I J C T A, 10(5) 2017, pp. 895-903

Comparision of PI/Fuzzy Techniques for Compensation of Unbalanced Voltages in Grid Connected PMSG Based Wind Turbine

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Abstract: This paper proposes an effective controller for grid connected wind turbine based permanent magnet synchronous machine for improving unbalanced voltages. In this paper, we proposed a comparative analysis under different controllers like PI and Fuzzy Controller to PMSG system. A control structure is designed based on the positive sequence reference signals. With the help of these controllers, the double frequency oscillations in DC-link voltages and variations in active power can be eliminated. More ever, the proposed system can be implemented in Matlab/Simulink and the performance of the proposed Grid based PMSG wind system under grid fault conditions is verified.

Keywords: PMSG, Wind Turbine, PI, Fuzzy, Fault analysis, Grid-system.

1. INTRODUCTION

Lately, many new breeze farms make use of wind turbines predicated on permanent magnet synchronous machine. This wind turbine based synchronous generators have been increasing demand in the industrial areas. The studies on the control strategies of PMSG under asymmetrical and symmetrical grid faults have become one of the key research section of the wind power technology development. In the present scenario, for protecting the system from these problems several control strategy have been introduced. In, predicated on the examination of the dc-link voltage distortions under unbalanced grid voltages, this paper proposed an average dual PI current control strategy predicated on negative and positive series part decomposition. The operational system structure is organic, which is difficult to adapt control parameters. In, an up-to-date control design using proportional controller was suggested to control the negative and positive series components current of the grid-side converter (GSC), that are integrated in the stationary reference framework?

Generally, permanent magnet synchronous machine is commonly used for wind turbine because of it rigid construction. The configuration of the proposed integrated grid and WECS based PMSG are first introduced in this paper [1]. Main constraints in general wind turbine are steady-state operating conditions under various wind speeds and marine-current speeds and the dynamic stability of the studied system. An RSC and GSC converters are introduced for improving the steady state and dynamic stability with the designed PI damping controller under different operating conditions. In this paper the controlling of PMSG is verified by using Fuzzy.

2. ARCHITECTURE OF PROPOSED GRID CONNECTED WIND SYSTEM

Grid Integration

1. *Reactive power capability:* the successful wind forms generally maintain the power factor over a range of approximately 0.95.

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In this paper a PMSG based WECS hybrid system with various controllers is considered, sustaining power to a load and the network as appeared in Figure 1 where C_{DC} is the dc link capacitor. The turbine coupling shaft is demonstrated as one mass drive framework as the appraised rotor rate is low with a higher number of rotor poles for the PMSG.

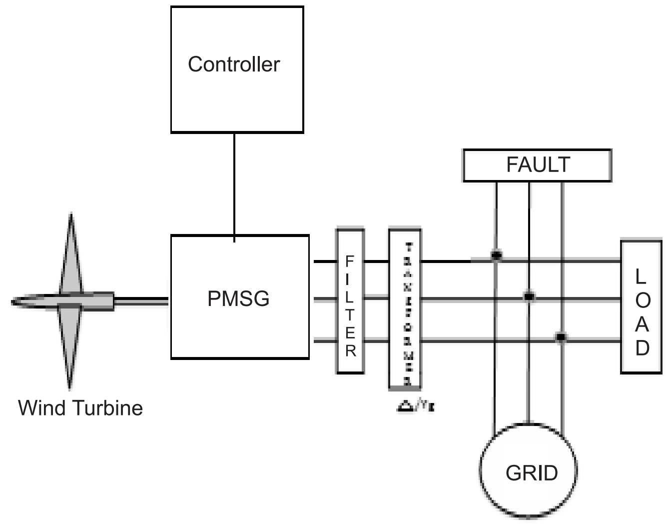

Figure 1: Hybrid System

In the present scenario, due to increasing of energy demands and higher reliability of requirements are move to concentrate on the utilization of DG systems as an alternate solution. In rural areas the most useful DG sources as PV, Wind and Fuel Cell generation systems. Nowadays, the wind power systems is the feasible solution to the clean bulk power to grids out of all renewable systems because of the following advantages. The wind generation supports not only being clean and renewable but also it have low running and maintaince cost. Figure 1 shows the grid connected hybrid system. In this case the wind turbine is designed with the help of permanent magnet synchronous machine as a distribution generation system. The

3. WIND TURBINE

Wind turbine is basically a device which is used to converter wind energy to electrical energy. In this the kinetic energy produced by the wind blades is the most desirable type of wind energy which is converted to electrical energy. Basically, wind turbines are classified into two types [8]: i.e., Horizontal and Vertical axis wind turbines. A vertical axis machine has its blades rotating on AN axis perpendicular to the bottom. There square measure variety of obtainable styles for each and every kind has bound benefits and downsides.

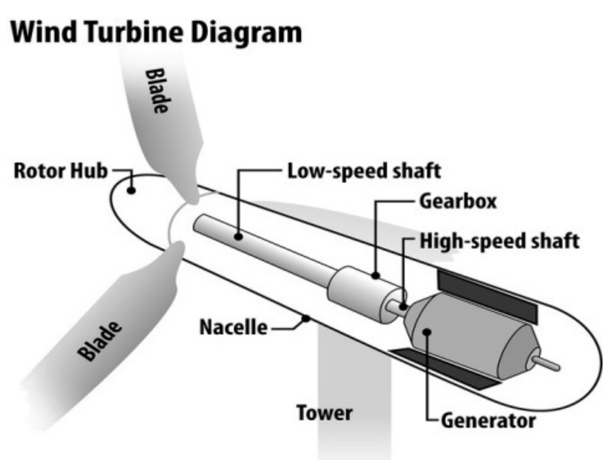

Figure 2: Basic diagram of wind turbine

Architecture of PMSG

A synchronous machine is generally a rotating machine whose steady state speed is proportional to frequency of the armature current. The basic structure of the permanent magnet synchronous machine for wind system is shown in Figure 3. Generally, PMSG machines are two types such as cylindrical and salient rotor types. The operational modes of PMSM is decided by the sign of electro-mechanical torque (such as +Ve sign for motoring operation and –Ve sign represents generating condition). For modelling PMSM machine the electrical and mechanical parts are indicated in the form of state space analysis. In case of PMSM machine the stator flux produced by the permanent magnet is always sinusoidal.

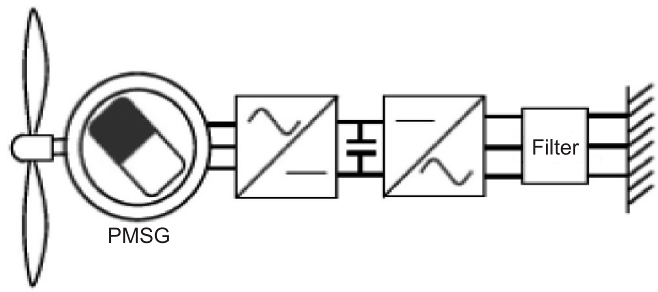

Figure 3: Structure of PMSM in Wind Turbine

The control strategy for the PMSG machine is shown in Figure 4. This control structure is designed by the help of *d-q* transformation technique. There are current components in grid side converter such as i^{+}_{gdq} and i^{-}_{gdq} act as +ve sequence components for regulating common DC link voltage (V_{dc}). A general PI controller is used in this paper for controlling unbalanced voltages ($V^{*}_{dc} - V_{dc}$).

$$U^{*}_{gdq} = -U^{pi}_{gdq} + U^{r}_{gdq} + jwL_{g}I^{+}_{gdq} \tag{1}$$

$$\Delta V_{dc} = V^{*}_{dc} - V_{dc} \tag{2}$$

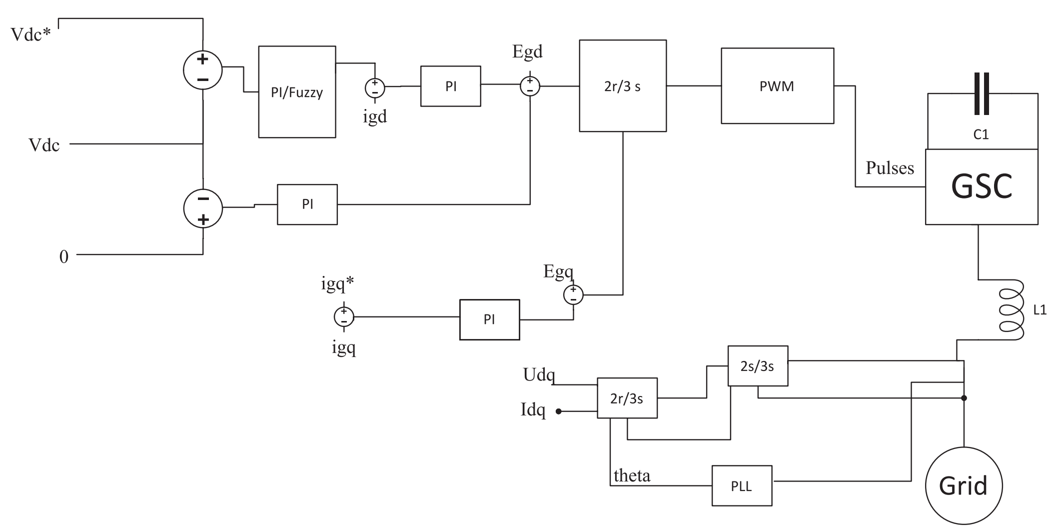

Figure 4: PMSG Control Diagram

Proportional and Integral Controller

The oscillations produced by the system is damped with the help of PI controller. In this proportional controller helps to produce the reference signal which is proportional to error signal. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system.

The general expression for PI controller is expressed as,

$$K_{p}\Delta + K_{I}\int \Delta\, dt \tag{3}$$

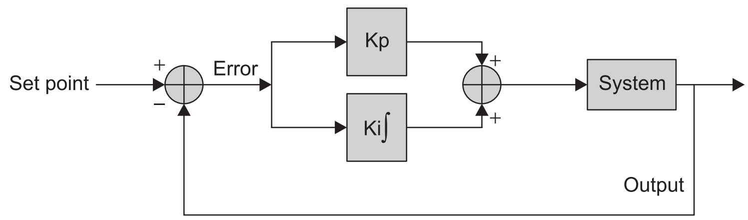

Figure 5: Configuration of PI controller

Fuzzy Logic Controller

In the previous section, control strategy based on PI controller is discussed. But in case of PI controller, it has high settling time and has large steady state error. In order to rectify this problem, this paper proposes the application of a fuzzy controller shown in Figure 6. Generally, the FLC [12] is one of the most important software based technique in adaptive methods.

As compared with previous controllers, the FLC has low settling time, low steady state errors. The operation of fuzzy controller can be explained in four steps [13].

1. Fuzzification
2. Membership function
3. Rule-base formation
4. Defuzzification.

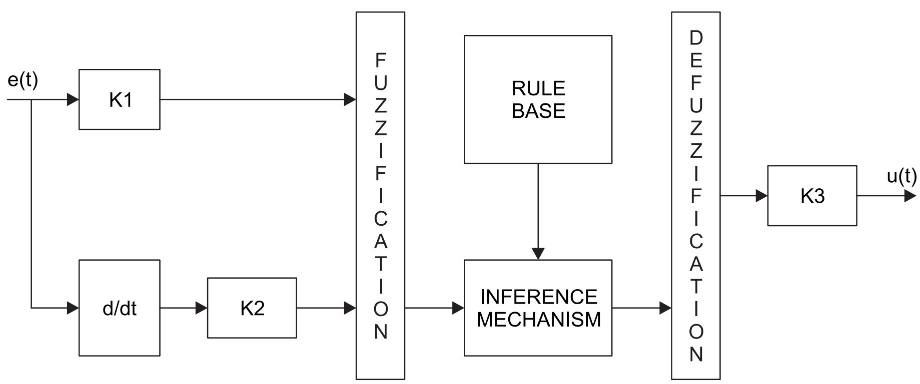

Figure 6: basic structure of fuzzy logic controller

In this paper, the membership function is considered as a type in triangular membership function and method for defuzzification is considered as centroid. The error $c(t)$ which is obtained from the comparison of reference and actual values is given to fuzzy inference engine. The input variables such as error and error rate are expressed in terms of fuzzy set with the linguistic terms VN, N, Z, P, and Pin this type of mamdani fuzzy inference system the linguistic terms are expressed using triangular membership functions. In this paper, single input and single output fuzzy inference system is considered. The number of linguistic variables for input and output is assumed as 3. The numbers of rules are formed as 9. The input for the fuzzy system is represented as error of PI controller. The fuzzy rules are obtained with if-then statements. The given fuzzy inference system is a combination of single input and single output. This input is related with the logical operator AND/OR operators. AND logic gives the output as minimum value of the input and OR logic produces the controlled output $u(t)$ as maximum value of input.

4. SIMULATION DIAGRAM & RESULT

Simulation review of proposed PMSG wind mill was completed using Simulink Library. The PMSG was making rated active GSC and power was working with unity electric power factor. Figure 7-14 shows the performance waveforms for the proposed system under different fault conditions. The GSC controller is verified by different controller (PI/Fuzzy) to attain better performance level under two cases.

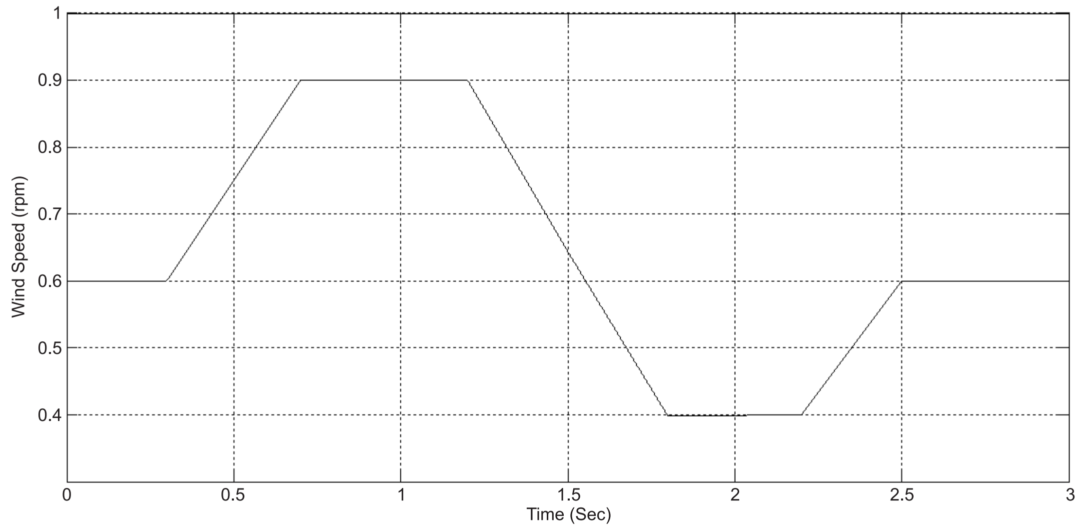

Figure 7: Wind Turbine Speed

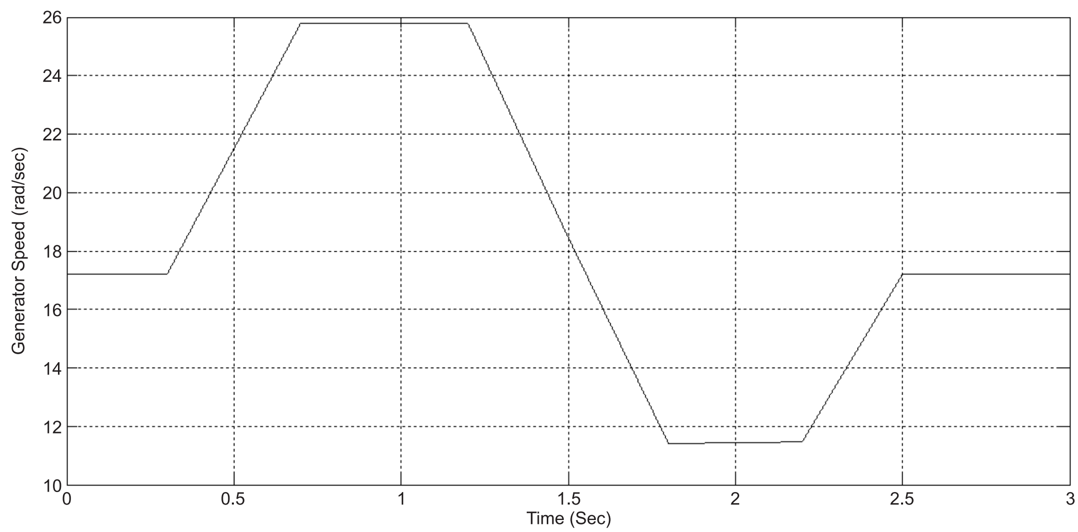

Figure 8: Speed of generator

Case 1: Single Phase to Ground Fault

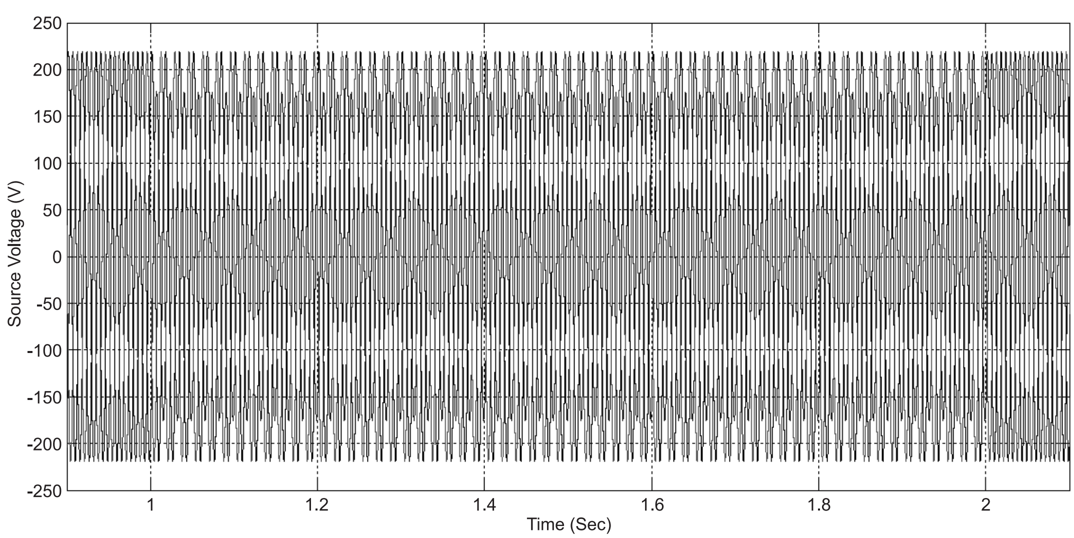

Figure 9: Three Phase Grid Volatge Under L-G Fault

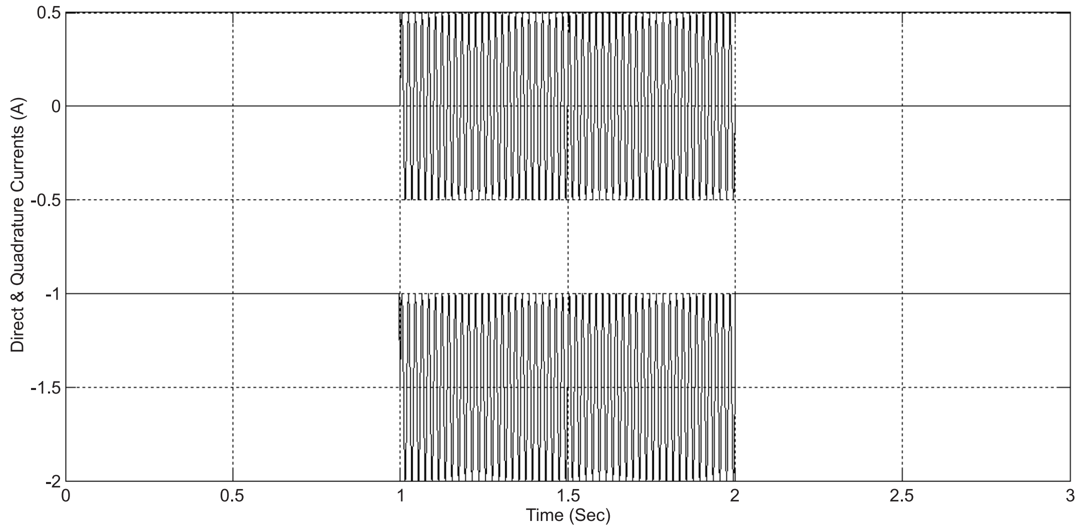

Figure 10: Direct and Quadrature Currents Under L-G Fault

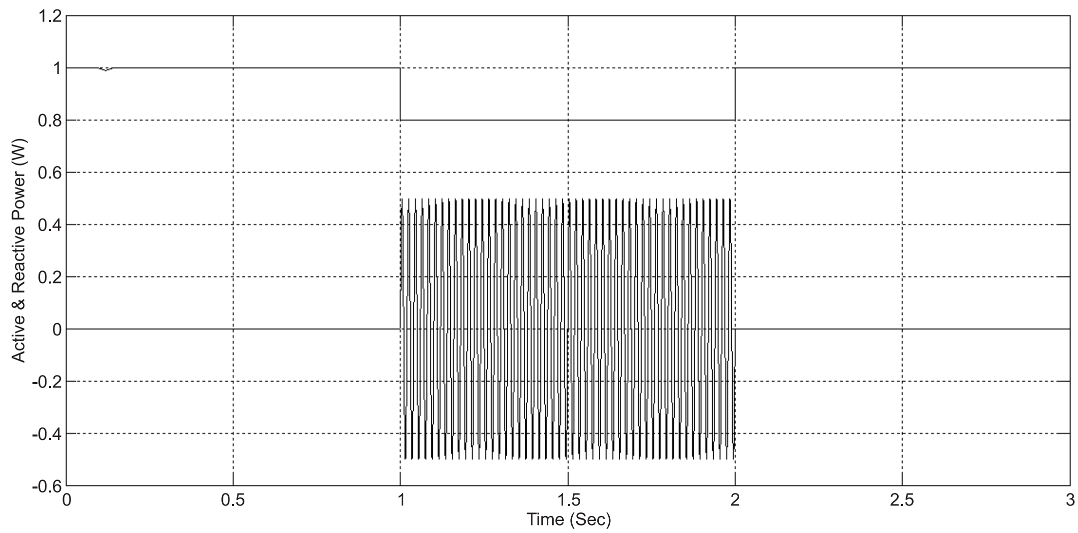

Figure 11: Active and Reactive Powers Under L-G Fault

Case 2: Three Phase Fault

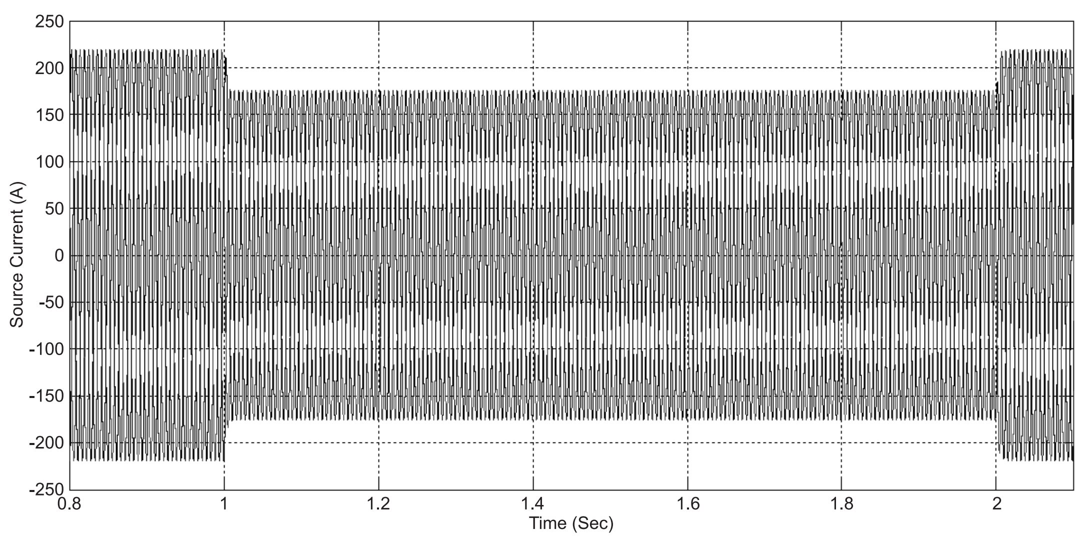

Figure 12: Three Phase Grid Volatge Under Three Phase Fault

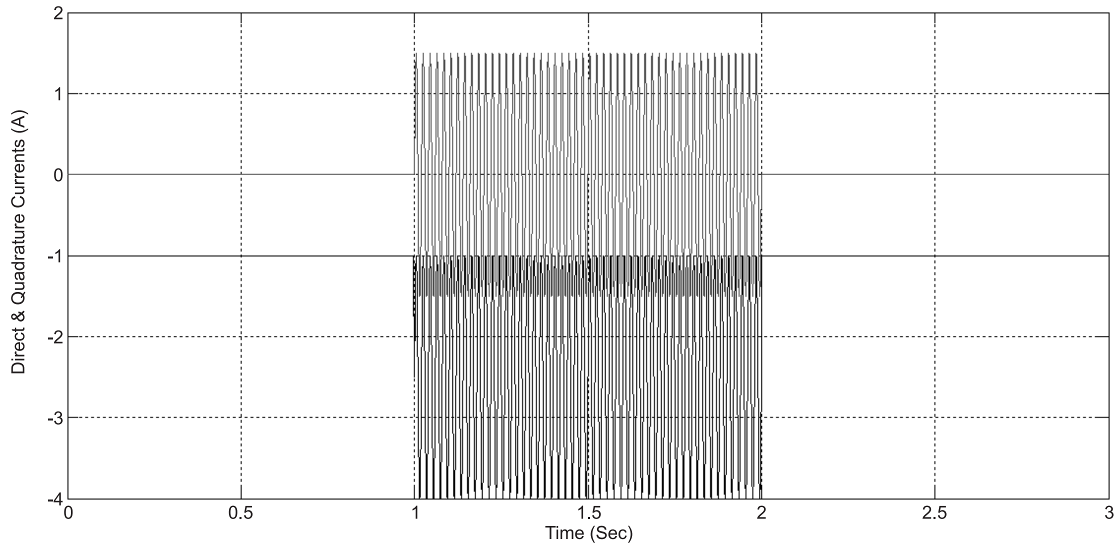

Figure 13: Direct and Quadrature Currents Under Three Phase Fault

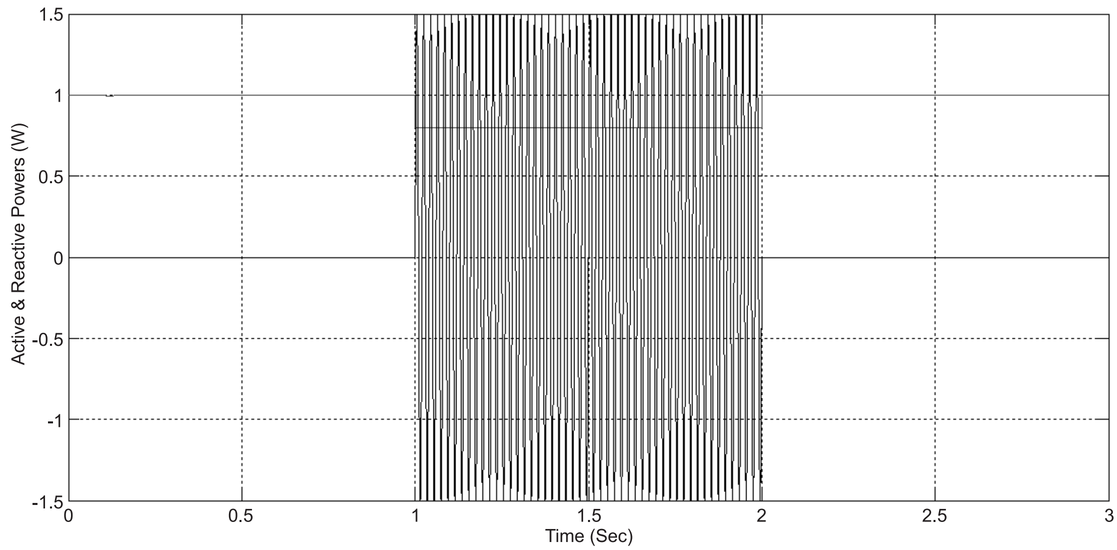

Figure 14: Active and Reactive Powers Under Three Phase Fault

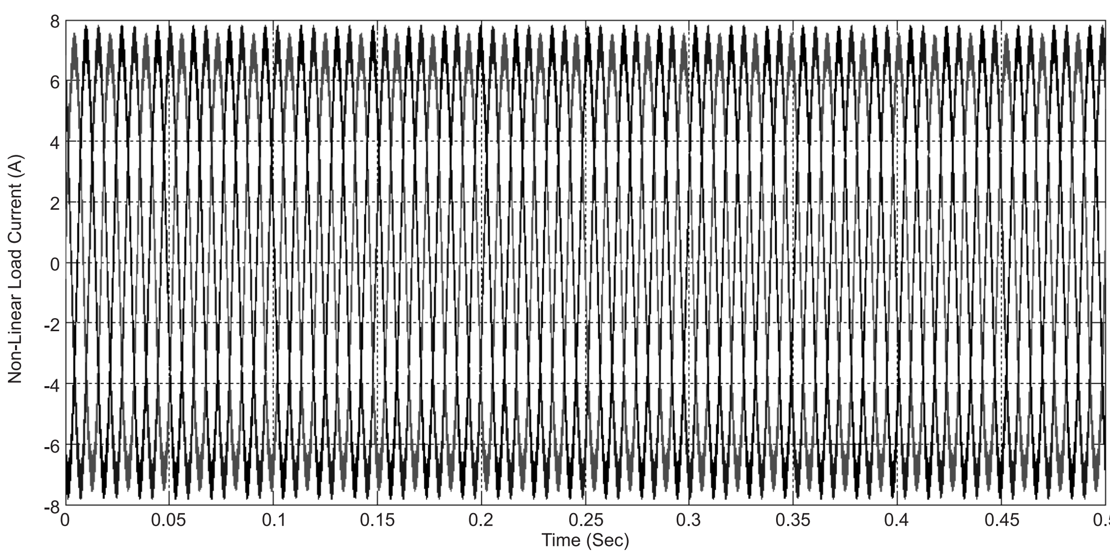

Figure 15: Non-Linear Load Current

Analysis of Total Harmonic Distrotion for Load Current

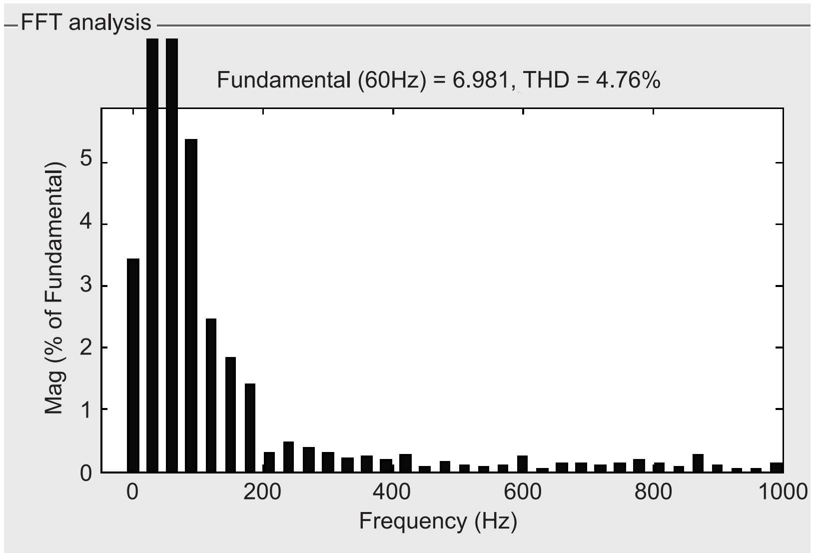

Figure 16: Analysis of THD with PI Controller

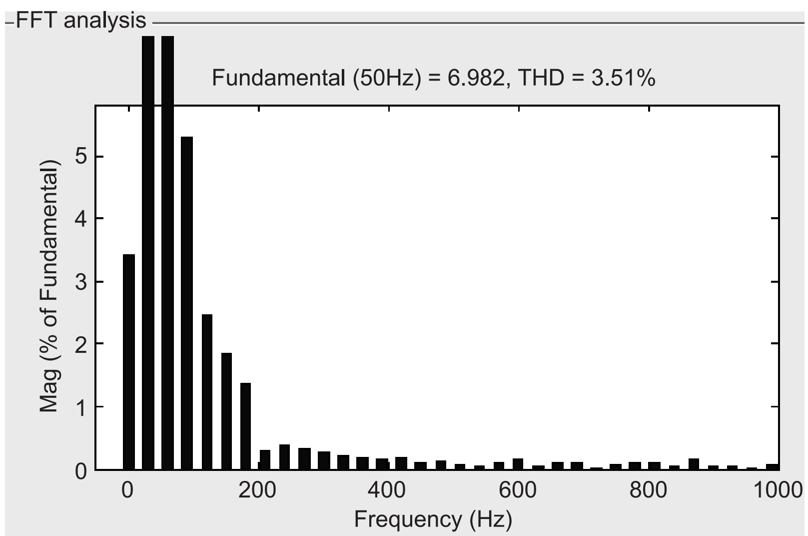

Figure 17: Analysis of THD with FUZZY Controller

In this paper the proposed system is tested under utilization of non-linear load and the mitigation of harmomnics caused by it. Due to this, we proposed a concept of PI and Fuzzy controller for better control of harmonics. The harmonic analysis for the load current under PI and Fuzzy technique is shown in Figure 16 and Figure 17. From the results, we conclude that the fuzzy controller shows the better performance for mitigating harmonics as compared to conventional PI controller.

5. CONCLUSION

This paper proposes a different (PI/Fuzzy) control techniques for Converter which is used in PMSG for reducing unbalanced voltage conditions. For restraining the oscillation components, in this paper an control technique with reference signal as positive synchronous frame coordinates is proposed. As a total result, the suggested Fuzzy-based control strategy is easy without any decomposition and complicated research calculation. From the simulation results and harmonic distrotion factor, we conclude that the Fuzzy controller shows the better result as compared to PI controller.

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