POWER QUALITY IMPROVEMENT IN GRID CONNECTED WIND ENERGY SYSTEM USING FUZZY CONTROLLED UPQC

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ABSTRACT

Wind power generation is grasping more attention nowadays because it offers the benefits of reduced cost, increased efficiency, less pollution and so on. But the known disadvantage is that the integration of wind farm with grid leads to many power quality problems such as voltage sag, swell, unbalance, harmonics, flickers etc. This paper concentrates mainly on diminution of source voltage sag and load current harmonics which are caused mainly due to the use of nonlinear loads such as personal computers, variable frequency drives, SMPS, monitors, printers etc in both industrial and commercial sectors. For the betterment of power quality issues, custom power devices are used. Among many of the custom power devices, Unified Power Quality Conditioner (UPQC) have been used nowadays which diminishes both voltage sag and current harmonics. The performance of UPQC can be improved by using a new strategy of control which is implemented using Fuzzy Logic Controller and from the simulation results, the performance of fuzzy controlled UPQC is better which can be validated by comparing its performance with the conventional control of PI controller.

Index Terms— Voltage sag, Current harmonics, Unified power quality conditioner, Fuzzy logic controller, PI Controller.

I. INTRODUCTION

Wind power is one of the most favorable renewable energies that are available in the world. Wind farms which have many wind turbines act as power plant and hence they can be connected to the grid directly. Tremendous development in the power electronics system improves the characteristics of wind farms [1,2]. The variable speed wind turbine using doubly fed induction generator is becoming a popular concept as it provides good power factor, high efficiency and better controlability [6]. Since the wind's nature is fluctuating in nature, power from the wind farm will not be constant and uniform hence it creates stability problems and power quality problems such as voltage sag, swell, unbalance, harmonics etc. Voltage sag is one of the most severe problems which leads to disoperation of drive systems and current harmonics are caused by loads of nonlinear type [9, 10]. Custom power devices play an important role in the mitigation of both voltage sag and load current harmonics simultaneously. Dynamic Voltage Restorer (DVR) is well suited to protect sensitive types of equipment from voltage unbalance but DVR does not respond for load current harmonics [11]. The device STATCOM is used for the reduction of load current harmonics and provides reactive power control but doesn't consider voltage related problems [12]. UPQC is the only device which has the capability to mitigate both voltage sag and current harmonics [13]-[15]. Fuzzy Logic Controller is proposed in this paper which is well appropriate for nonlinear loads and it doesn't require any mathematical modeling.

II. UNIFIED POWER QUALITY CONDITIONER

For alleviation of power quality problems in both supply and load side, UPQC is used. Basically, UPQC has two Voltage source inverter, which is connected back to back sharing a common dc link as in Fig.1. The series inverter is operated in voltage control mode and shunt inverter in current control mode and maintains the dc bus voltage at the reference value. The features of UPQC are as follows,

- It mitigates harmonics in supply current thus providing current quality for nonlinear loads.
- It also provides reactive power compensation and so the supply voltage and current harmonics in phase.
- UPQC maintains the load voltage at rated value even though in the presence of supply disturbance

It does not require extra dc link voltage support for the series compensator.

III. PROPOSED SYSTEM

In this work, the doubly fed induction generator-based wind turbine is synchronized with the grid in terms of voltage and frequency. The wind speed is maintained at 8 m/s. The power quality problems such as voltage sag and load current harmonics are created using diode bridge rectifier with RL load in the simulation model.

For enhancement of above PQ problems, UPQC is designed and proposed control strategy using Fuzzy Logic Controller (FLC) is implemented along with Power Angle Control approach for the generation of both reference voltage and reference current for series and shunt inverter respectively. By comparing the simulation results, the effectiveness of proposed system can be validated by comparison with the conventional PI controller.

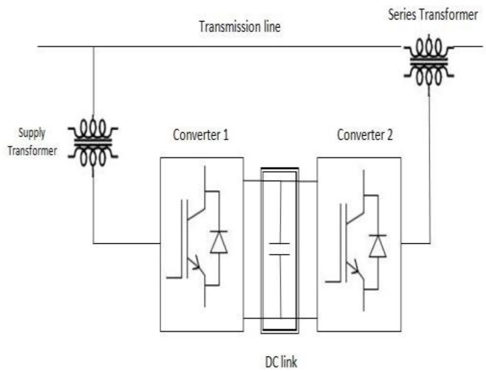

Fig. 1.UPQC Layout

IV. CONTROL STRATEGY

A. Conventional PI control strategy

Here UPQC is controlled with the conventional PI controller. The gain values for P and I are chosen as $k_p = 0.1$ and $k_i = 2$ using trial and error method.

B. Fuzzy Logic Controller

Fuzzy logic offers an effortless way to arrive at conclusion based upon blurred, imprecise or missing input data. The structure of fuzzy logic controller has

- A fuzzification module which converts the linguistic values of the error signals into fuzzy values.
- A rule elevator which is used for the evaluation of fuzzy rules. Basically, used operations are AND, OR and NOT. The rules for the fuzzy logic controller is shown in Table. 1.
- A defuzzification module which converts the linguistic variable to real world variable.

TABLE I. FUZZY RULE REPRESENTATION

e \ de	NB	NS	Z	PS	PB
NB	PB	PS	NS	NS	NB
NS	PS	PS	NS	PB	NB
Z	NB	NB	NS	PS	PB
PS	NS	NS	PB	NB	PS
PB	NS	NS	PB	PB	PB

The change in dc voltage value is fed as input to the controller which generates appropriate gate signals for the switches of back to back converter using PWM generator. Input which includes error and change in error, Output which includes the duty ratio for a fuzzy logic controller is shown in Fig. 2 – 4.

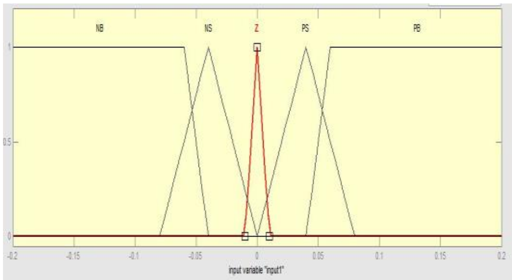

Fig. 2: Error as input

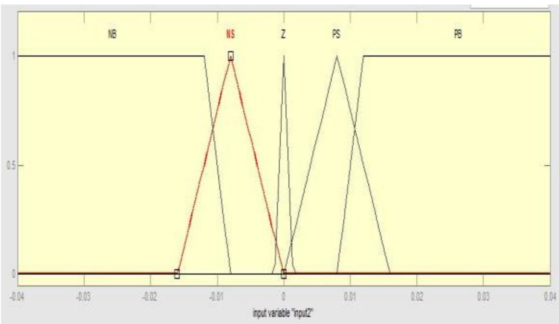

Fig. 3.Change in error as input

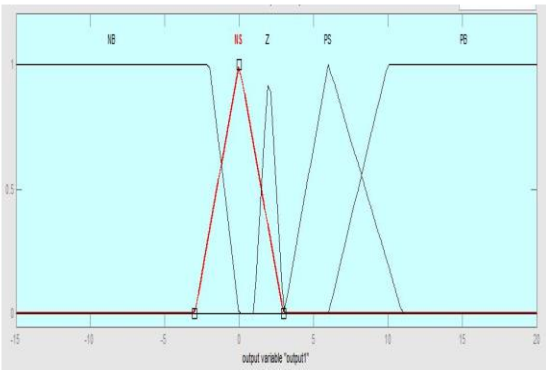

Fig. 4.Output variables to defuzzification process

V. SIMULATION RESULTS

The proposed system is introduced in three phase 420V, 50Hz grid system which is supplied from a 5HP,460V,50Hz Doubly-fed Induction generator based wind turbine using MATLAB Simulink. The simulation model of the proposed system is shown in Fig. 5.

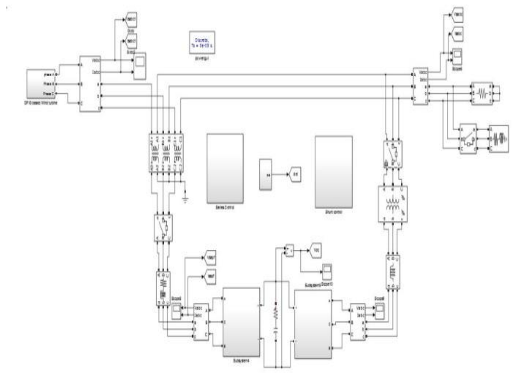

Fig. 5.Simulation model of proposed system

A. Uncompensated system

In the proposed system, voltage sag and current harmonics are simulated using nonlinear load of RL for a duration of 0.02 to 0.08 seconds. The simulation results for the uncompensated system and the Total Harmonic Distortion in load current using FFT analysis is shown in Fig. 6 – 8 respectively.

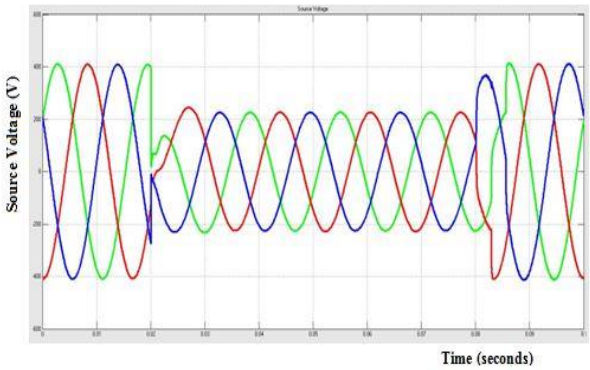

Fig. 6.Voltage sag of uncompensated system

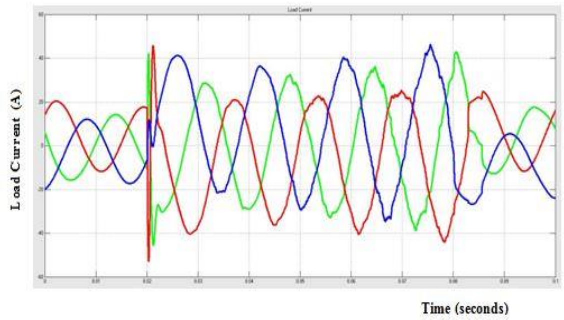

Fig. 7: Current harmonics of Uncompensated system

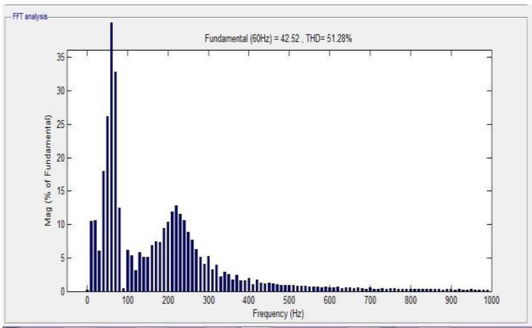

Fig. 8.THD of Load Current

B. UPQC with PI controller

To compensate voltage sag and current harmonics, the custom power device is accomplished by using the PI controller. For good compensation, the gain values of PI controller are chosen using trial and error method. The simulation results of the proposed system and THD value of load current are shown in Fig. 9 – 11 respectively.

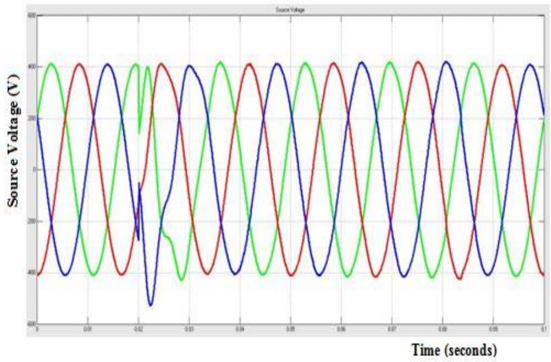

Fig. 9.Source voltage

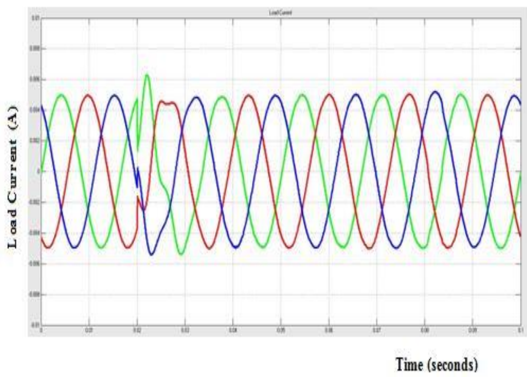

Fig. 10.Load current

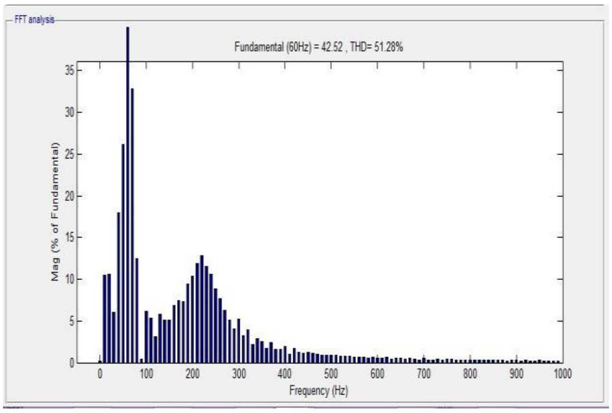

Fig. 11.THD in Load current

C. UPQC with Fuzzy controller

The proposed fuzzy controller is implemented to compensate the power quality problems. The simulation results and THD values of load current are shown in fig. 12 - 14 respectively.

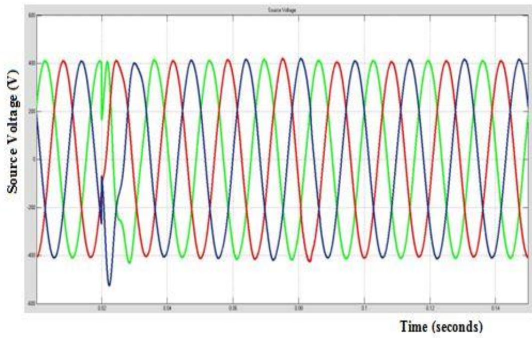

Fig. 12: Source Voltage

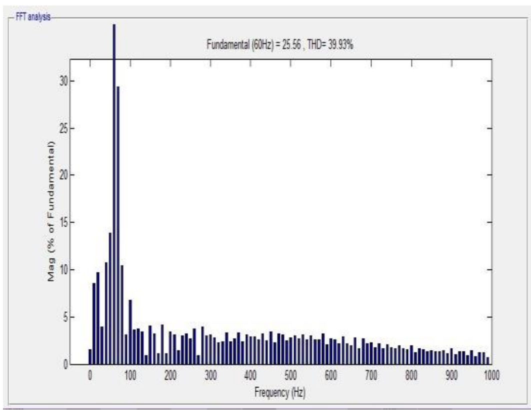

Fig.13.Load Current

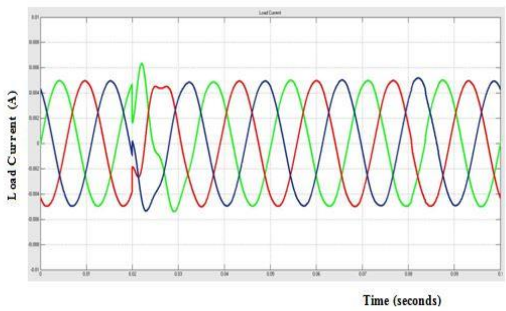

Fig.14.THD in Load current

VI. PERFORMANCE COMPARISON

The performance of the proposed system is validated by comparing the proposed control strategy with the conventional PI controller. The comparison result of UPQC with PI and Fuzzy logic controller is shown in table II.

TABLE II. PERFORMANCE COMPARISON

SYSTEM	THD IN LOAD CURRENT (%)
Uncompensated system	51.28
UPQC with PI controller	39.93
UPQC with Fuzzy logic Controller	7.21

VII. CONCLUSION

In this paper, enhancement of voltage and current quality in grid-connected wind power system has been done. Power quality issues such as voltage sag and current harmonics are simulated using MATLAB. Hence from the simulation results, it is observed that voltage sag is mitigated successfully but the load current has high THD value, but the proposed Fuzzy logic controller mitigates voltage sag, as well as the THD value of load current obtained, is also a small value. Thus the proposed system is proven as an efficient device than the conventional one.

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