Improving the Control Performance of the DFIG based WECS using ANFIS Controller

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Abstract : Due to increasing concerns about CO_2 emissions and the shortage of fossil fuels, renewable energy has become a major topic in economic discussions. One renewable source of energy is that can be extracted from the wind. This Paper covers the basics of using a doubly-fed induction generator (DFIG) to convert the mechanical energy of the wind into useful electrical power that can be used to supply electricity to grid. In this Paper a suitable ANFIS Controller is designed which improves the system performance. ANFIS controls the variable speed, stator current, and rotor current. The simulations results shows the effectiveness of the purposed methodology and has got very good dynamic characteristics. The performance of double fed induction generator (DFIG) variable speed wind turbine under network fault is studied using simulation developed in MATLAB. SIMULINK results show the transient behavior of the double fed induction generator when a sudden short circuit occurs at the generator. After clearance of the short circuit fault the control schemes manage to restore the wind turbines normal operation. The performances have been tested on 1.5 MW doubly fed induction generator (DFIG) in a Matlab/Simulink software environment.

Index Terms **–ANFIS Controller, wind energy, double-fed induction generator (DFIG)**

1.INTRODUCTION

It was the year 1887 when wind power was first time used for producing the electricity. But in the year 1973, when the oil price accelerated. The investigation of non-petroleum energy and researcher started doing researches on wind energy based power generation for bulk use. wind energy generation equipment is most widely installed in remote areas because remote areas have weak grids with unbalance voltages. To overcome the problems associated with fixed speed wind turbine, we employ variable speed wind turbine. Double fed induction generator is one of the components of variable speed wind turbine system. In DFIG the stator is directly connected to the grid and rotor is connected through converters to grid. Wind power generation technology faces many of challenges like selection of technology, power quality issues & mode of operation control. Wind generation is dependent on the quality and quantity of the wind hitting the blades. The better the wind you have the more power you will generate. The power available in wind increases by the cube of the wind speed – if wind speed doubles, power output increases by eight. Turbulent wind (from obstruction, geographical features, etc.) will reduce the power output as the turbine swings back and forth hunting for the wind. These are the few requirements of site for wind generation system: The higher a turbine, the more power is generated, the better quality the wind. A wind turbine should be at least 40 ft above any object within a 400 ft radius. Note there is often exception to this rule depending on your site. It is often more economical to install a higher tower than purchasing a larger turbine Space.

2. LITERATURE SURVEY

Castilla, M et al (2010) presented a direct rotor current mode control (CMC) for the RSC of the IGs, which is aimed to improve the transient response in relation to the dynamic performance achieved with the conventional (indirect) CMC [15]. These control schemes are compared the performance and cost with the indirect CMC schemes.

Shuhui Li et al (2012) presented a direct current vector control method in a DFIG wind turbine based on which an integrated control strategy is developed for wind power extraction, reactive power and grid voltage support controls of the wind turbine [16]. A transient simulation arrangement using SimPower Arrangement is built to validate the effectiveness of the proposed control method. This control approach is more stable, reliable, has better dynamic performance, and superior behavior particularly under the ac arrangement bus voltage control mode. But, for high PCC bus voltage sag, it may be impossible to boost the PCC voltage to the rated voltage for the converter linear modulation constraints.

Changjin Liu et al (2013) proposed a novel DC capacitor current control loop is used to increase the loop gain, is added to the conventional GSC current control loop [17]. The rejection capability to the unbalanced grid voltage and the stability of the proposed control arrangement are discussed. But this proposed arrangement, 2nd order harmonic current in the dc capacitor as well as dc voltage fluctuation is eliminated.

Charan Jeet Madan and Naresh Kumar (2018), proposed a novel method called grey wolf optimization with fuzzified error (GWFE) model to simulate the optimized control arrangement[18]. The main objective of the paper was to simulate a low-voltage ride through (LVRT) control arrangement that is convenient for the development of a controller that should have the ability to rectify fault signals. Further, it compared the GWFE-based LVRT arrangement with the standard LVRT arrangement, arrangements with minimum and maximum gain, and conventional methods like genetic algorithm (GA), differential evolution (DE), particle swarm optimization (PSO), ant bee colony (ABC), and grey wolf optimization (GWO) algorithms.

3.BASIC CONSTRUCTION OF DFIG

When a wound rotor induction machine (WRIM) works as a generator and fed power from both stator and rotor side, it is termed as Doubly Fed Induction Generator (DFIG). DFIG scheme is used as a variable speed fixed frequency topology. In this scheme, stator is directly connected to the grid while the rotor circuit is connected to grid through an AC/DC/AC back to back frequency converter. The rating of this converter is typically 25-30% of the total power rating of the generator. This is the main advantage of DFIG over other variable speed topologies as it provides same features at lesser cost and provides good efficiency. Figure1 shows a typical DFIG configuration.

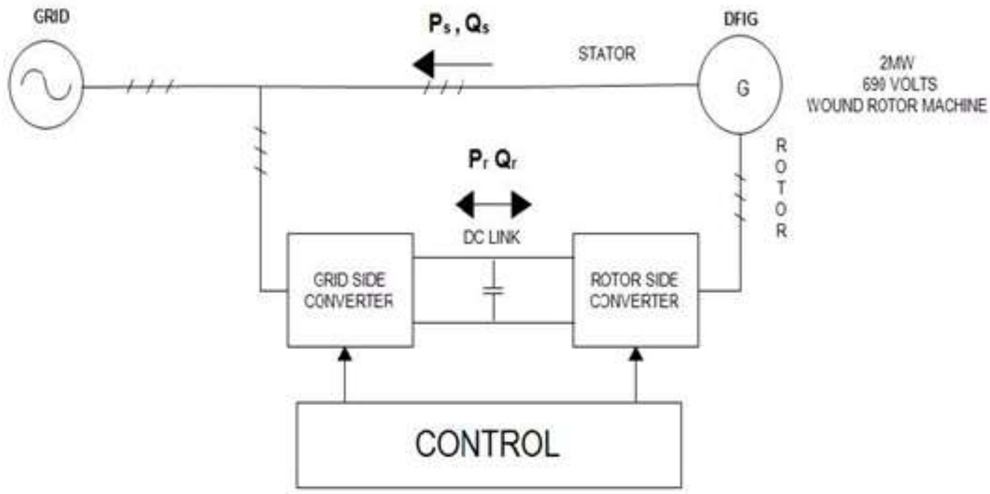


Fig.1 Basic configuration of Doubly fed induction Generator

P_r and Q_r are the rotor active and reactive power and P_s and Q_s are the stator active and reactive power respectively. In the above figure we can see that the power flow in stator side is unidirectional i.e. from stator to grid. But the power flow in rotor circuit is bidirectional i.e. either from grid to rotor or rotor to grid. Usually the deviation in power due to wind fluctuation is managed through this rotor circuit. So the power rating of this circuit along with the converters is less compared to the main machine rating (Usually 20-30% of the machine rating).

4.MATHMATICALLY MODELLING:

The methodology When the DFIG is connected to a 3 phase balanced supply, a rotating magnetic field will be created in stator circuit. Also due to the power fed to rotor side a magnetic field will be also established in rotor side. The two magnetic fields represented by rotating reference frame are given below.

$$\phi_{ds} = L_{ss}\, i_{ds} + L_m\, i_{dr}$$
$$\phi_{qs} = L_{ss}\, i_{qs} + L_m\, i_{qr}$$
$$\phi_{dr} = L_{ss}\, i_{dr} + L_m\, i_{ds}$$
$$\phi_{qr} = L_{ss}\, i_{qr} + L_{m} i_q \qquad (1)$$

Similarly the stator and rotor voltages in rotating reference frame are given by the following equations.

$$V_{ds} = R_s\, i_{ds} + (d\, \phi_{ds}/dt) - \omega_s \phi_{qs}$$
$$V_{qs} = R_s i_{qs} + (d\, \phi_{qs}/dt) + \omega_s \phi_{ds}$$
$$V_{dr} = R_r i_{dr} + (d\, \phi_{dr}/dt) - (\omega_s - \omega_r)\phi_{qr}$$
$$V_{qr} = R_r i_{qr} + (d\, \phi_{qr}/dt) + (\omega_s - \omega_r)\phi_{dr} \qquad (2)$$

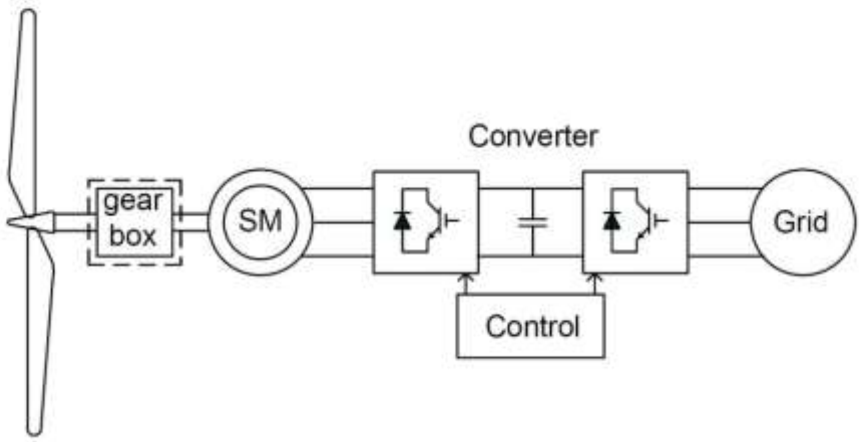
Similarly the active and reactive power of the stator is given by

$$Ps = 3/2\ (V_{ds} * i_{ds} + V_{qs} * i_{qs})\ ;$$

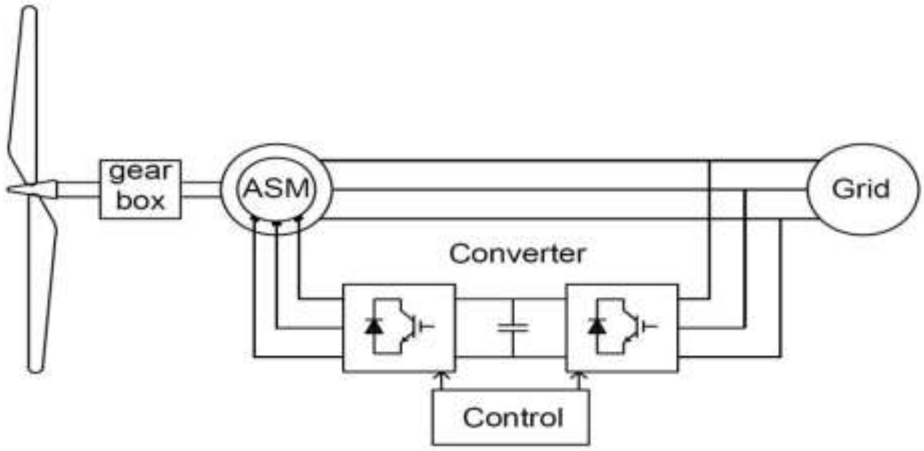
$$Qs = 3/2\ (V_{qs} * i_{ds} - V_{ds} * i_{qs}); \qquad (3)$$

4.1 System Configuration of a Variable-Speed DFIG Wind Turbine:

To simulate a realistic response of a DFIG wind turbine subjected to power system faults, the main electrical components as well as the mechanical parts and the controllers have to be considered in the simulation model.



(a)



(b)

Fig.2 (a & b) Variable speed wind turbines

5. ANFIS CONTROLLER:

Generally the combination of fuzzy logic and neural network is called as ANFIS (Adaptive Neuro Fuzzy Inference System). Neural system has many inputs and also has multiple outputs but the fuzzy logic has multiple inputs and single output, so the combination of this two is known as ANFIS which is used for nonlinear applications. ANFIS scheme for the speed control of DFIG, neural network techniques are used to select a proper rule base, which is achieved using the back propagation algorithm. This integrated approach improves the system performance, cost-effectiveness, efficiency, dynamism, reliability of the designed controller. The simulation results show the effectiveness of the method developed & has got very good dynamic responses. Now days, the DFIG play a vital role in the industrial sector especially in the field of electric drives. Without proper controlling of the speed, it is virtually impossible to achieve the desired task for any industrial application. DFIG, particularly the Wound rotor induction generator (WRIG), enjoy several advantages like simplicity, reliability, low cost and virtually maintenance-free electrical drives. In this context, the fuzzy logic concepts coupled with artificial neural networks (hybrid control) play a very important role in developing the controllers for the plant, which might yield excellent results. Here, follows a brief review of the literature relating to the work done by various authors on the fuzzy logic coupled with ANNs, i.e., the Adaptive Neuro Fuzzy Inference System (ANFIS) w.r.t. the speed control of DFIG systems. In the last few years, fuzzy logic has met a growing interest in many Generator control applications due to its non-linearity handling features and independence of the plant modeling. The fuzzy controller (FLC) operates in a knowledge-based way, and its knowledge relies on a set of linguistic if-then rules, like a human operator. An ANFIS controller is a device which controls each and every operation in the system making decisions. From the control system point of view, it is bringing stability to the system when there is a disturbance, thus safeguarding the equipment from further damages. It may be hardware based controller or a software based controller or a combination of both. In this section, the development of the control strategy for control of various parameters of the DFIG such as the speed, flux, torque, and voltage, current is presented using the concepts of ANFIS control scheme, the block diagram of which is shown in the Fig. 3.

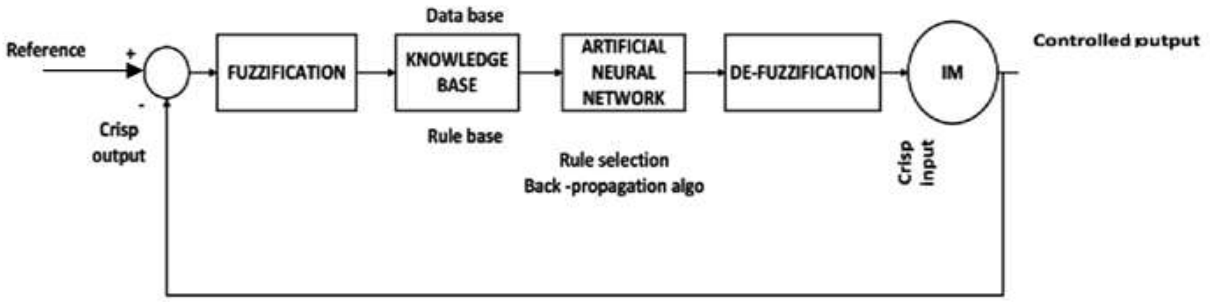
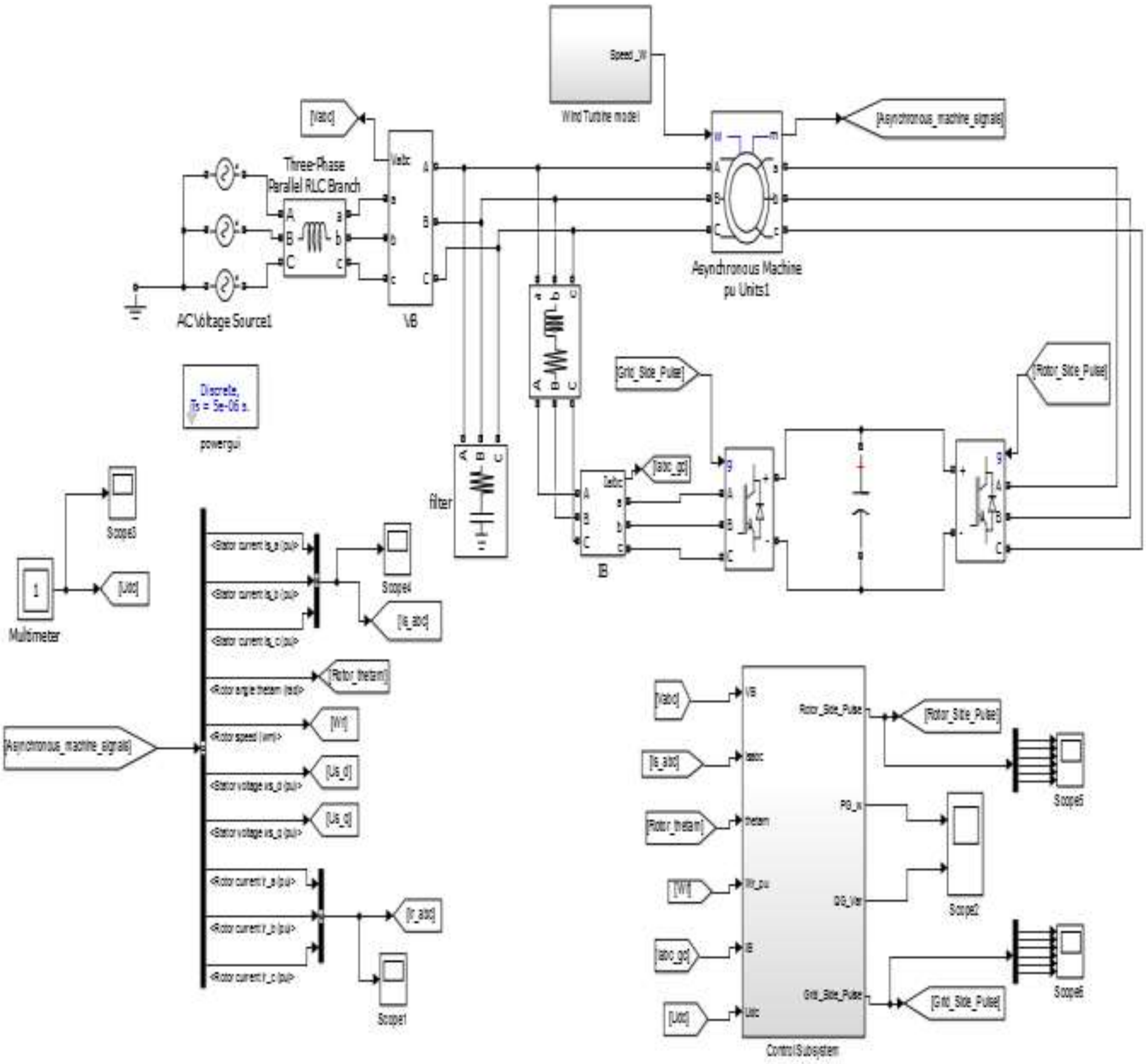


Fig. 3 Block diagram of the ANFIS control scheme for the speed control of the DFIG

6.. RESULTS AND DISCUSSION

6.1 Results of Various Parameters:

6.1.1 Simulink Model:



Waveform 1 shows the improved three phase stator current of generator using ANFIS controller.

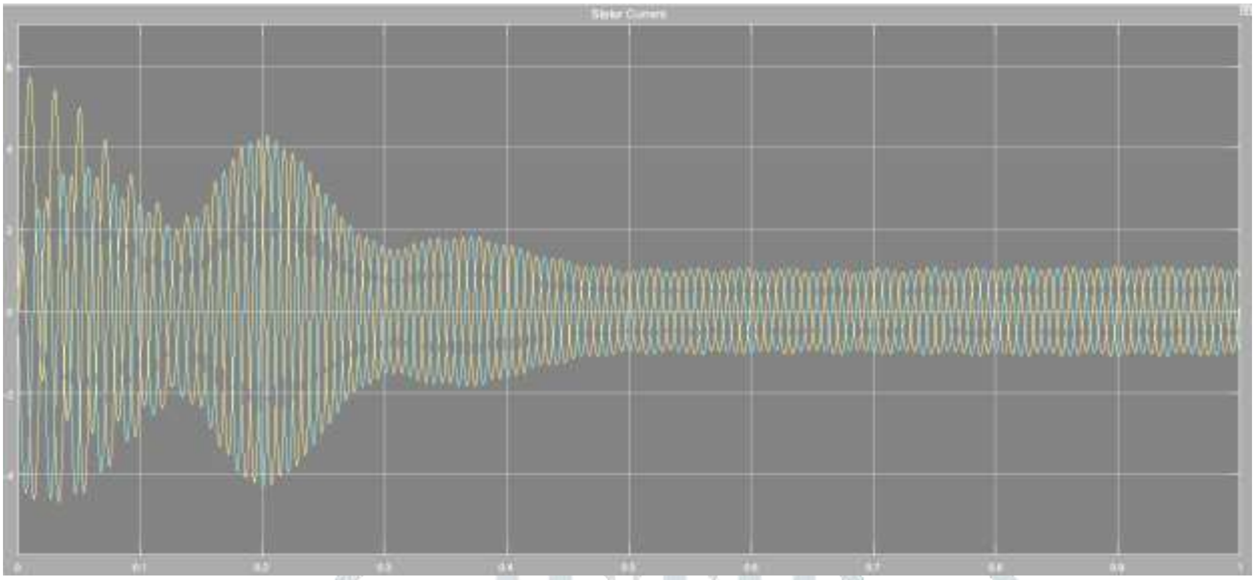


Fig.4-Waveform 1- Three phase stator current.

Waveform 2-shows the improved three phase Rotor current of generator using ANFIS controller.

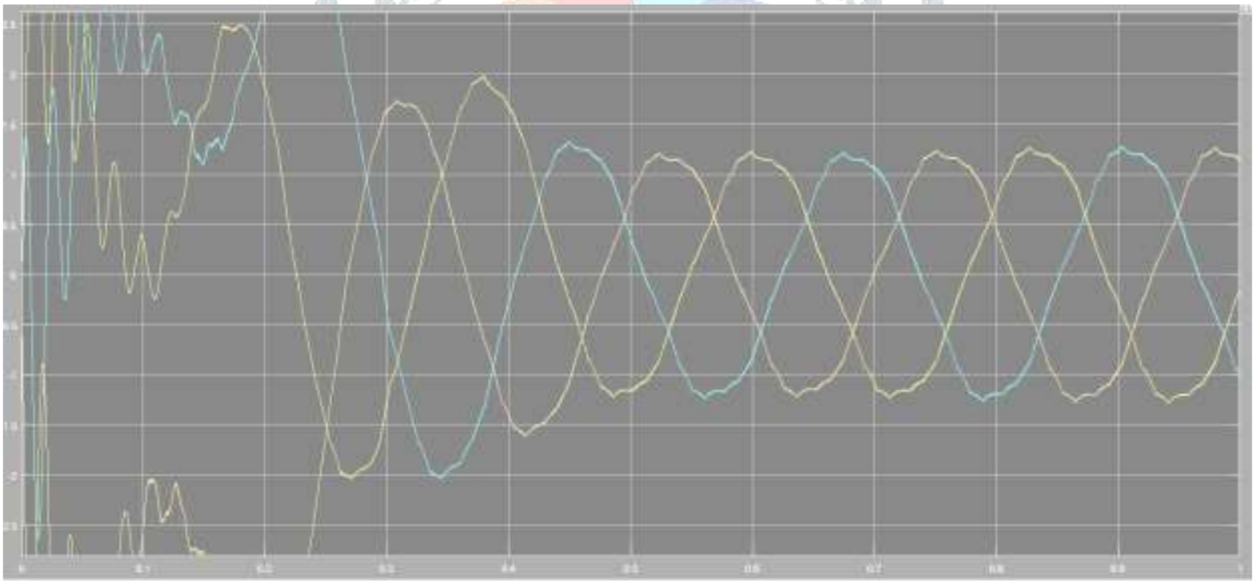


Fig.5-Waveform-2 Three phase rotor current.

Waveform-3 shows the Rotor side pulse

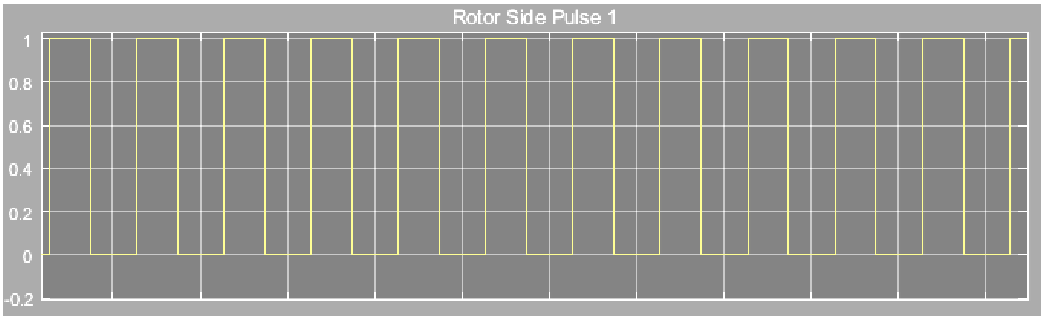


Fig.6-waveform-3 rotor side pulse

Waveform-5 shows the Grid side pulse:

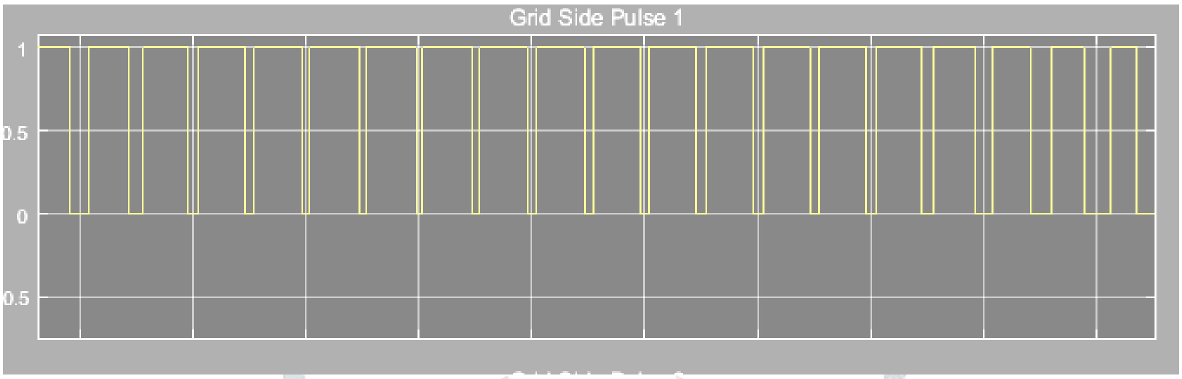


Fig.7-waveform-5 Grid side pulse.

Waveform-6 shows the improved RLC Voltage:

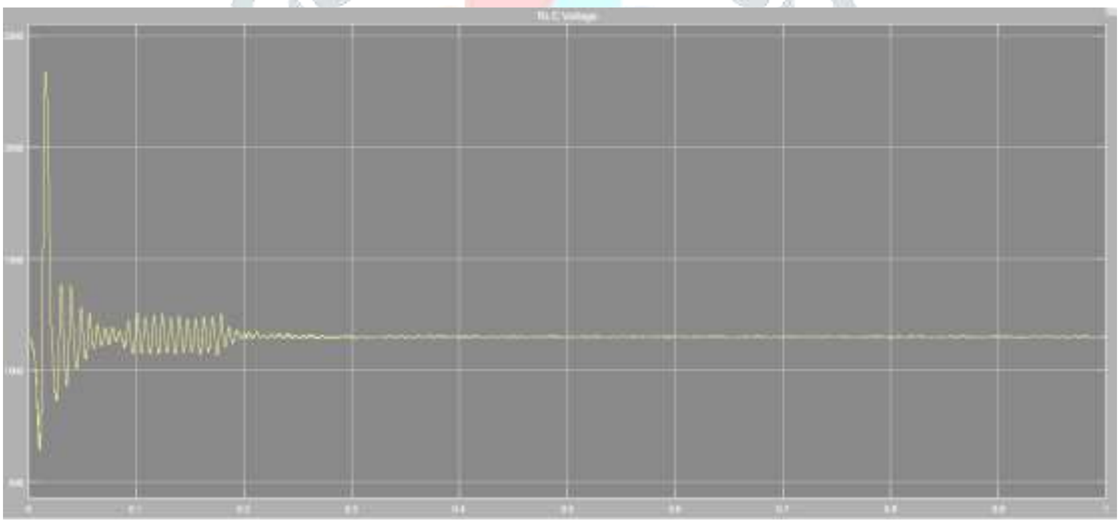


Fig.8-waveform-6 RLC voltage

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