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ANFIS Based DFIG-WECS with Grid Integration for Power Smoothening

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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 to implement 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 project. The ANFIS based DFIG system is to be implement in MATLAB.

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

1. 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.

2. 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.
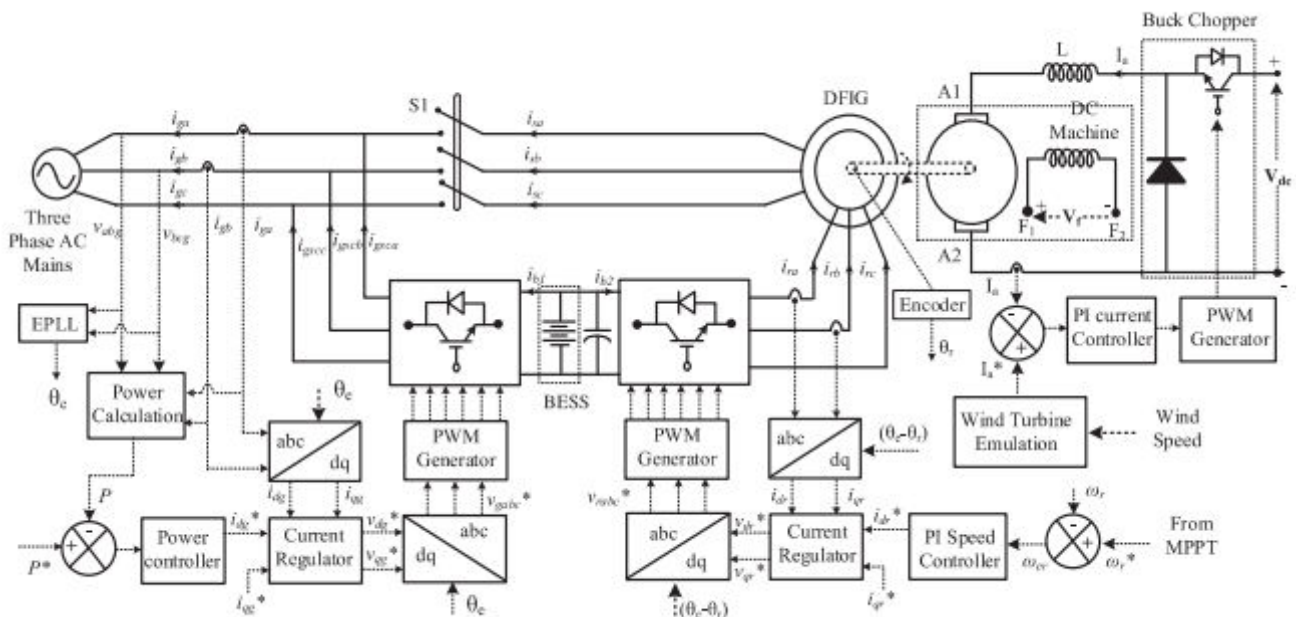

Fig 1 Microgrid power system

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.

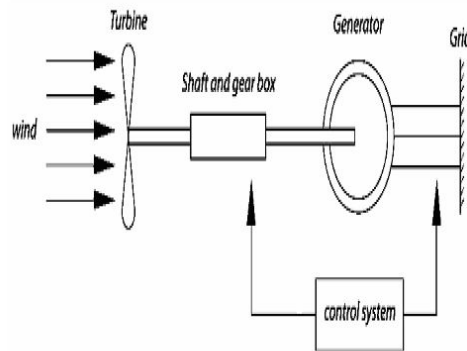The typical layout of wind power generation as shown below.

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:

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

MODELLING AND DESIGN OF DFIG

The doubly fed induction generator is the better solution for variable speed machines with tolerance ±30% of synchronous speed. The grid and the rotor are directly connected for the main stator winding is controlled with converters via slip rings as sown in Figure 4.
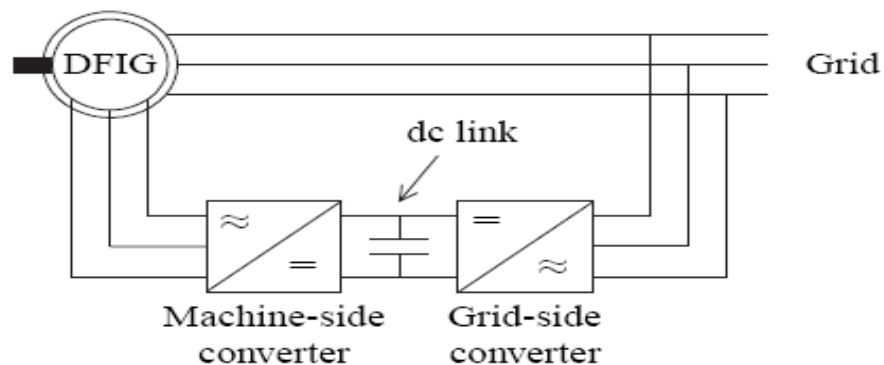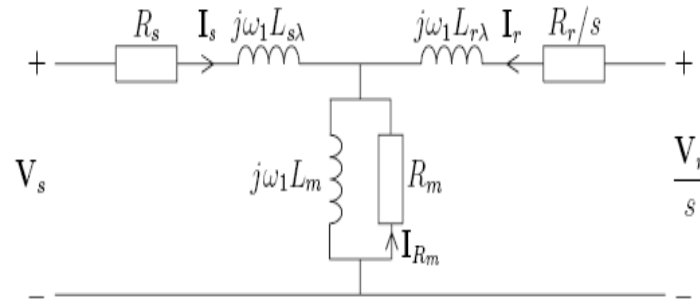

Figure 3: DFIG system with a Back to Back Converter

Figure 4: Equivalent circuit of DFIG

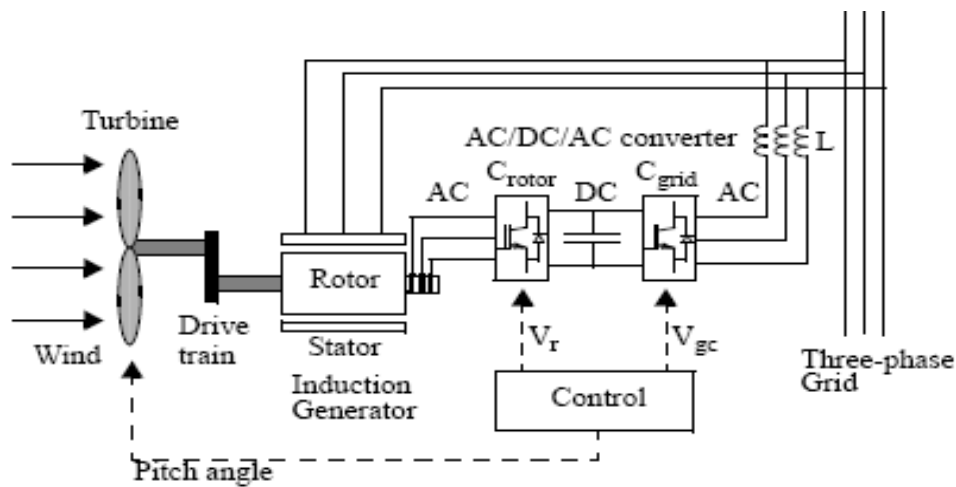**Wind-Turbine based doubly fed Induction Generator:**

Figure 5: DFIG Connected to Wind Turbine

Rotor voltage command signal Vr and grid command signal Vgc and the pitch angle command are generated by the control techniques 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.

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 6 and write the equations by using KVL as

$$\overline{V}_r = \overline{I}_r R_r + \frac{d\psi_r}{dt} \quad (11) \qquad \overline{\psi}_r = L_r \overline{I}_r + M \ \overline{I}_s e^{-j\epsilon} \quad (12)$$

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

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

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

Figure 6 shows the overall RSC control scheme which is having two cascade loops. 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.
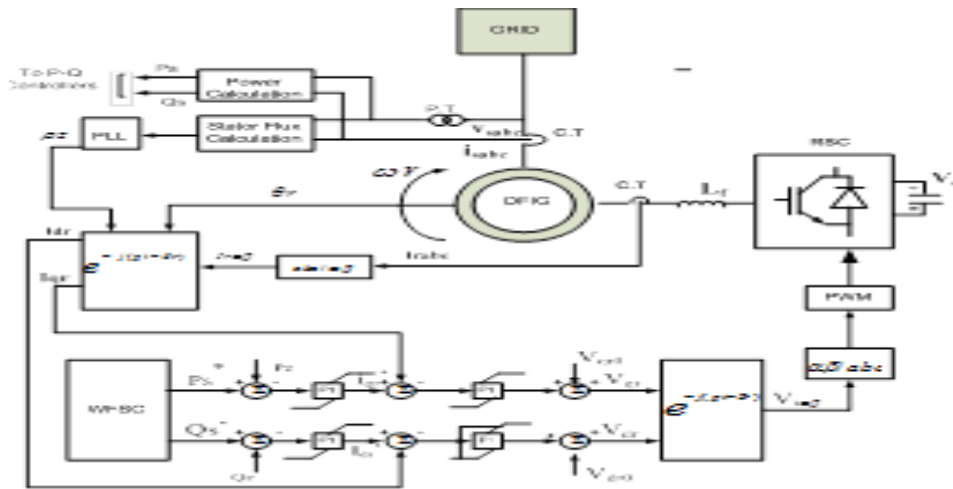

Figure 6: Control Diagram for the rotor side controller

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}. Each input consists of 5 membership functions. Figure 7 shows the configuration of ANFIS for a mamdani type and it has two input and one output.
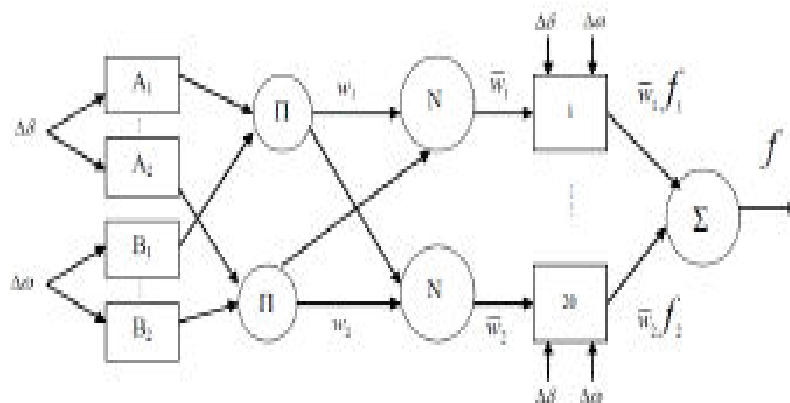

Fig 7: ANFIS architecture

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. These explanations are implemented in Matlab/Simulink software.
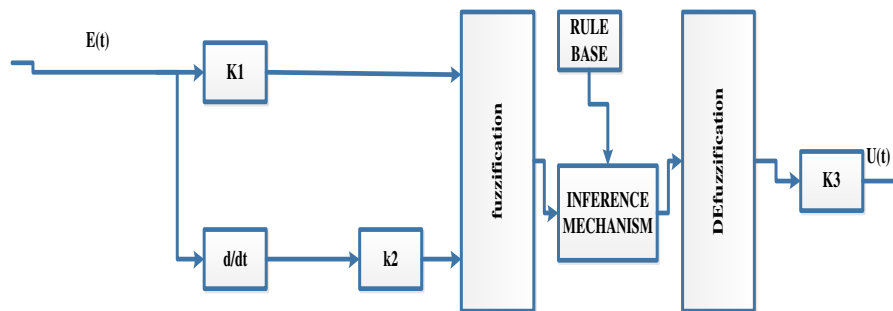
Fuzzy Controller:

Fig 8: Configuration of Fuzzy Inference System

SIMULATION DIAGRAM AND RESULTS:

The steady state and dynamic behaviors of regulated power DFIG based WECS is presented in this section. Test results are recorded in terms of line voltage (vab), grid currents (iga ,igb and igc), stator currents (isa ,isb and isc), GSC currents (iGSCa ,iGSCb and iGSCc), rotor currents (ira ,irb and irc), stator power (PS), grid power (PG), GSC power (PGSC), battery voltage (Vb), battery current (Ib), quadrature axis rotor current (Iqr), direct axis rotor current (Idr), quadrature axis reference rotor current (I∗ qr), direct axis reference rotor current (I∗ dr), rotor speed (ωr), reference rotor speed (ω∗ r) and wind speed (vw). The power that is discharging from the battery through GSC and RSC are considered as positive. Conversely, the battery charging is taken as negative through both GSC and RSC.
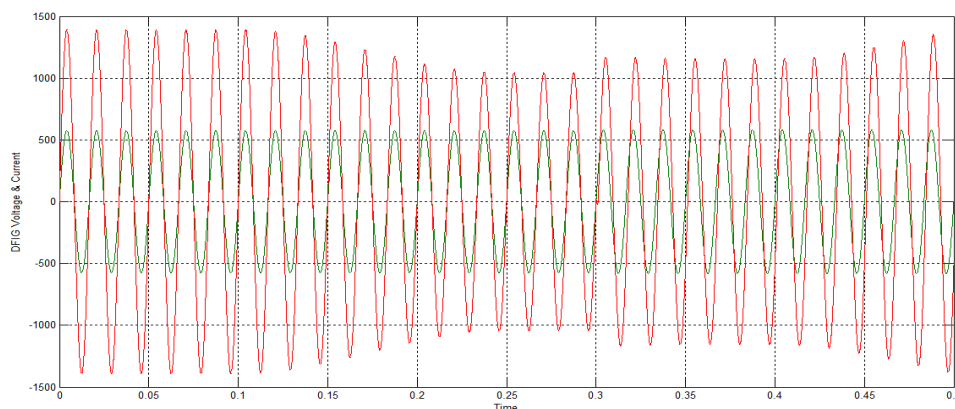

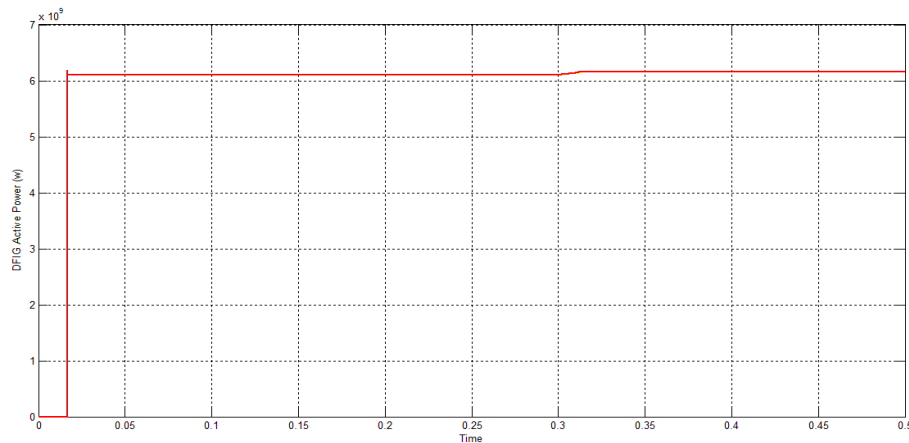Figure 9: Simulation Waveform for DFIG Stator Voltage and Current

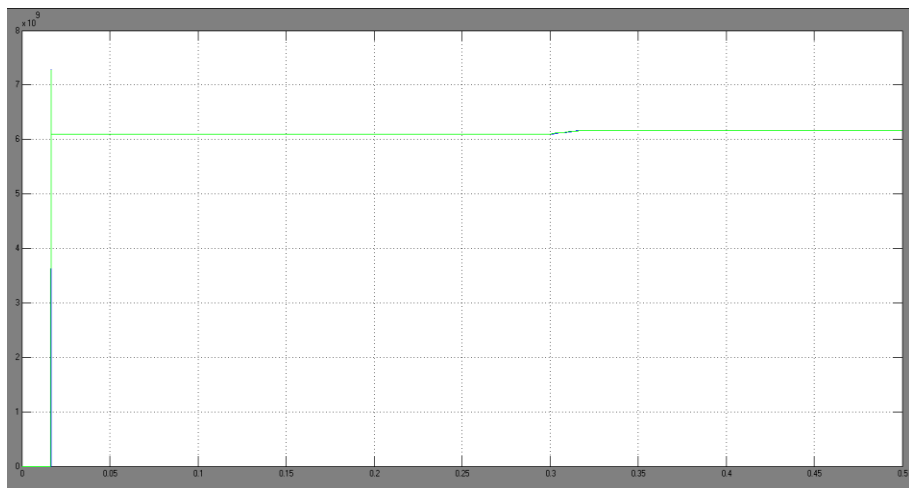Figure 10: Simulation Waveform for DFIG Stator Active Power

Figure 11: Simulation Waveform for DFIG Stator Reactive Power

CONCLUSION

This paper has successfully implemented the microgrid based unified power quality conditioner along with the Neuro-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 fuzzy logic 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 series and parallel converter system with conventional PI controller and ANFIS logic 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 set theory.

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