSC, the controller is used for controlling rotor power Ps and the power Qs in terms of controlling rotor regulation and rotating reference frame.

By considering the simplified equivalent circuit for stator winding as shown in figure 3 and write the equations by using KVL as

$$\bar{V}_r = \bar{I}_r R_r + \frac{d\psi_r}{dt}$$

$$\bar{\psi}_r = L_r \bar{I}_r + M\ \bar{I}_s e^{-j\epsilon}$$

Substituting the value of $\bar{\psi}_r$ in above equation e get

$$\bar{V}_r = \bar{I}_r R_r + \frac{d}{dt}(L_r \bar{I}_r + \frac{M}{L_s}\bar{\psi}_s e^{-j\epsilon} - \frac{M^2}{L_s}\bar{I}_r$$

$$= \bar{I}_r R_r + \frac{d}{dt}\left(L_r \bar{I}_r - \frac{M^2}{L_s}\bar{I}_r\right) + \frac{d}{dt}\left(\frac{M}{L_s}\psi_s e^{-j\epsilon}\right)$$

Fig 4 shows the overall RSC control scheme which is having two cascade loops. The active and reactive powers of the DFIG is controlled by the outer loop and direct axis current component Idr*, quadrature axis current component Iqr* are generated. Inner-loop current regulation is the second cascaded control loop. Vdr0 and Vqr0 are the from the two regulated current controllers outputs. And these signals are used for generating Pulses to RSC converter by PWM technique.

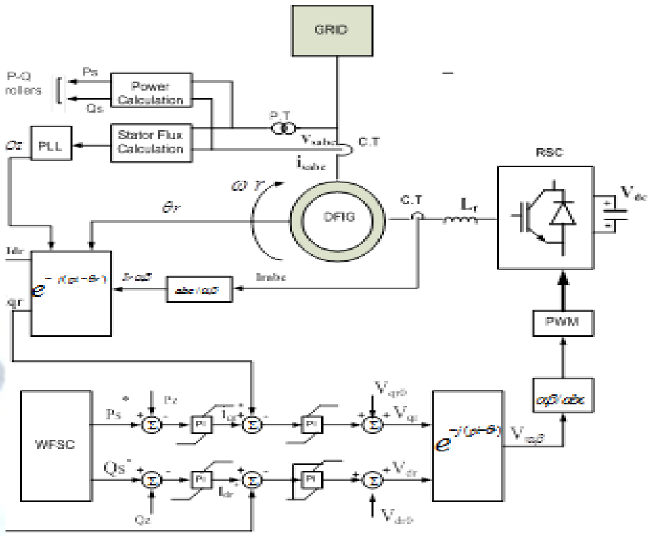

Fig 4 Control Diagram for the rotor side controller

CLOSED LOOP CONTROL DIAGRAM GRID SIDE CONVERTER:

Controlling of the reactive power Qg which is exchanged between the stator side converter and the grid with the help of dc link voltage is the complete control scheme for the GSC.

Form the equivalent circuit shown in figure 3. Applying KVL to above circuit we get

$$v_a = I_a R_f + L_f \frac{dI_a}{dt} + v_{ag}$$

$$v_b = I_b R_f + L_f \frac{dI_b}{dt} + v_{bg}$$

$$v_c = I_c R_f + L_f \frac{dI_c}{dt} + v_{cg}$$

Transform the above three phase coordinates in to two phase d-q transformation and separate real & imaginary terms we get

$$v_{sd} = I_{sd} R_f + L_f \frac{dI_{sd}}{dt} - w_s L_f I_{sq} + v_g$$

$$v_{sq} = I_{sq} R_f + L_f \frac{dI_{sq}}{dt} - w_s L_f I_{sd}$$

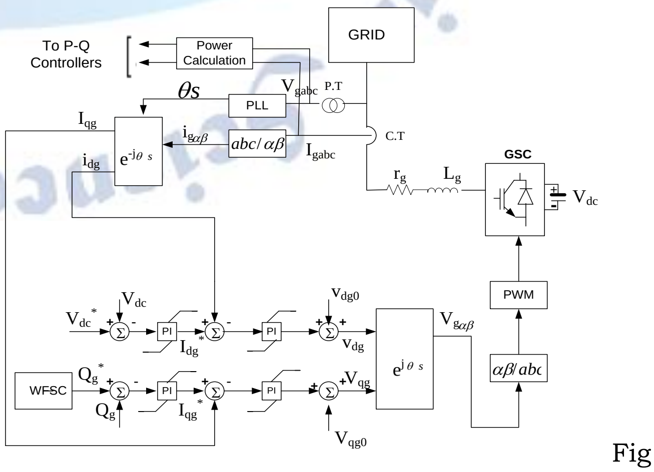

Fig 5: Grid side controller (GSC) scheme

Fig 5 shows the complete closed loop control diagram for the grid side converter and it having two cascaded control loops. The reactive power is indirectly controlled by the dc link voltage controlling done by the outer control loop for generating the reference signals of the d-axis current component idg* and q-axis current component iqg* for the inner-loop current regulation. Then these signals are used for generating pulses with the help of PWM technique

$$P_{ei,\max} = P_{mi,\max} - P_{Li} = P_{si,\max} + P_{ri,\max}$$

The stator active power Ps can be written as

$$P_s = \frac{3}{2}(v_{ds}i_{ds} + v_{qs}i_{qs}) = \frac{3}{2}[\omega_s L_m (i_{qs}i_{dr} - i_{ds}i_{qr}) + r_s(i_{ds}^2 + i_{qs}^2)]$$

The rotor side active power can be expressed as:

$$P_r = \frac{3}{2}(v_{dr}i_{dr} + v_{qr}i_{qr}) = \frac{3}{2}[-s\omega_s L_m (i_{qs}i_{dr} - i_{ds}i_{qr}) + r_r(i_{dr}^2 + i_{qr}^2)]$$

ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM:

The ANFIS is one of the important controller in adaptive techniques. This section provides the information regarding the designing of neuro-fuzzy controller. These neural network controller consists of two inputs that are Δe and Δde and it has one output that is f ∈ {Δe, Δde} [11]. Each input consists of 5 membership functions. Figure 6 shows the configuration of ANFIS for a mamdani type and it has two input and one output.

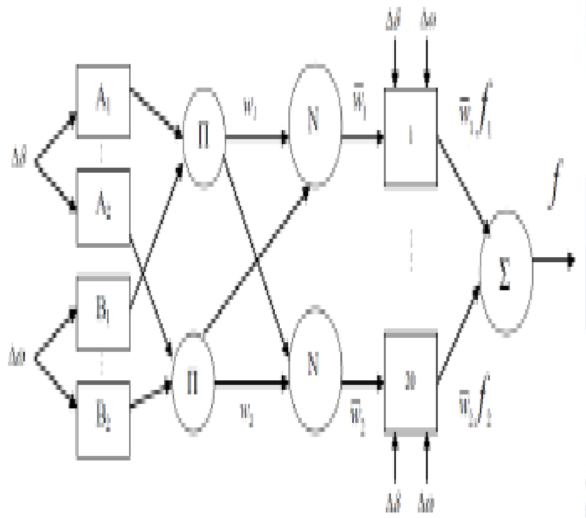

Fig 6: ANFIS architecture

According to Figure 7, it is a mamdani based fuzzy controller with two inputs and one output and the rules are formed according to if-then statements. μAi and μBi are the membership functions of memberships with the fuzzy sets and these inputs are related with the operator logical AND. The hybrid learning algorithms are implemented for obtaining the values of system parameters. These learning algorithms is a function of linear and non-linear parameters [12]. These explanations are implemented in Matlab/Simulink software.

Algorithm for Neuro Controller:

1. Assume the inputs and outputs in the normalized form with respect to their maximum values and these are in the range of 0-1.
2. Assure the No.of input stages given network.
3. Indicate the No.of hidden layers for the network.
4. Design the new feed forward network based on the system parameters 'transig' and 'poslin'.
5. Assume the learning rate be 0.02 for the given network.
6. Identify the number of iterations for the system.
7. Enter the goal.
8. Train the network based on the given input and outputs.
9. For the given network Generate simulation with a command 'genism'

FUZZY CONTROLLER:

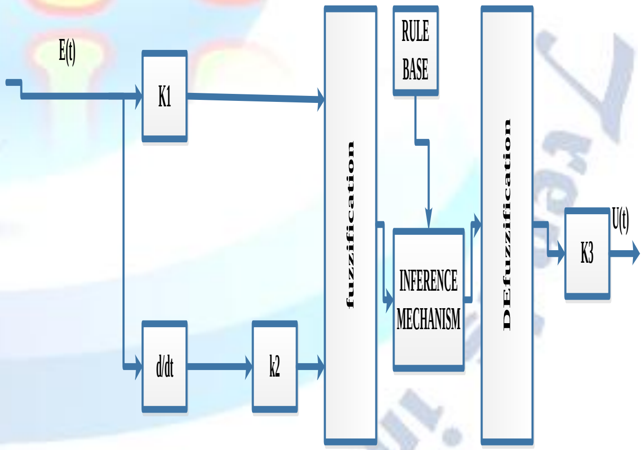

Fig 7: Configuration of Fuzzy Inference System

SIMULATION AND RESULTS

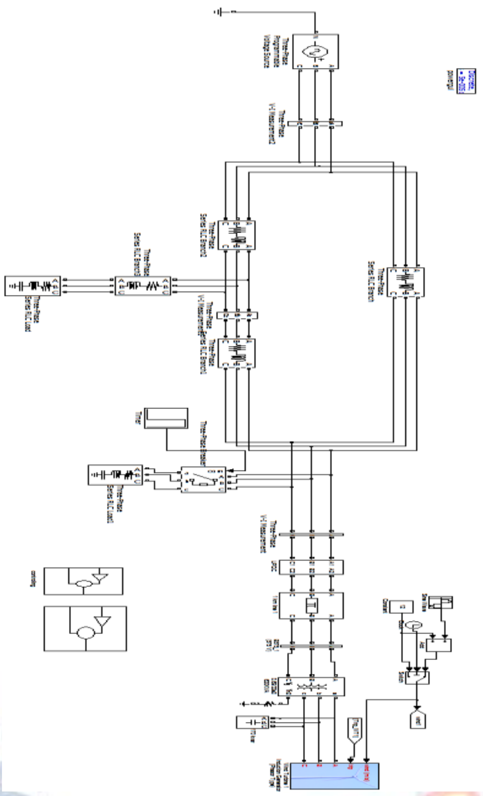

Fig 8 Simulation implementation of Grid interfaced wind system with and without fuzzy controller.

In this paper the simulation is done for micro grid and the results are compared with two cases.

Case 1: with PI Controller

In this the conventional PI controller is used for series and shunt controllers. The obtained results are shown in below figures.

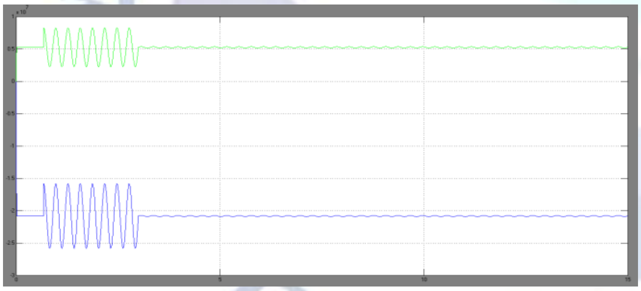

Fig 9. Simulation result for active and reactive powers

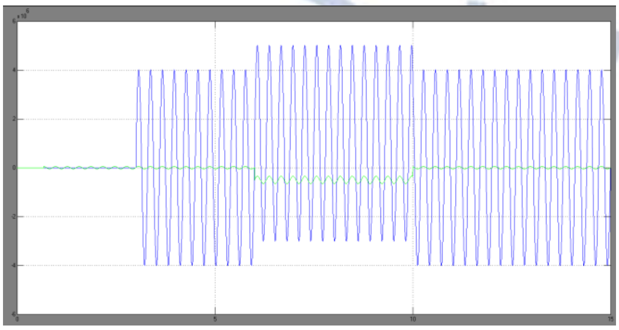

Fig 10 Simulation result for Grid and Series Converter Voltage

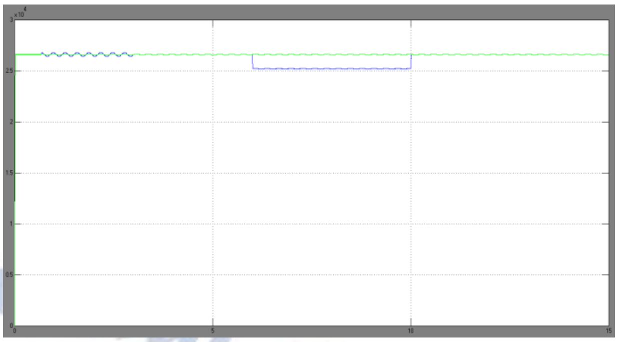

Fig 11 Simulation result for series and shunt converter active power

Case 2: With ANFIS Controller

In this the fuzzy controller is used for series and shunt controllers. The obtained results are shown in below figures.

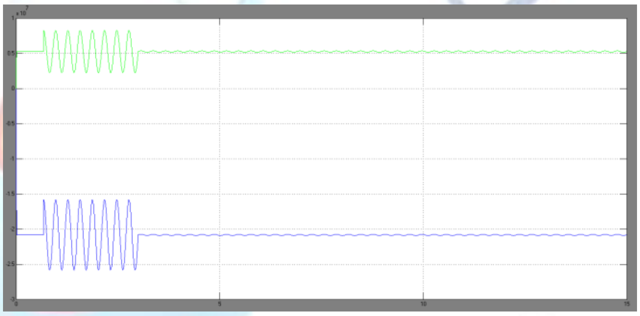

Fig 12. Simulation result for active and reactive powers

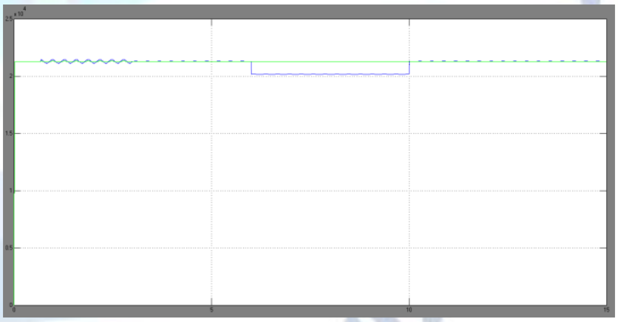

Fig 13 Simulation result for series and shunt converter active power

CONCLUSION

This paper has successfully implemented the microgrid based DFIG along with the fuzzy logic controller. Generally, the microgrid concept mainly concentrate on the reduction of transmission losses and the power quality problems occurred in the system is compensated by unified power quality conditioner. The ANFIS controller is used for getting better performance by the reduction of total harmonic distortion in the system.

The simulation results obtained for the Grid interfacing using GSC and RSC converter of dfig system with conventional PI controller and ANFIS controller. Due to the presence of non-linearity in the system, harmonics will produce which leads to voltage distortions. By using conventional PI controller in the system we can reduce these distortions. This drawback can be overcome by adopting ANFIS.

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