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# Enhancement of Power quality in Renewable Energy Sources Using Artificial Intelligent Technique

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***Abstract*— Most of the researches are going of electricity generation using Renewable Energy Sources as non renewable energy sources are reducing day by day. Distribution side generation using these Renewable energy sources are increasing gradually. In this paper by using a Wind Energy Converter System (WECS) connected to a Current source inverter which maintains the quality of voltage and frequency., which maintains the quality of power in desired limits. Here the Current source Inverter acting as filter reduces the disturbances imminent in the system. Here fuzzy based controller used for controlling the the output voltage of wind system. By using fuzzy controlling methods harmonics are reduced in the load connected to wind energy system. All of the studies have been carried out through dynamic simulation using the MATLAB/Simulink Power System Toolbox.**

***IndexTerms*—Power Quality, Active Power Filter, Fuzzy PI controller, harmonics compensation.**

## I. INTRODUCTION

Increase in demand for power, depletion of conventional energy sources and their effects on environment are making power engineers to look for alternatives for power generation. Power generation through wind[1],[2] is highly popular across the world due to advancement of technology and low installation costs when compared to solar and other sources of renewable energy. Now-a-days, these sources are interconnected with the distribution system. The utilization of these sources indirectly reduces the line losses in the transmission because these sources are installed closely to the utilization point.

With the increase in wind power interconnection with the grid, the power quality becomes a vital issue for power engineers. In order to overcome this power quality issue, current controlled voltage source inverters are used to interface the intermittent RES. In [3] an inverter operates as active inductor at a certain frequency to absorb the harmonic current. But the exact calculation of network inductance in real-time is difficult and may deteriorate the control performance. A similar approach in which a shunt active filter acts as active conductance to damp out the harmonics in distribution network is proposed in [4]. In [5], a control strategy for renewable interfacing inverter based on p-q theory is proposed. In this strategy both load and inverter current sensing is required to compensate the load current harmonics. Thus, the Shunt Active Filter [6] drains the distorted Components of the load currents from the grid in a way that the system current is in phase with the system voltages.

Hence, to improve dynamic behavior of a SAF and its robustness under range of load variations, the proposed method uses instantaneous p-q theory for reference current generation and fuzzy logic controller for DC voltage control.

## II. BASIC CONFIGURATION OF ACTIVE FILTER

Shunt active power filter compensate current harmonics by injecting equal-but-opposite compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180º. With a suitable control scheme, the active power filter can also compensate the load power factor. The compensation characteristic of the shunt active power filter is shown in Fig. 1.

The shunt APF based on Voltage Source Inverter (VSI) is an efficient method to harmonic problems. The performance of an active filter [7],[8] depends mainly on the technique used to compute the reference current and the control method used to inject the desired compensation current into the line.

## III. WIND INTERFACED SHUNT ACTIVE FILTER CONFIGURATION

The most important objective of the SAF [9] is to compensate the harmonic currents. The voltage source inverter is a key element of a DG system as it interfaces the renewable energy source to the grid and delivers the generated power. The variable speed wind turbines generate power at ac voltage. Thus, the power generated from these renewable sources needs power conditioning before connecting on dc- link.

## IV. CONTROL OF GRID INTERFACING INVERTER

The regulation of dc-link voltage carries the information regarding the exchange of active power in between renewable source and grid [10]-[13]. The actual dc-link voltage is sensed and passed through a first-order *low pass filter* (LPF) to eliminate the presence of switching ripples on the dc-link voltage. The difference of this filtered dc-link voltage and reference dc-link voltage is given to a fuzzy PI controller to maintain a constant dc-link voltage under varying generation. Thus the output of dc-link voltage regulator results in an active current. The multiplication of active current component with unity grid voltage vector templates generates the reference grid currents. These reference grid currents are compared with actual grid currents to compute the current errors. These current errors are given to hysteresis current controller. The hysteresis controller then generates the switching pulses for the gate drives of grid-interfacing inverter.

The instantaneous currents can be written as $i_s(t) = i_1(t) - i_c(t)$ (1)

Source voltage is given by $V_s(t) = V_m \sin \omega t$ (2)

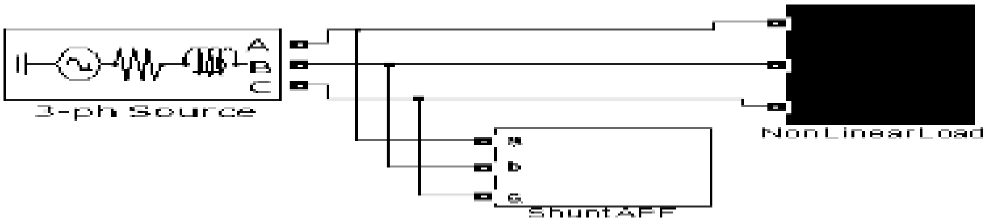


Fig.1. Compensation characteristics of a shunt active power filter

## V. REFERENCE CURRENT GENERATION

If a non-linear load is applied, then the load current will have a fundamental component and harmonic components which can be represented as

$$i_L(t) = \sum_{n=1}^{\infty} I_n \sin(n\omega t + \emptyset_n)$$

$$= I_1 \sin(n\omega t + \emptyset_1) + \textstyle\sum_{n=2}^{\infty} I_n \sin(n\omega t + \emptyset_n) \quad (3)$$

The instantaneous load power can be given as

$$P_L(t) = V_s(t) * i_l(t) \quad (4)$$

$$= V_m I_1 \sin^2 \omega t * \cos \emptyset_1 + V_m I_1 \sin \omega t * \cos \omega t * \sin \emptyset_1 + V_m \sin \omega t * \textstyle\sum_{n=2}^{\infty} I_n \sin(n\omega t + \emptyset_n)$$

$$= P_f(t) + P_r(t) + P_h(t) \quad (5)$$

From (4), the real (fundamental) power drawn by the load is

$$P_f(t) = V_m I_1 \sin^2 \omega t * \cos \emptyset_1 = V_s(t) * i_s(t) \quad (6)$$

From (6), the source current supplied by the source, after compensation is

$$i_s(t) = P_f(t)/V_s(t) = I_1 \cos \emptyset_1 \sin \omega t = I_m \sin \omega t \quad (7) \quad \text{Where } I_m = I_1 \cos \emptyset_1$$

There are also some switching losses in the PWM converter, and hence the utility must supply a small overhead for the capacitor leakage and converter switching losses in addition to the real power of the load. The total peak current supplied by the source is

$$I_{sp} = I_{sm} + I_{s1} \quad (8)$$

If the active filter provides the total reactive and harmonic power, then $i_s(t)$ will be in phase with the voltage and purely sinusoidal. At this time, the active filter must provide the following compensation current:

$$i_c(t) = i_L(t) - i_s(t) \quad (9)$$

Hence, for accurate and instantaneous compensation of reactive and harmonic power it is necessary to estimate, the reference current. The peak value of the reference current $I_{sp}$ can be estimated by controlling the DC side capacitor voltage. Ideal compensation requires the mains current to be sinusoidal and in phase with the source voltage, irrespective of the load current nature. The desired source currents, after compensation, can be given as

$$i_{sa}{}^* = I_{sp} \sin \omega t$$

$$i_{sb}{}^* = I_{sp} \sin(\omega t - 120^o)$$

$$i_{sc}{}^* = I_{sp} \sin(\omega t + 120^o)$$

The capacitor voltage is compared with a reference value and the error is processed in a fuzzy PI controller. The output of the fuzzy PI controller has been considered as the amplitude of the desired source current, and the reference currents are estimated by multiplying this peak value with unit sine vectors in phase with the source voltages.

## VI.IMPLEMENTATION OF FUZZY PI CONTROLLER

Fuzzy logic controllers (FLCs) [14], [15] are intelligent control systems characterized by a set of linguistic statements based on expert knowledge or experience. Fuzzy logic was first proposed by Lotfi A. Zadeh of the University of California. A simple FLC consists of four major elements: a fuzzifier, rule base, inference engine and a defuzzifier. The fuzzifier converts real system variables into fuzzy variables. The inference unit provides the necessary connection between the controller input and output fuzzy sets. The rule base expressed in the form of IF-THEN rules is used by the inference unit. The defuzzifier takes the results of fuzzy reasoning and produces a new real control action. A "PI fuzzy controller" can be used as shown in Fig.2. The FLC has two inputs, the error e(k) and change of error Δe(k), which are defined by e(k) = r(k)−y(k), Δe(k) =e(k) − e(k − 1), where r and y denote the applied set point input and plant output, respectively. Indices k and k−1 indicate the present state and the previous state of the system, respectively. The output of the FLC is the incremental change in the control signal Δu (k). The controller has two input variables and one output variable.

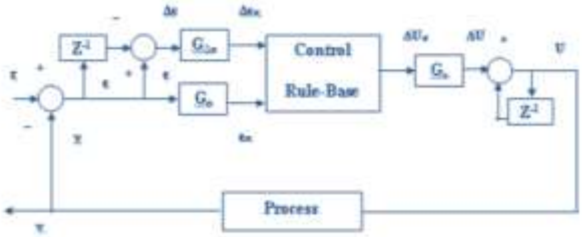


Fig. 2 Block diagram of Fuzzy PI Controller

The input and output variables of fuzzy PI controller can be defined as

$$E(k) = e(k).Ge \quad (11)$$

$$CE(k) = ce(k).Gce \quad (12)$$

$$I(k) = i(k).G\Delta i \quad (13)$$

Where e(k) is the error between reference voltage and DC capacitor voltage, ce(k) is the change of error in voltage, I(k) is the output of the fuzzy logic controller, and Ge, Gce and G Δ i are scaling factors. In the case of a PI type FLC, the actual value of the controller output is obtained By Eq. (10) as follows:

$$u(k) = u(k-1) + \Delta u(k) \ (14)$$

Where u(k) is the controller output, u(k- 1) controller output and Δu(k) the incremental c output , which is determined by the rules of the fo If e is E and Δe is ΔE, then Δu is Δ

## VI. SIMULATION RESULTS AND DISCUSSION

The proposed system not only supplies extracted wind power to the power system, but it also mitigate harmonic currents which are drawn by non-linear loads. In order to demonstrate the validity of the proposed system a simulation is carried out using MATLAB/SIMULINK environment. In this fuzzy controller, Mamdani's Fuzzy Inference Method is adopted. Figure 3 indicates the membership functions are triangle ones having linguistic labels of NB (Negative Large), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium) and PB (Positive Large) because of its simplicity.

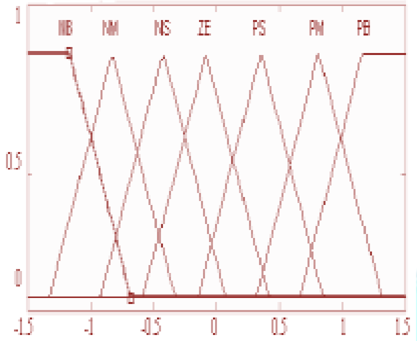


Fig. 3a. Membership Functions for *e*.

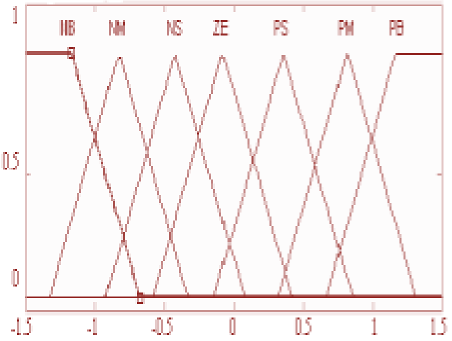


Fig. 3b. Membership Functions for Δ*e*.

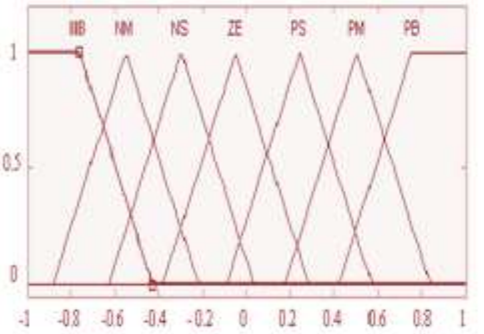


Fig. 3c. Membership Functions for Δu.

Rules form the basis for the fuzzy logic to obtain the fuzzy output. The rule-based form uses linguistic variables as its antecedents and consequents. The antecedents express an inference or the inequality, which should be satisfied. The consequents are those, which we can infer the output.

Table 1 shows the rule base of fuzzy PI controller with "Vdc" and "Vdc-ref" as inputs. Output variable is change in current. The rule base consists of 49 IF-THEN rules.

| **Δe/e** | **NB** | **NM** | **NS** | **ZE** | **PS** | **PM** | **PB** |
|---|---|---|---|---|---|---|---|
| **NB** | NB | NB | NB | NM | NM | NS | ZE |
| **NM** | NB | NB | NM | NS | NS | ZE | PS |
| **NS** | NB | NM | NS | NS | ZE | PS | PM |
| **ZE** | NM | NS | NS | ZE | PS | PS | PM |
| **PS** | NM | NS | ZE | PS | PS | PM | PB |
| **PM** | NS | ZE | PS | PS | PM | PB | PB |
| **PB** | ZE | PS | PM | PM | PB | PB | PB |

TABLE I. RULE BASE OF FUZZY PI CONTROLLER

**Before compensation**

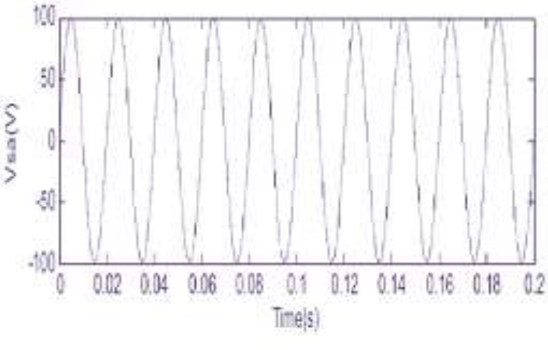


Fig. 4. Source voltage for nonlinear load

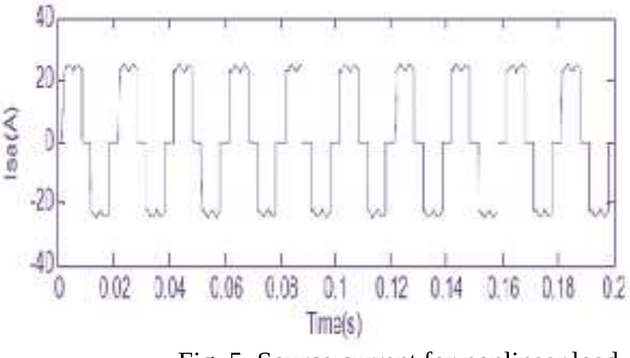


Fig. 5. Source current for nonlinear load

**After compensation**

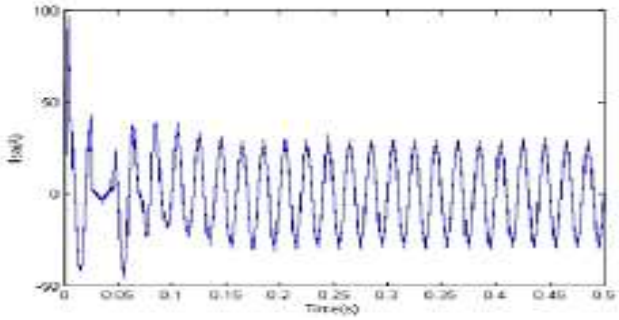

Fig. 6. Source current for nonlinear load

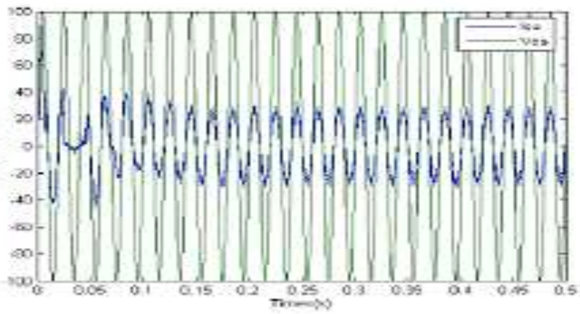

Fig. 7. Voltage and current of Source

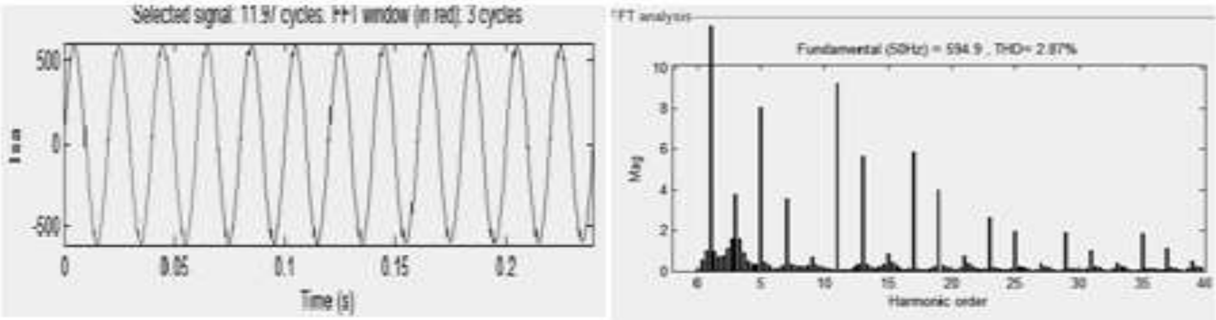


Fig. 8. Harmonic Spectrum of Source Current of SAF with controller

Figure 4 shows the simulated responses of source voltage and .5 shows the source current waveform before compensation whereas Fig. 6represents source current after compensation using FLC PI controller. Fig. 7 shows both source voltage and current are in phase with each other after compensation which indirectly indicates that the harmonics are eliminated and reactive power is compensated to make power factor close to unity. As the source current is becoming sinusoidal after compensation, the power quality is improved. The simulation results show the spectral analysis, performed on the source current after active filtering represented in Fig. 8.
The ASF filter reduces considerably the total harmonic distortion of current, from 27.88% to 2.87% in case of fuzzy PI controller which is below IEEE standard.

## VII. CONCLUSION.

Wind power seems to be clean energy source of the future. So, in order to optimize its use, the proposed system couples a wind turbine with shunt active power filter (SAPF). From the results obtained, it is proven that the proposed system, injects surplus power into the mains with harmonic mitigation capability. Thus, the proposed system is an effective tool for bringing green energy for future generations.

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