Stability Control of Doubly Fed Induction Generator Using Genetic Heuristic (GH) Controller for Wind Farm

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Abstract: In this paper, a Genetic Heuristic Controller (GHC) used to improve the transient stability of the doubly-fed induction generator based wind farm under fault conditions. The proposed controller builds on GHC controller to evaluate the optimized values in the nonlinear system. The stability of the system is based on the interaction between the controller and the power plant. Compared to existing approaches with one action network and one critic network, our Genetic Heuristic architecture introduced to improve the effective, stable system. This work presents a new coordinated control strategy for DFIG (Doubly Fed Induction Generator).The coordination of rotor side converter and grid side converter will be achieved by GA controller by this the fault is ride-through using the crowbar-based systems. The effectiveness of the proposed approach is tested and investigated a DFIG system with high wind penetration and a static synchronous compensator. Matlab simulation analysis and comparative studies with traditional GHC approaches are presented to demonstrate the superior performance of our method.

Keywords: Genetic Heuristic Controller, Doubly Fed Induction Generator, Data transportability, Matlab simulation, GA Controller, back-to-back converters and power system stability.

1. INTRODUCTION

The environmental impacts and diminishing reserve of fossil fuel is forcing the power system planners across the globe to view for increased use of renewable energy. Until now, wind power is the clean and cheapest of the commonly used renewable sources. The hence its percentage share in the total power generation and stability of power during load is considerably is the central issue in many countries. Subsequently, doubly fed induction generator (DFIG) were introduced which uses many converters in its rotor circuit to enable operation i both sub-synchronous and super synchronous speed regimes extracting maximum power from the wind. To begin with, DFIG Wind turbine for non-linear speed and analy the stability of wind turbines were used for wind energy generation and power system applications.

2. PREVIOUS REASEARCH

The clean and inexhaustible nature requires Wind energy that can meet the growing energy needs of humans [1]. When the grid fault occurs, the stator flux would contain dc and negative sequence components which can produce large electromotive force (EMF) in the rotor circuit [2-3]. When the voltage dip is detected, the rotor flux linkage is controlled immediately to track and limits the changing stator flux linkage by the control of RSC, and in this way, the rotor current can be reduced [4-5]. The stability of the power system using various controllers was discussed in [8]–[9] Grid, power integration of this variable power in increasing capacity, raises concern about its impact in [10]. Permanent magnet synchronous machines are used for generating wind power though this requires converters

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of higher capacity which makes it a costlier option. On the other hand, the choice of the use of DFIG-based wind generation for short term frequency support complete system damping, voltage support and have also been investigated [11-13]. A power system stabilizer (PSS) for DFIG is proposed in [8]. DFIG using the bacterial forging technique for damping controller is introduced in [9].

In this paper, a GHC method is proposed to control the output power of a DFIG based wind farm for a short time during the after fault condition with the aim of improving the transient stability of the system. This is achieved by modifying the reference frequency for the electromagnetic torque of the DFIG. The improvement of the transient stability of the system helps to restore the balance of mechanical and electrical power. The proposed GHC controller is verified for constant as well as variable wind speed conditions in an efficient manner.

3.   PROPOSED METHODOLOGY

The parallel connection of wind turbines or generators form wind model, GH-rotor side converter (RSC), GH-grid side converter (GSC), pulse width modulated (PWM), IGBT voltage source converters (VSCs). The DFIG has a wound rotor induction generator with its stator windings directly connected to the windings of both RSC and GSC windings using two AC/DC back-to-back converters.

Fig. 1 shows the revised four-machine two-area system, which is based on the classic model. The transient stability performance of the proposed power system has improved using nonlinear function of optimized GHC controller. The Conventional four-machine two-area system is designed by using generator 3 (G3) wind farm. In this paper, instead of replacing G3 with a wind farm, the generator 4 (G4) is replaced with a DFIG-based wind farm. The parameters of the benchmark system and the power flow can be showed here.

3.1. Modeling of the DFIG Wind turbine

The general architecture of the proposed system circuit is shown in the fig.3.The Kinetic energy of the wind is converted into Mechanical energy by the Turbine. Then this energy will be converted into electrical energy using Generator. This energy transmitted to grid via stator (direct) and rotor (back-to-back converters). RSC, acts as a rectifier (AC/DC) and GSC serves as a inverter. Fig. 2 delineates the structure of the DFIG wind turbine that is mainly composed of RSC and the GSC. The voltage controller of the rotor side converter provides much higher damping effect on the oscillation mode than the grid side converter. Here, the rotor side converter is used. The voltage, speed, proposed GHC pulse width modulation (PWM), and pitch angle controllers are equipped with the DFIG. The DFIG power can be written in terms of the quadrature (q)-axis current (iqr) and the direct (d)-axis current (idr), respectively as

$$P_{DFIG} = \frac{x_s}{x_s + x_u} V i_{qr}$$

$$Q_{DFIG} = \frac{x_u V i_{dr}}{x_s + x_u} - \frac{V^2}{x_u}$$

where PDFIG and QDFIG are active and reactive power outputs of the DFIG wind turbine, respectively, xs is a stator self-reactance, xu is a magnetizing reactance, DFIG terminal voltage is V and $V 0$ ref is a terminal voltage reference. The active power output can be controlled by iqr in the speed controller. By considering the d-q reference frame and the generator convention, the stator and rotor voltages are given by the following equations

$$V_{ds} = -R_s i_{ds} -_s \lambda_{qs} + \frac{d\lambda ds}{dt} \tag{1}$$

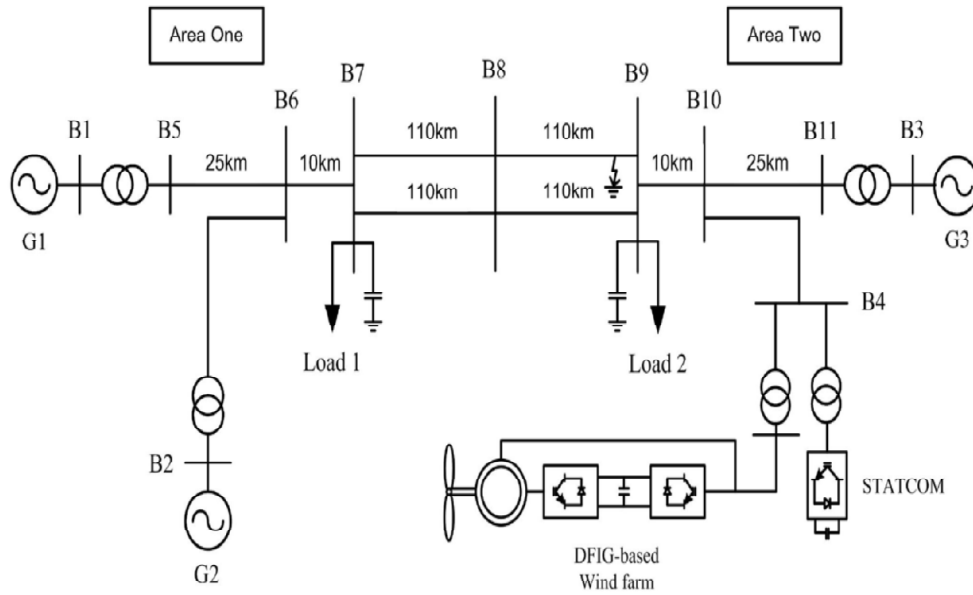$$V_{qs} = -R_s i_{qs} +_s \lambda_{ds} + \frac{d\lambda qs}{dt} \tag{2}$$

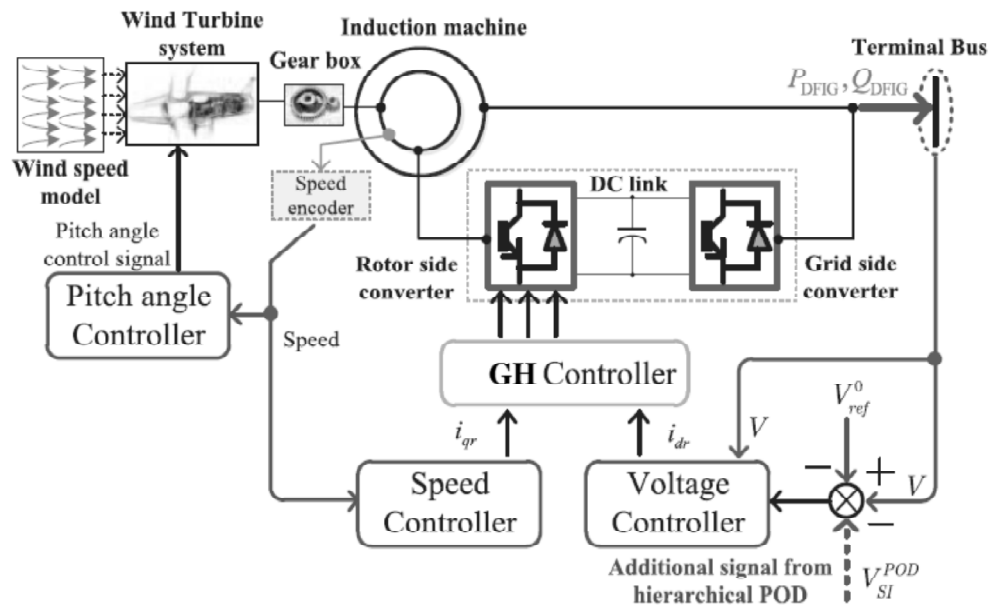**Figure 1: Single-line diagram of the benchmark power system that includes a DFIG-based wind farm.**

Figure 2: Block diagram of the DFIG WT

$$V_{dr} = R_r I_{dr} - \left({}_s - {}_r \right) \lambda_{qr} + \frac{d\lambda_{dr}}{dt} \tag{3}$$

$$V_{qr} = R_r i_{qr} + \left({}_s - {}_r \right) \lambda_{dr} + \frac{d\lambda_{qr}}{dt} \tag{4}$$

From (1) and (4) The flux linkage in is defined as

$$\lambda_{ds1} = -L_s\, i_{ds} + L_m\, i_{dr} \tag{5}$$

$$\lambda_{qs1} = -L_s\, i_{qs} + L_m\, i_{qr} \tag{6}$$

$$\lambda_{dr1} = L_r\, i_{dr} + L_m\, i_{ds} \tag{7}$$

$$\lambda_{qr1} = L_r\, i_{qr} + L_m\, i_{qs} \tag{8}$$

3.2. Model Of Grid Side controller

B. Grid Side controller Modelling

From Fig.4 shows that, GSC is to maintain the dc link voltage (Vdg) and control the terminal reactive power (iqg). The dc link voltage and reactive power are controlled independently via idg and iqg, respectively. The equations are given as follows:

$$\frac{dx5}{dt} = v_{DC\_ref} - v_{DC} \tag{9}$$

$$i_{dg\_ref} = -K_{pdg}\,\square\Delta v_{DC} + K_{idg}\,x_5$$

$$\frac{dx6}{dt} = i_{dg\_ref} - i_{dg} = -K_{pdg}\Delta v_{DC} + K_{idg}\,x_5 - i_{dg}$$

$$\frac{dx7}{dt} = v_{qg\_ref} - i_{dg}$$

$$\Delta v_{dg} = K_{pg}\,\frac{dx6}{dt} + K_{ig}\,x_6 = K_{pg}\,(-K_{pdg}\Delta v_{DC} + K_{idg}\,x_5 - i_{dg}) + K_{ig}\,x_6$$

$$\Delta v_{qg} = K_{pg}\,\frac{dx7}{dt} + K_{ig}\,x_7 = K_{pg}(i_{qg\_ref} - i_{qg}) + K_{ig}\,x_6 \tag{10}$$

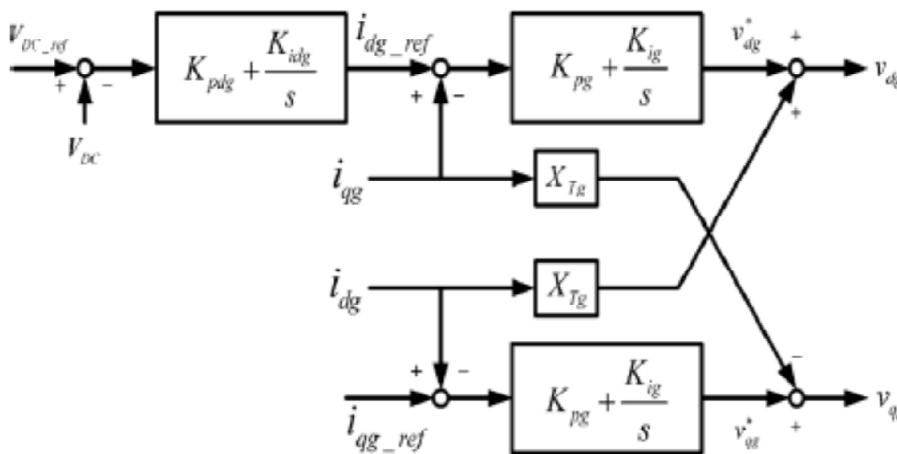**Figure 3: Schematic diagram of grid side controller**

Where

K_{pdg} & K_{idg} the PI gains of the dc link capacitor voltage regulator

K_{pg} & K_{ig} the PI gains of the grid side converter current regulator

V_{DC_ref} the voltage control reference of the dc link capacitor

i_{qg_ref} the control reference for the axis component of the GSC current

In this work, it is designed to be reactive neutral by setting $Q_{gc\_ref} = 0$. The grid side converter is controlled by a PI controller in such a way to guarantee a smooth DC voltage and ensure sinusoidal current in the grid side

3.3. Modelling of the optimized Genetic Heuristic (GH) control system

In the above-described control system, no provisions are taken for the FRT of the DFIG. The proposed control scheme manages to attenuate the system disturbances caused by the fault, eve n in the case where the wind turbine
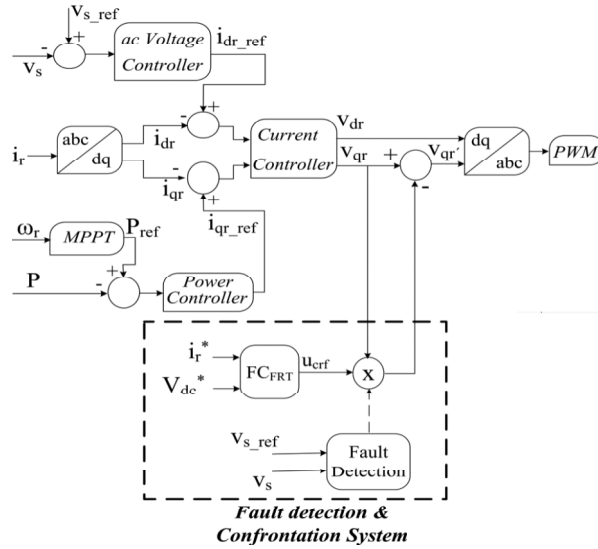
Figure 4: Optimized control system.

(WT) feeds a relatively weak ac grid. GHC achieving an optimal c ordination between the two converters, in this work, the system stability is attempted, in order to ride-through the fault without any additional hardware. In a view to encounter the difficulties in previous controller has few problems for particular period of time, the machine is insensitive to the measurement noise and to the lack of accurate information concerning the machine parameters. So that by considering the nonlinearity of the system, efficient GHC controllers designed based on computational intelligence (CI), All the controllers used are FCs whereas the tuning of the FC which achieves the FRT, FCFRT is that the derivation of its rules is quite complicated and it cannot come up from simple Super fuzzy reasoning.

RSC control system is shown in Fig. 4. To successfully protect the DFIG, from the rotor over current and dc-link voltage optimized GH-RSC are implemented here. The extra energy is induced in the rotor during the transient obtained from the converters to the grid. If the value of the dc voltage will rise suddenly, risking exceeding its limits if the value of the rotor current is sharply dropped quickly "pumping" the stored energy in the rotor to the grid. The control of GSC is unbothered in the system. Respectively, if the value of the rotor current is slowly reduced to avoid the dc overvoltage, unacceptable values produced when the system is at high risk. To achieve top FRT condition the correction signals of the rotor current should add to respective values of the dc voltage. As depicted in Fig. 4, output v_{qr} of the current controller is corrected by a quantity u_{crf} derived by a FC, FC_{FRT}. The inputs of FC_{FRT}, v_{dc}^* and i_r^* are given by

$$V_{dc}^* = \frac{Vdc - Vdc\_ss}{Vdc_{mv} - Vdc\_ss} \tag{11}$$

$$I_r^* = \frac{ir - ir\_ss}{ir_{mv} - ir\_ss} \tag{12}$$

From the Equations (11) and (12) shows that the deviations of the two quantities from their steady state values are divided by their maximum acceptable deviations. It should also be mentioned that only the positive deviations are taken into account to the modulation of u_{crf}. Negative deviations are taken as zeros. This contributes to a smoother transition from the FDCS to the steady state control system.

4. RESULTS AND DISCUSSION

The proposed GH controller is designed with wind stability power system has been designed and simulated with MATLAB Simulink. The efficiency of the proposed model has been evaluated as follows.

With the proposed modification of the conventional control system, theDFIG manages to ameliorate its overall response during the fault and post-fault periods and to successfully ride through the fault,without the use of any auxiliary hardware.

The project concentrates on three-phase symmetrical grid faults, since the term "fault-ride-through capability" of national grid codes refer to this type of faults. In this system, the three phase to ground fault takes place for the time period of $t = 3\ s$.
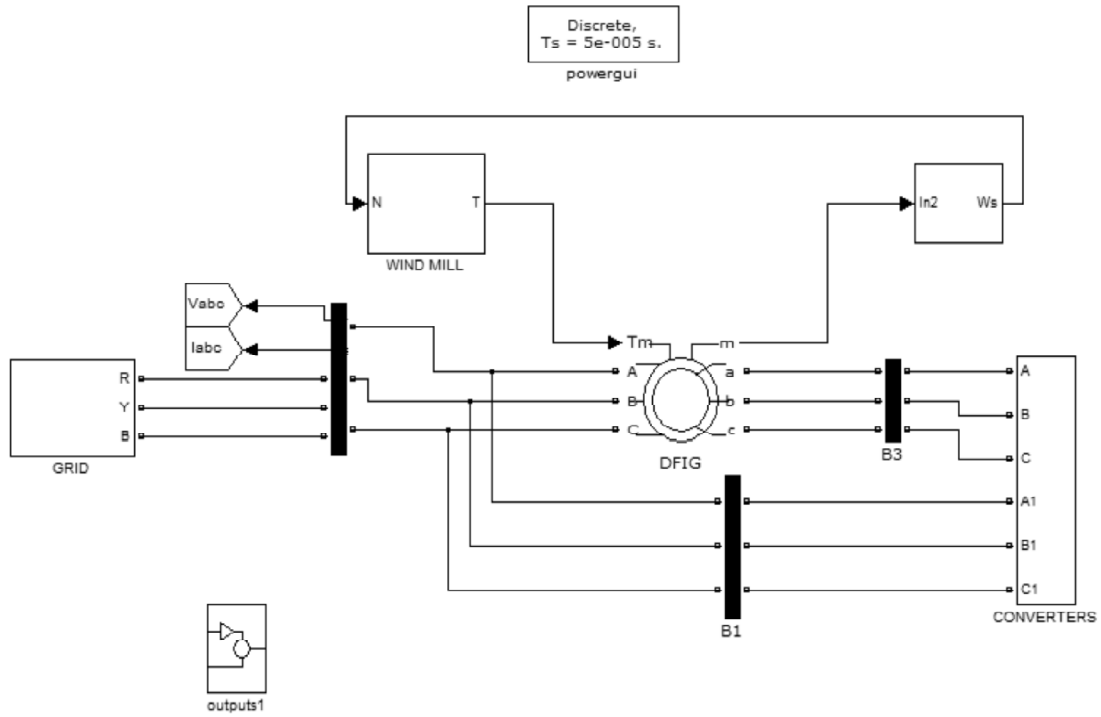
Figure 5: DFIG Wind Turbine with controllers
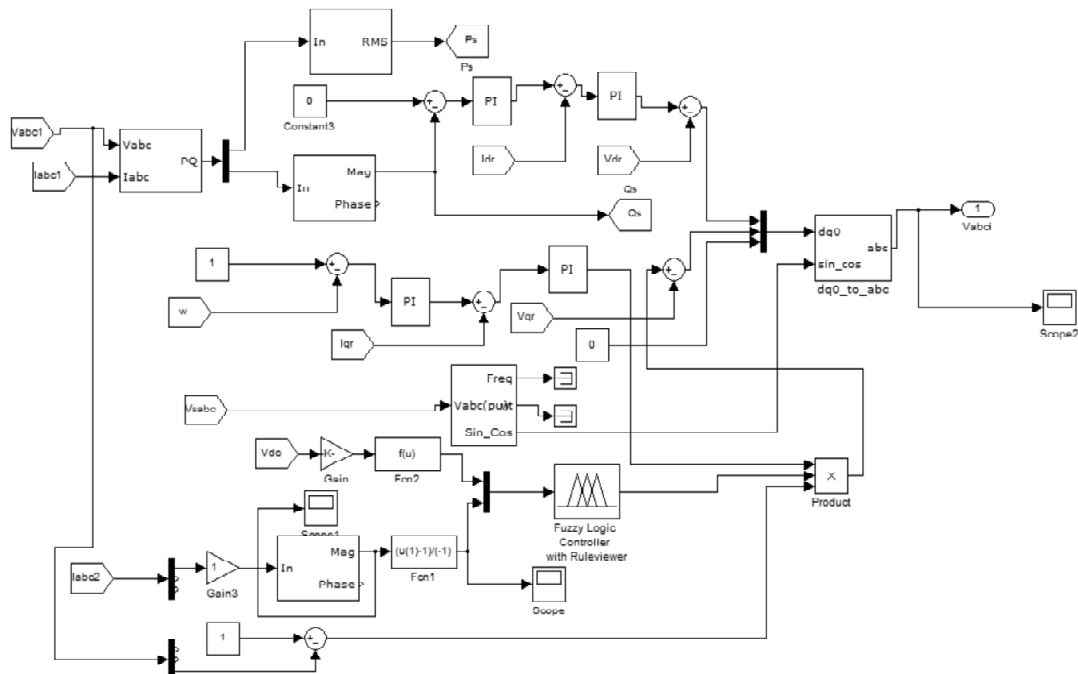
Figure 6: RSC with controller
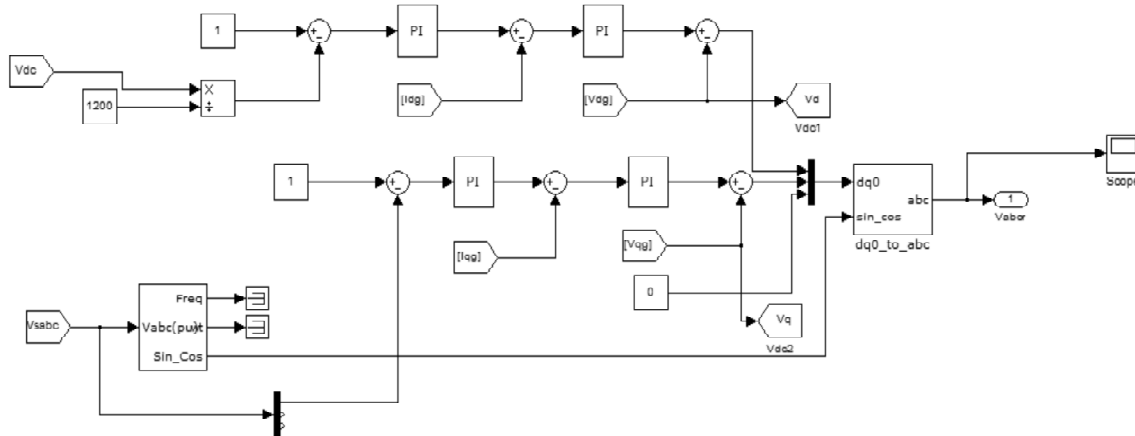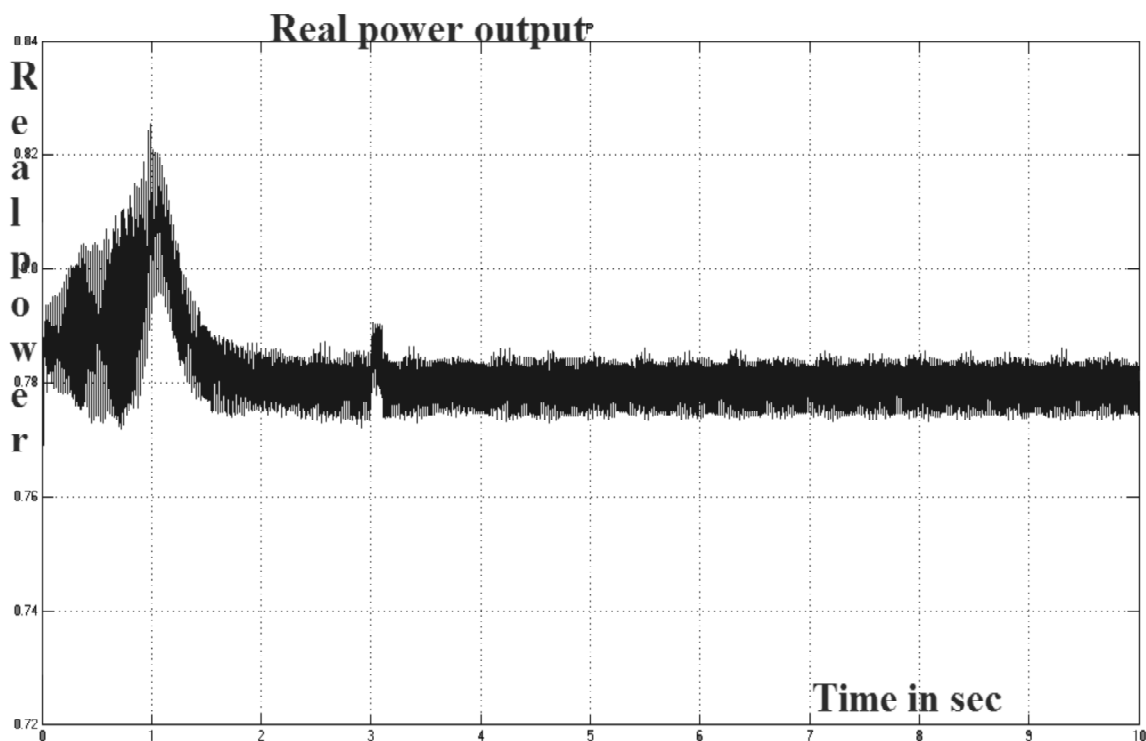
Figure 7: GSC with controller

Figure 8: Waveform of Real power

The above figure has the real power waveform of Grid connected DFIG with Fuzzy controller, for the time duration of fault 3s.it states that with the help of fuzzy controller under fault conditions the real power does not gets much violated when compared with the system, without fuzzy controller.

The below figure has the reactive power. Commonly the GSC acts to set Qgc = 0 and maximize active power output.

The above figure has the rotor speed. In that, according to the wind speed there will be a change in power. Due to the controller its original position attained and remain constant continuously until there is no fluctuation.

The above figure has the rotor current. In that, according to the wind speed there will be a change in current. Due to the controller its original position attained and remain constant continuously until there is no fluctuation.

The above figure has the grid voltage. Due to the controller operation after the fault condition it attains its original position and remain constant.
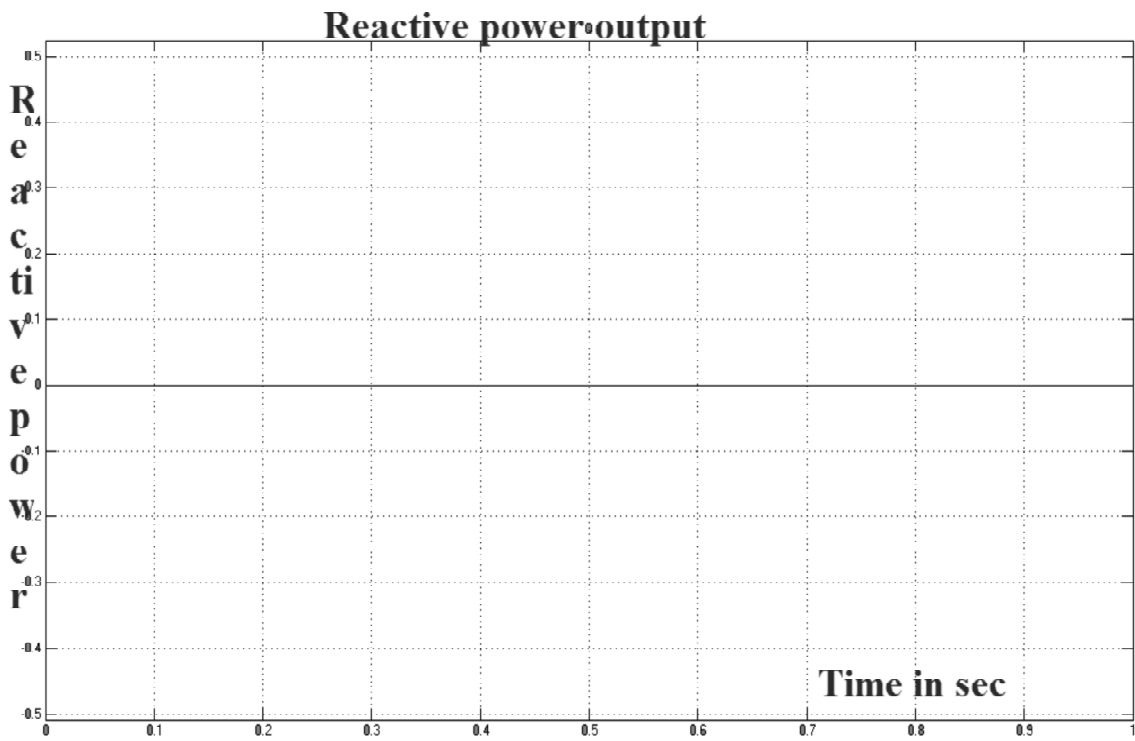
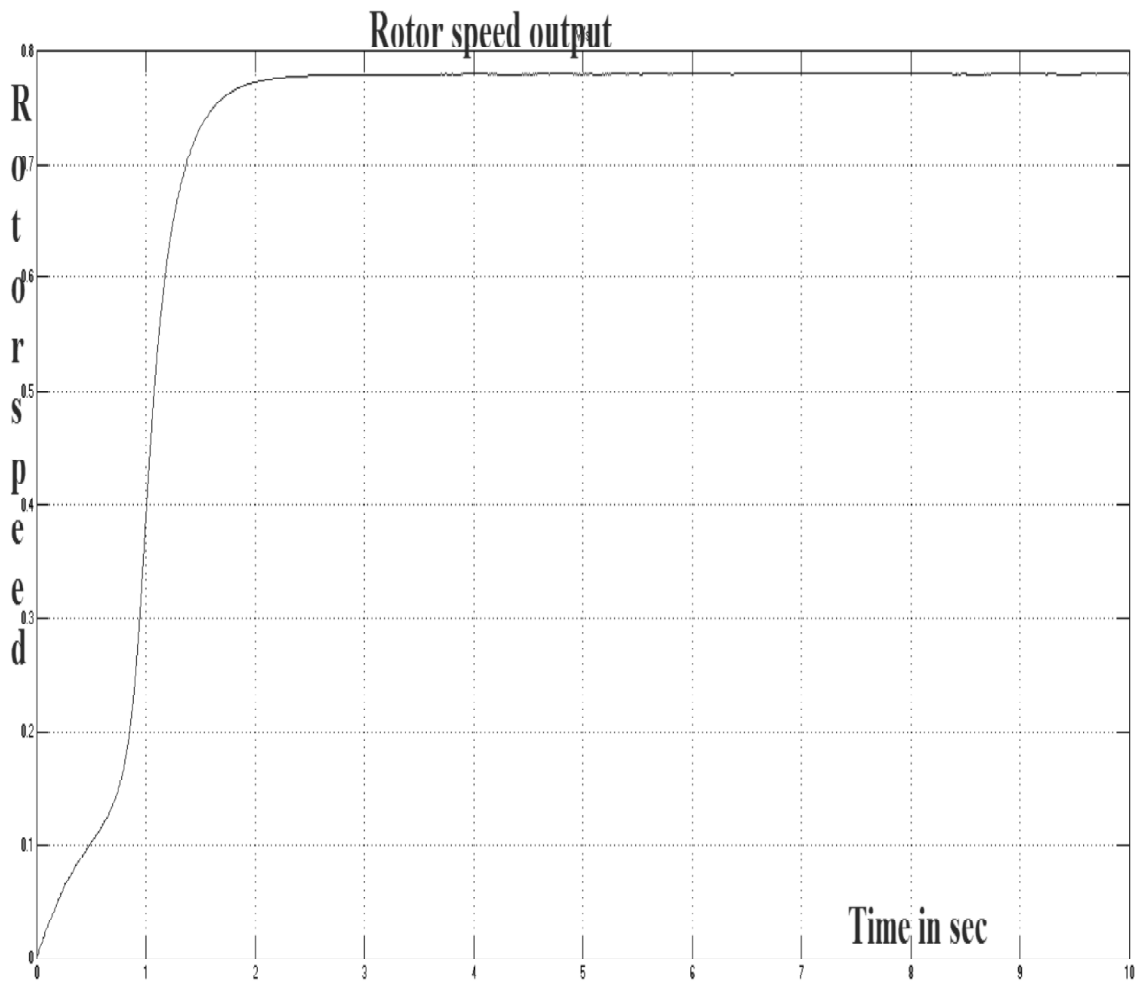**Figure 9: Waveform of Reactive power**
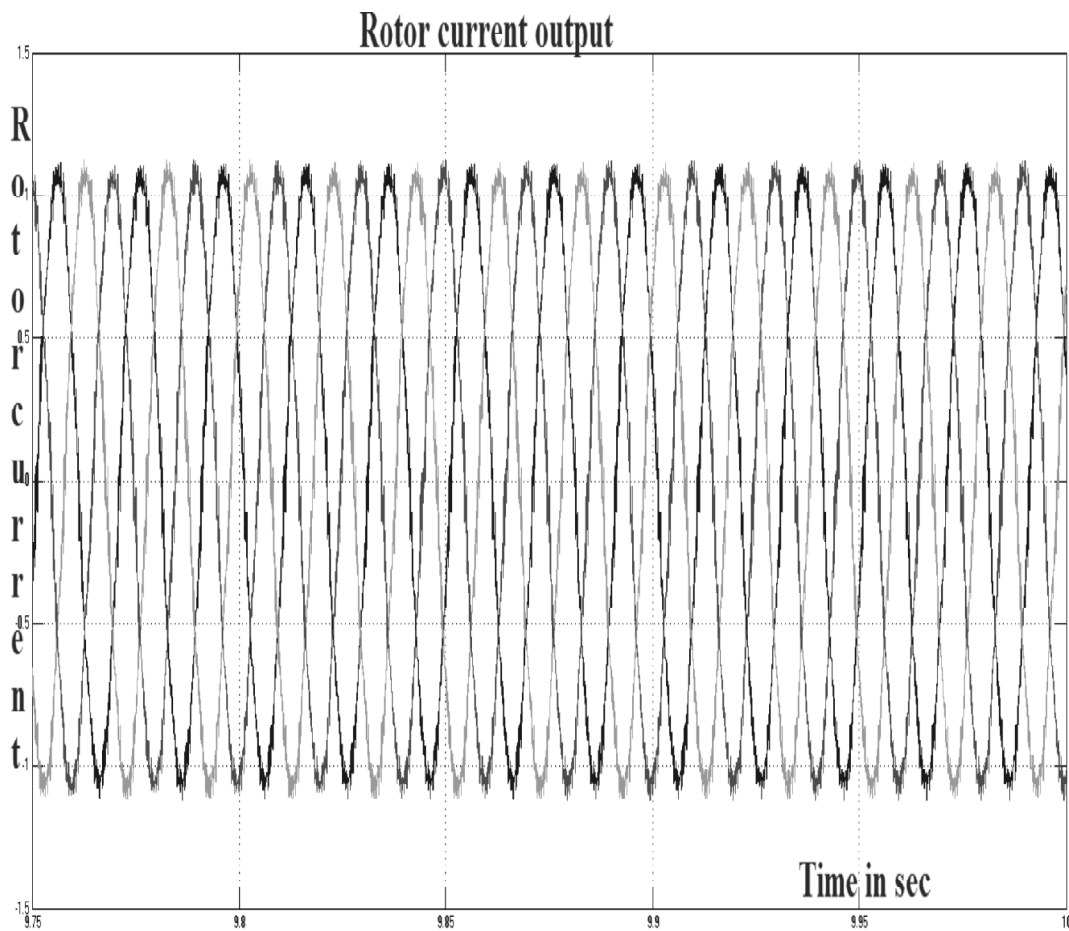

Figure 10: Wave form of Rotor speed

Figure 11: Waveform of 3 phase Rotor current

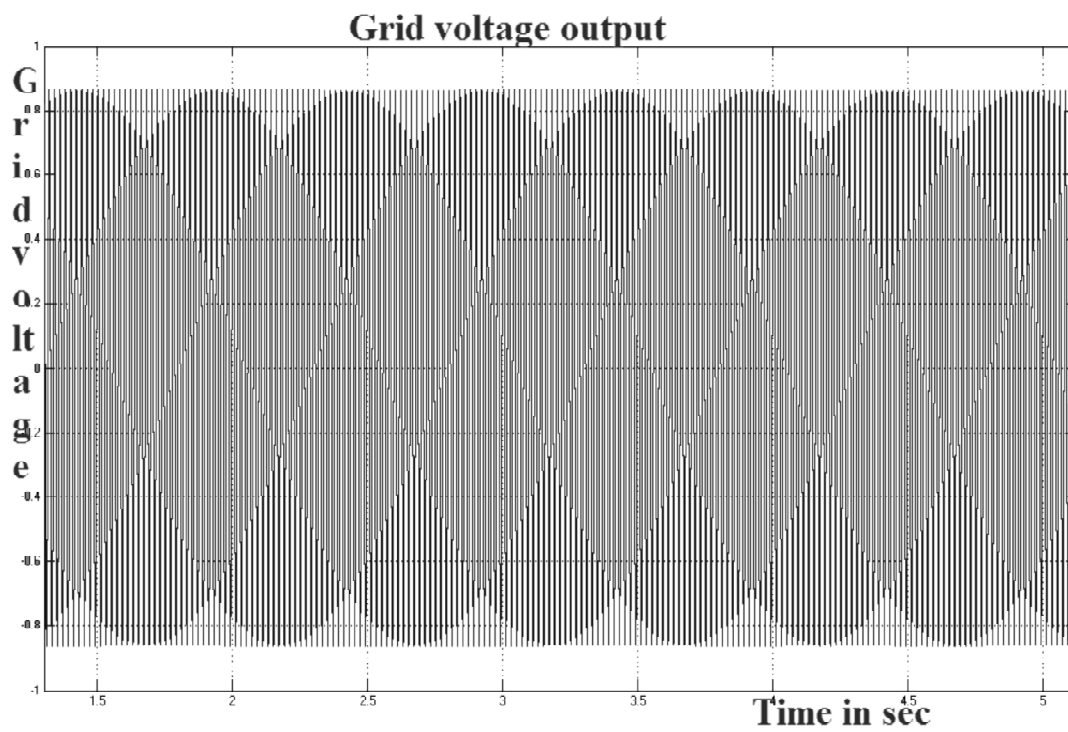**Figure 12: Waveform of Grid voltage**

The THD value of vh1 to vh19 is taken from the FFT analysis of BAR Relative base value is MATLAB simulation

$$THD = \sqrt{\frac{Vh2^2 + Vh3^2 + ... + Vhn^2}{Vh1^2}} \text{ if, } n = 19$$

$$THD = \frac{\sqrt{0.06^2 + 0.08^2 + 0.06^2 + 0.08^2 + 0.03^2 + 0.05^2 + 0.06^2}}{100^2}$$

FFT analysis value for output voltage (Vabc) (ie) THD = 0.0048 = 0.48%

Fig 14.The GH controller based PSS can robustly eliminate the power oscillation. These simulation results confirm that the damping performance, robustness and control resiliency of the proposed Hierarchical GHC and PSS under the applied faults, system uncertainties, and contingencies.

The following graph shows the Efficiency comparison of different controller with proposed GHC based wind power system.
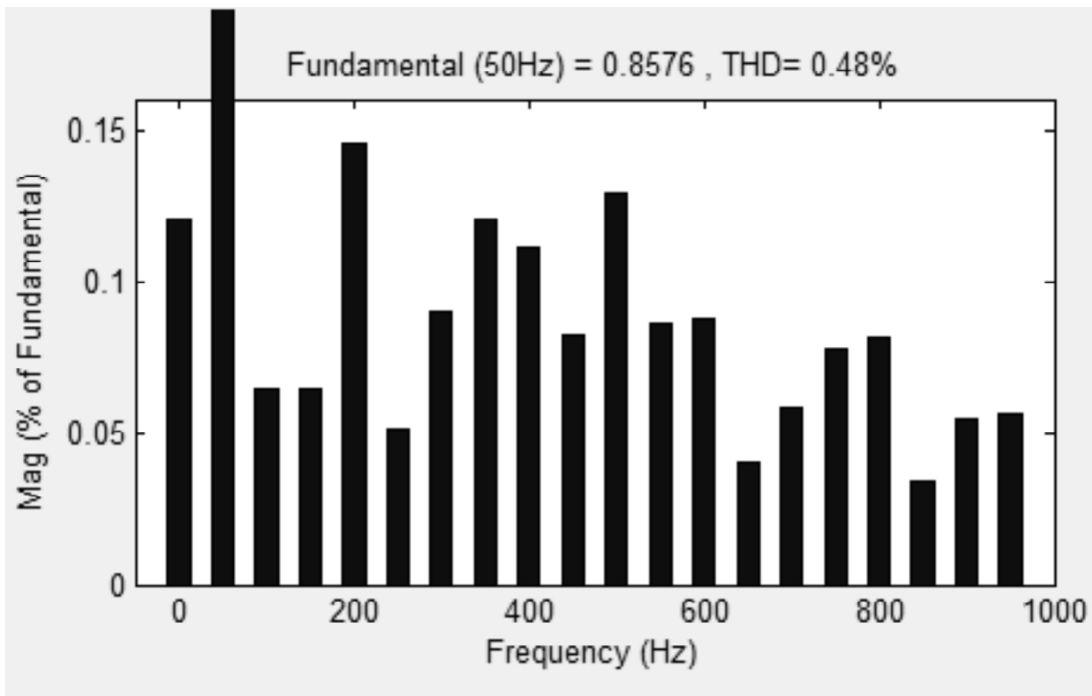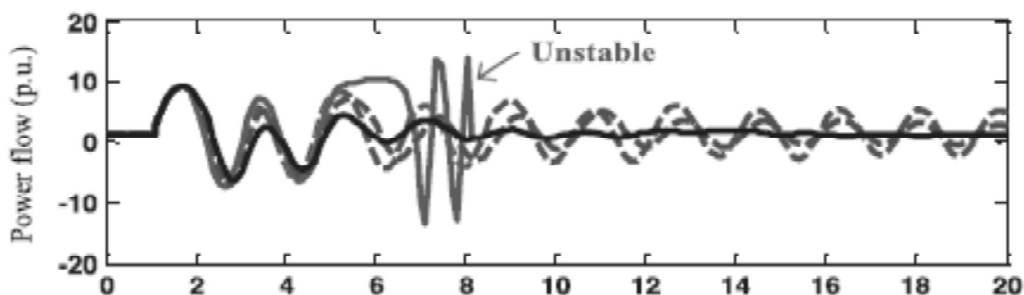

Figure 13: Output voltage FFT level

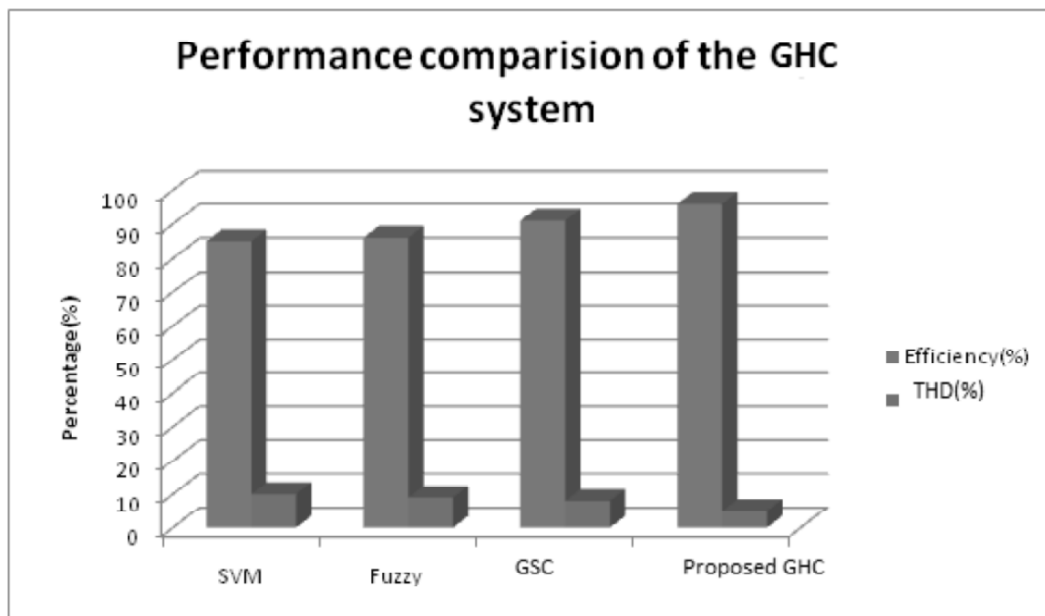**Figure 14: Characteristic Output curve of proposed system**

Figure 15: Comparison of voltage gain of converters (a)–(h).

5.   CONCLUSIONS

This paper proposes a coordinated control strategy to improve the LVRT capability of grid connected DFIG WTs using GHC controller design. The optimal coordination of the DFIG converters through Genetic Heuristic controller was implemented and tested on different fault conditions. The results show that using the proposed GHC control system, the DFIG can successfully ride-through the error, at low wind feeds or relatively weak AC grid. The overcurrents at the rotor windings and the dc over voltages are effectively eliminated with reactive power during and after the fault, contributing to the support of the AC voltage.

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