Power quality improvement by BFO-Fuzzy Controlled DVR

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Abstract— **Among the power quality problems like sag, swell, harmonic etc, voltage sag and harmonic are the most severe disturbances in the distribution system. To overcome these problems the concept of DVR conttroller using BFO-Fuzzy technic is introduced. Simulation results were presented to illustrate and understand the performances of DVR under voltage sags/swells conditions. The controlling of DVR is done by controlling the duty cycle of pulse width modulator (PWM). For this, in this paper bacterial foraging optimization along with fuzzy logic is used**.

Keywords— **DVR, STATCOM, BFO Fuzzy controller**.

I. Introduction

Power quality is an big issue that is becoming increasingly important to electricity consumers at all stage of usage. Power Quality has now become an issue of big interest for research and analysis in the field of power system and other areas where better power quality is concerned. With the increase of the use in sensitive equipments and non linear loads in the domestic and industrial area, an enhanced awareness of power quality is developed amongst electricity consumers. A sinusoidal voltage waveform having constant magnitude and frequency represents the best form of electrical supply.

However presence of unbalance loads and non zero impedance of the supply system may generate a large number of inequalities and disturbances in the system which ultimately leads to a poor power quality. These disturbances create situations in which the waveform of the supply voltage (voltage quality) or load current (current quality) deviate from the sinusoidal waveform for all three phases of a three-phase structure at rated frequency with amplitude corresponding to the rated Root Mean Square (RMS) value. A number of the power quality disturbances may encountered in the system. The adequate range of power quality disturbances covers sudden, short duration variations viz. impulsive and oscillatory transients, voltage sags, short interruptions, as well as steady state deviations, such as harmonics and flicker. These problems are solved by a series connected device named Dynamic Voltage Restorer (DVR).

Dynamic voltage restorer is a series connected device is used for mitigating voltage disturbances in the distribution system. DVR maintains the load voltage at a nominal magnitude and phase by compensating the voltage sag and swell, voltage unbalance and voltage harmonics presented at the point of common coupling. These systems are able to compensate voltage sags by increasing the appropriate voltages in series with the supply voltage, and therefore avoid a loss of power.

The concept of compensation techniques which is applied in DVR, can be divided into two categories as follows-

i) The reactive power compensation
ii) Active and reactive power compensation

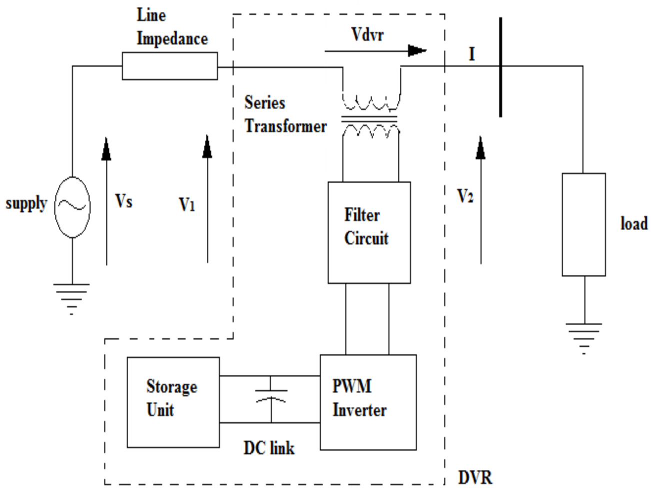

Fig. 3.1 Schematic Diagram of DVR

1.1 Equations related to DVR

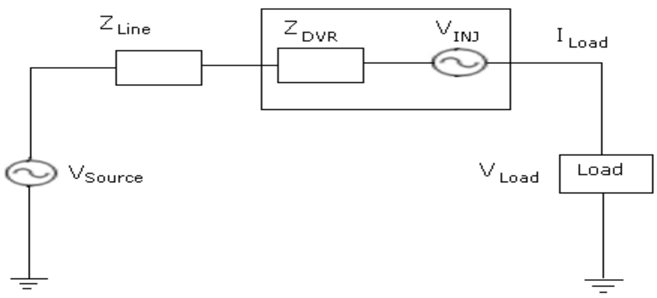

Fig. 3.2 Equivalent Circuit Diagram of DVR.

The load impedance Z_{TH} depends on the fault level of the load bus. When the system voltage (V_{TH}) drops, the DVR injects a series voltage V_{DVR} through the injection transformer so that the desired load voltage magnitude V_L can be maintained. The series injected voltage of the DVR can be written as

$$V_{DVR} = V_L + Z_{TH} I_L - V_{TH}$$

Where
V_L: The desired load voltage magnitude
Z_{TH}: The load impedance.
I_L: The load current
V_{TH}: The system voltage during fault condition
The load current I_L is given by,

$$I_L = \frac{[P_L + jQ_L]}{V_L}$$

When VL is considered as a reference equation can be rewritten as,

$$V_{DVR}\angle\alpha = V_L\angle 0 + Z_{TH}\angle(\beta - \theta) - V_{TH}\angle\delta$$

α, β, δ are angles of V_{DVR}, Z_{TH}, V_{TH} respectively and θ is Load power angle. The complex power injection of the DVR can be written as,

$$S_{DVR} = V_{DVR} I_L^{*}$$

It requires the injection of only reactive power and the DVR itself is capable of generating the reactive power.

II. RELATED WORK

The Development of (DVR) has been proposed by many researchers. The paper presents a review of the researches on the DVR application for power quality Improvement in electrical distribution network. The types of DVR control strategies and its configuration has been discussed and may assist the researchers in this area to develop and proposed their new idea in order to build the prototype and controller.This problem occurs in voltage sags, swells, harmonics, surges, sustained over voltage and under voltage originated from power system can often damage / or disrupt computerized process The discharging time of DC link capacitor is very high, and so it is the main problem in MCUPQC device. To eliminate this problem, an enhanced Neuro-fuzzy controller (NFC) based MC-UPQC is proposed in this paper. NFC is the combination of neural network (NN) based controller and fuzzy logic controller (FLC). In order to regulate the dc-link capacitor voltage, Conventionally, a proportional controller (PI) is used to maintain the dc-link voltage at the reference value. The transient response of the PI dc-link voltage controller is slow In this paper, performance improvement of the DVR based PI with Fuzzy Logic Controller using MATLAB/SIMULINK software. The performance of the DVR works well both in balance and unbalance conditions of voltages.

III. PROPOSED WORK

DVR is used to control injected voltage into transmission line to compensate faults whether sag or swell

3.1 Fuzzy Logic

Fuzzy logic is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets (where variables may take on true or false values), fuzzy logic variables may have a truth value that ranges in degree between 0 and 1.
The pulse width of PWM can be controlled and for this purpose some controllers like PI, fuzzy logic and BFO optimized fuzzy logic, are used here. Fuzzy logic algorithm's performance depends upon its membership functions and rule sets. When rules and membership functions are designed for a specific task then these are considered to be fixed. But due to change in system conditions steady state error changes. So to minimize steady state errors, membership function should be continuously changing with initial condition change. So position of membership functions is optimized.

3.2 Applying truth values

A basic application might characterize subranges of a continuous variable. For instance, a temperature measurement for anti-lock brakes might have several separate membership functions defining particular temperature ranges needed to control the brakes properly. Each function maps the same temperature value to a truth value in the 0 to 1 range. These truth values can then be used to determine how the brakes should be controlled.

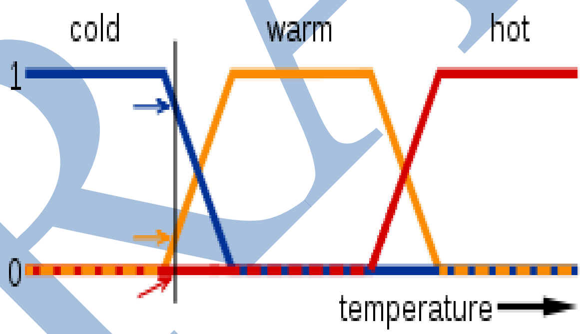

Fig:3.1 Fuzzy logic temperature

In this image, the meanings of the expressions *cold*, *warm*, and *hot* are represented by functions mapping a temperature scale. A point on that scale has three "truth values"—one for each of the three functions. The vertical line in the image represents a particular temperature that the three arrows (truth values) gauge. Since the red arrow points to zero, this temperature may be interpreted as "not hot". The orange arrow (pointing at 0.2) may describe it as "slightly warm" and the blue arrow (pointing at 0.8) "fairly cold".

3.3 Fuzzy Logic Designed for Proposed Work

The fuzzy logic controller for the proposed DVR has two real time inputs measured at every sampling time, named error and error rate and one output named actuating-signal for each of the phases. The input signals are fuzzified and represented in fuzzy set notations by membership functions. The defined 'if … then …' rules produce the linguistic variables and these variables are defuzzified into control signals for comparison with a carrier signal to generate PWM inverter gating pulses. Fuzzy logic control involves three steps: fuzzification, decision-making and defuzzification. Fuzzification transforms the non-fuzzy (numeric) input variable measurements into the fuzzy set (linguistic) variable that is a clearly defined boundary. In the proposed controller, the error and error rate are defined by linguistic variables such as large negative (LN), medium negative (MN), small negative (SN), small (S), small positive (SP), medium positive (MP) and large positive (LP) characterized by memberships. The memberships are curves that define how each point in the input space is mapped to a membership value between 0 and 1. The membership functions belonging to the other phases are identical Membership functions for the inputs are shown in Fig.3.1 and Fig.3.2. The membership function of output variable is shown in Fig.5.3.. Defining only membership function doesn't complete fuzzy logic desgining. Rule sets for taking decision have to be designed also. A set of 49 rules in our case is designed.

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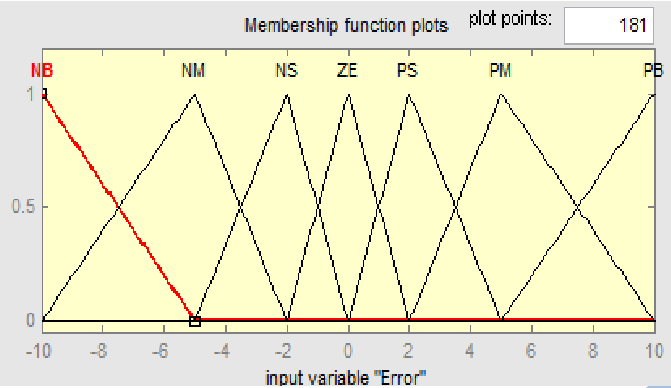


Figure 3.2: Membership function of input error

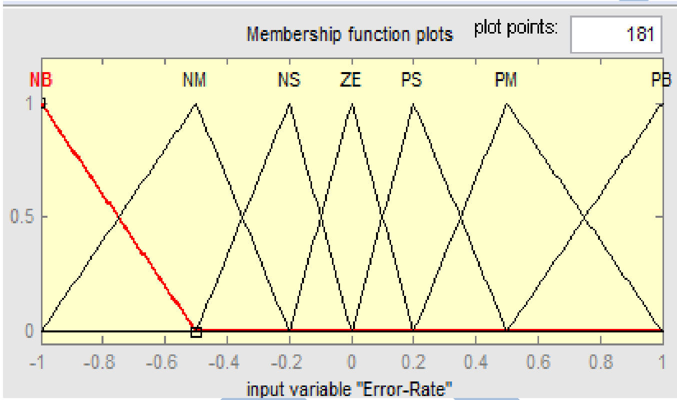


Figure 3.3: Membership function of input error rate

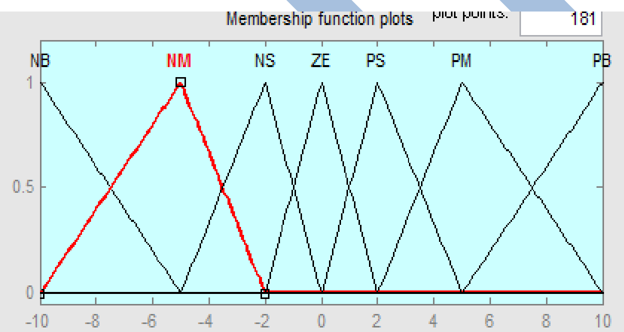


Figure 3.4: Membership function of actuating output

3.4 Bacterial Foraging Optimization

Bacteria Foraging Optimization Algorithm (BFOA), is a new comer to the family of nature-inspired optimization algorithms Recently natural swarm inspired algorithms like Particle Swarm Optimization (PSO) Ant Colony Optimization (ACO) have found their way into this domain and proved their effectiveness. Following the same trend of swarm-based algorithms, Passino proposed the BFOA in Application of group foraging strategy of a swarm of *E.coli* bacteria in multi-optimal function optimization is the key idea of the new algorithm. Bacteria search for nutrients in a manner to maximize energy obtained per unit time. Individual bacterium also communicates with others by sending signals. A bacterium takes foraging decisions after considering two previous factors. The process, in which a bacterium moves by taking small steps while searching for nutrients, is called chemotaxis and key idea of BFOA is mimicking chemotactic movement of virtual bacteria in the problem search space.

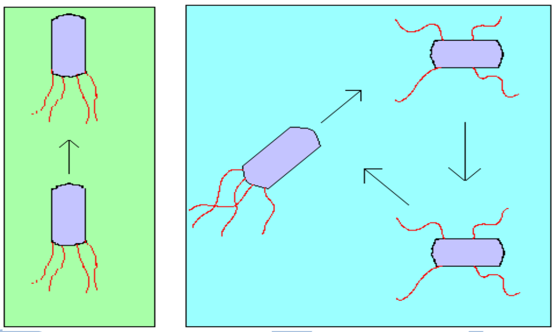


Fig.4.1. Swim and tumble of a bacterium

IV. MATLAB SIMULINK MODEL DESCRIPTION

A model for simulation of DVR with PI Controller and Fuzzy Logic Controller is shown in fig . In this model a three phase star ground connected source of 50 Hz is connected to three phase transformer having winding connections star ground, delta and delta for winding 1, 2 and 3 respectively.

V. DISCUSSION OF RESULTS

Results have been categorized into two categories. Since the sags and swells are two main problems, so, these problems are mitigated by proposed method separately and makes two categories also.

5.1 Voltage Sag Mitigation

In main simulink model as shown in figure 4.1 three phase faults are used along with two breakers. For introducing sag in the model breaker 2 should be closed and breaker 1 should be open. Timing for fault introduction can be controlled also. In our experiment it has been taken from 0.1-0.3 sec. Initially PI controller is selected for DVR controlling. Figure 5.1 shows the result.

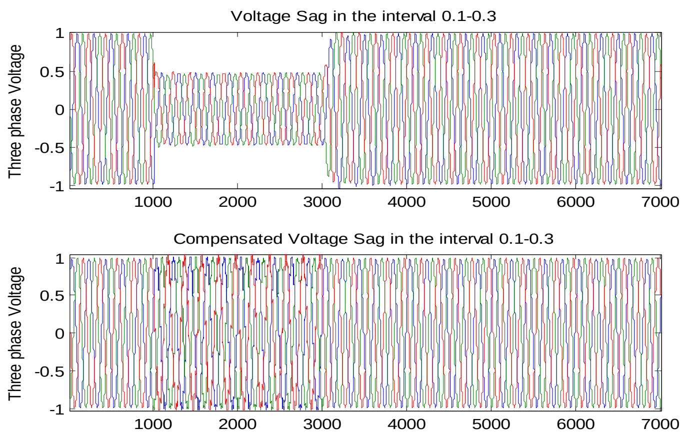


Figure 5.1: Uncompensated and Compensated output

By just looking at above figure, it is visible that a perfect sag compensation is obtained by PI controller but if figure is zoomed then some distortions in the output are visible as shown in figure 5.2. this figure shown is zoomed in simulink window and direct taken from there.

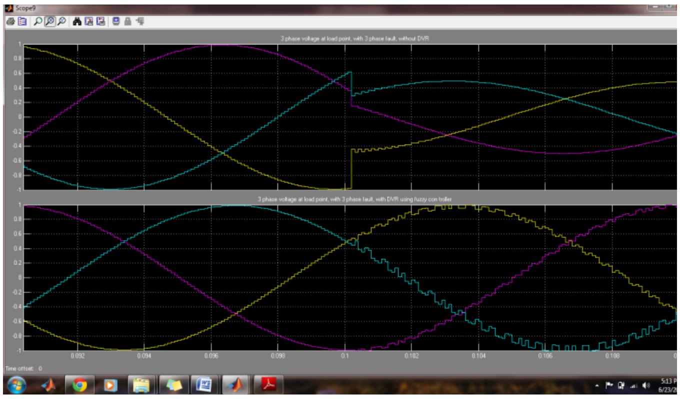
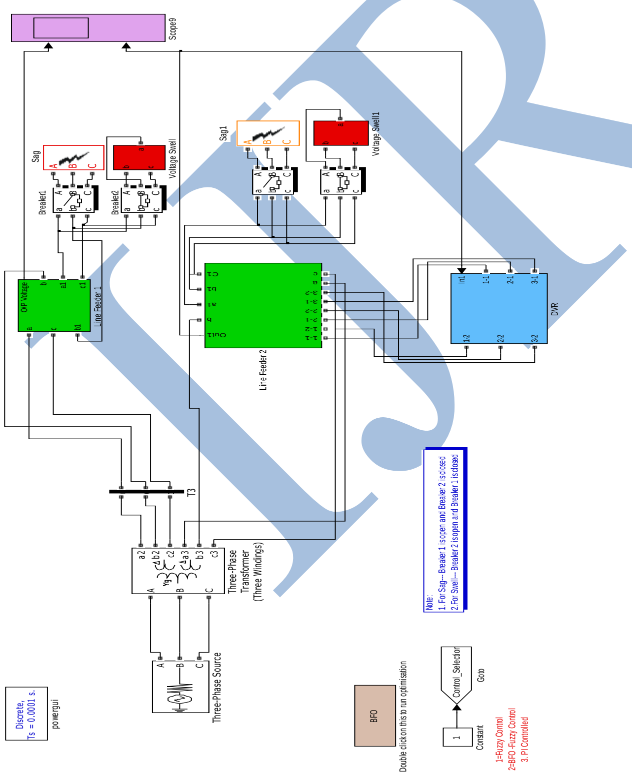


Figure 5.2; distortions in the PI compensated waveform

So because of these distortions total harmonic distortions are measured by FFT analysis. For this, FFT analysis from 'powergui' block is used which is placed in model to set the environment for simpower toolbox in simulink. The THD calculated by that is shown in figure 5.3. The THD in this case is 1.46%.



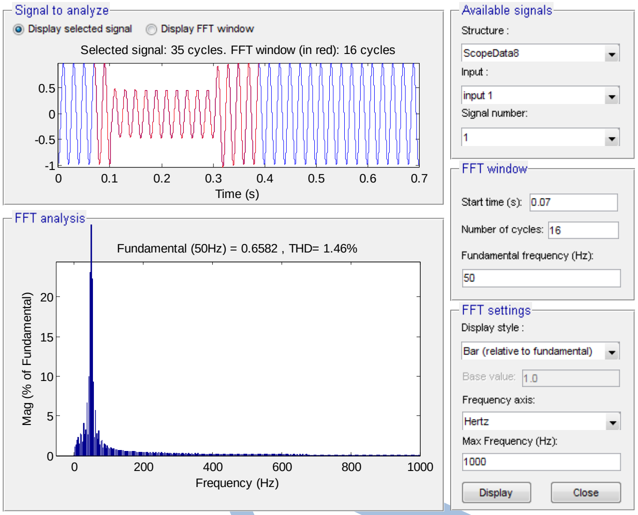


Figure 5.3: THD of uncompensated output

The PI compensated THD is 0.24 % that means THD has been reduced to a good amount but still there is scope of more reduction in THD. For this purpose we have used fuzzy logic with 49 rules further. The zoomed output of fuzzy logic is shown in figure 5.13 to show the distortions.

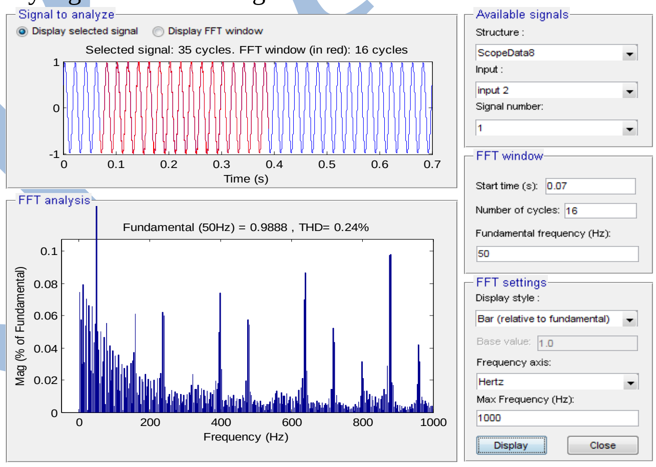


Figure 5.4: Compensated output's THD =0.24%

The total harmonic distortions, as in above case, is shown in figure 5.6. it comes out to be 0.19%, less than the distortions in case of PI controlled DVR. That proves fuzzy logic control is better than PI controlled DVR.

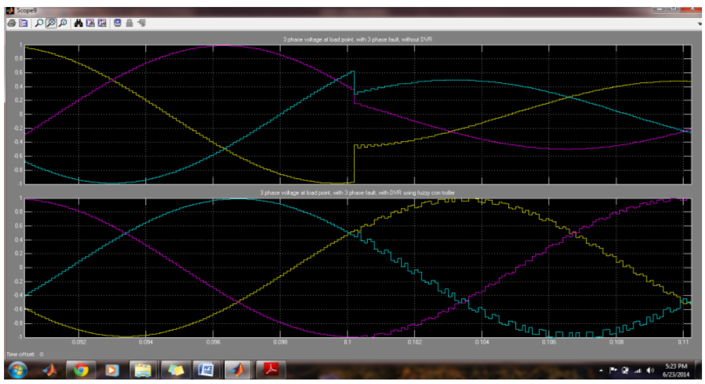


Figure 5.6: distortions in fuzzy logic compensated output

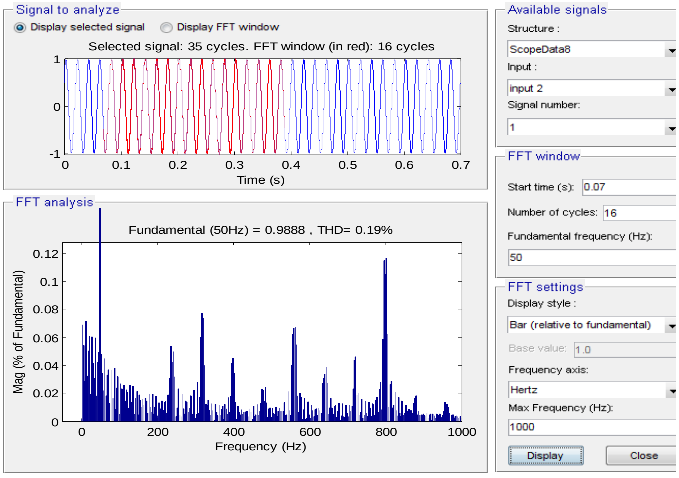


Figure 5.7: THD in case of fuzzy controlled DVR=0.19%

Now the 3rd controller that is BFO optimized fuzzy logic controller is used. Here table 5.2 tells the parameters taken for BFO optimization.

Table 5.2: parameters used for BFO

dimension of search space	12
The number of bacteria	6
Number of chemotactic steps	6
Limits the length of a swim	4

After optiomisation by BFO new membership functions are obtained as shown in figure 5.15.

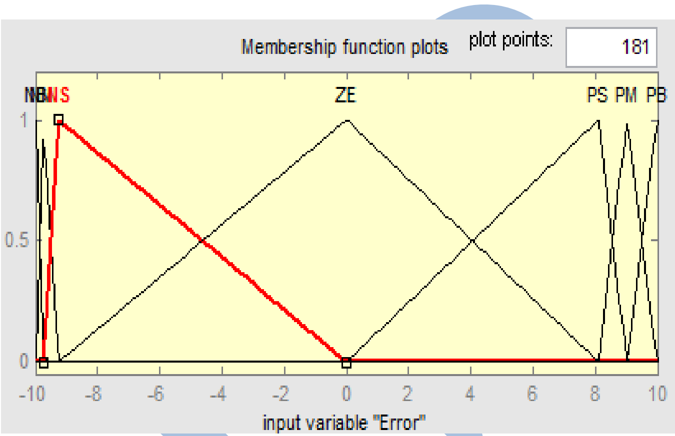


Figure 5.8(a): membership function for error

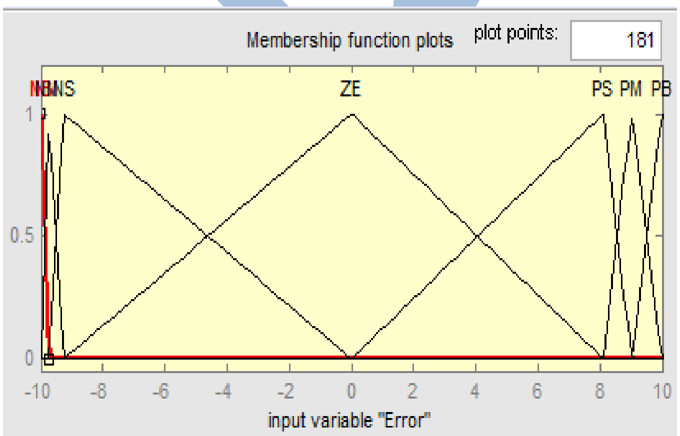


Figure 5.8(b): membership function for error rate

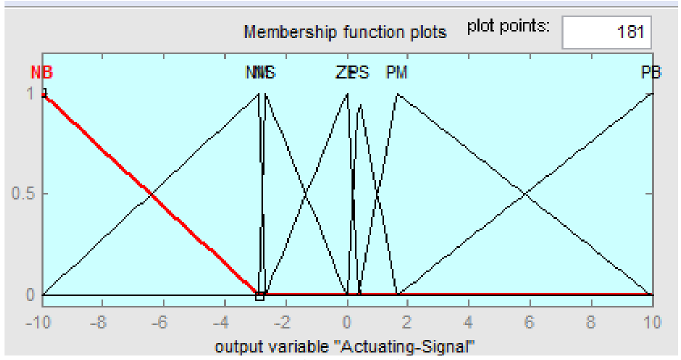


Figure 5.8(c): membership function for output

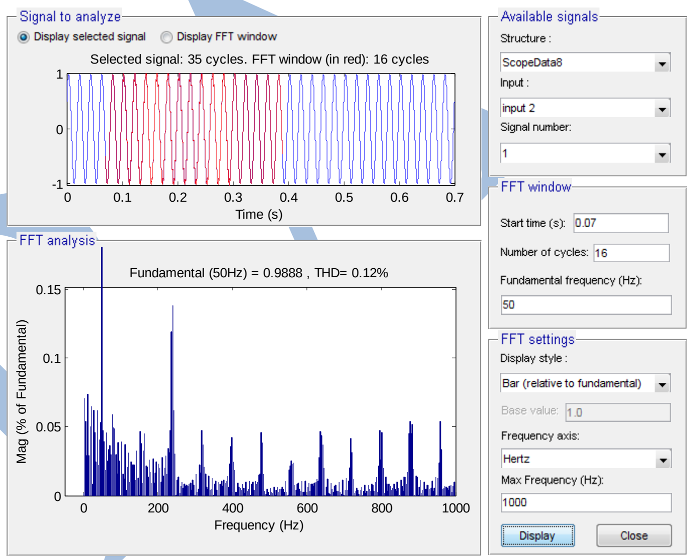


Figure 5.10: THD in case of BFO fuzzy controlled=0.12%

Table 5.3: Comparison of THD's of all methods

	THD (%)
Without Control	1.46
PI	0.24
Fuzzy Logic	0.20
BFO- Fuzzy Logic	0.12

VI. CONCLUSION

A new voltage sag compensator based on DVR has been presented in this paper .Control circuit based on rms voltage reference is discussed. The proposed technique could identify the disturbance and capable of mitigating the disturbance by maintaining the load voltage at desired magnitude within limits. The proposed technique is simple and only one IGBT switch per phase is required. Hence the system is more simple and economical compared to commonly used STATCOM. Simulation analysis is performed for voltage sag for three phase ystem and simulation results verify that the proposed device is effective in compensating the voltage sag disturbances

REFERENCES

[1]. A.Venkata Rajesh Dr. K. Narasimha Rao," Power Quality Improvement using Repetitive Controlled Dynamic Voltage Restorer for various faults" IJERA Vol. 2, Issue 1, Jan-Feb 2012, pp.168-174

[2]. B.Rajani, Dr.P.Sangameswara Raju," Comparision Of PI, Fuzzy & Neuro-Fuzzy Controller Based Multi Converter Unified Power Quality Conditioner" IJEET Volume 4, Issue 2, March – April (2013), pp. 136-154

[3]. M.Sharanya, B.Basavaraja , M.Sasikala," An Overview of Dynamic Voltage Restorer for Voltage Profile Improvement" International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-2, December 2012

[4]. S.Ezhilarasan, G.Balasubramanian," Dynamic Voltage Restorer For Voltage Sag Mitigation Using Pi With Fuzzy Logic Controller"IJERA Vol. 3, Issue 1, January -February 2013, pp.1090-1095

[5]. Seyedreza Aali and Daryoush Nazarpour," Voltage Quality Improvement with Neural Network-Based Interline Dynamic Voltage Restorer" Journal of Electrical Engineering & Technology Vol. 6, No. 6, pp. 769~775, 2011

[6]. Mohammad KIANI, Seyed Mohammad Ali MOHAMMADI," A bacterial foraging optimization approach for tuning type-2 fuzzy logic controller" Turkish Journal of Electrical Engineering & Computer Sciences Turk J Elec Eng & Comp Sci (2013) 21: 263 – 273

[7]. Rosli Omar, N.A. Rahim and Marizan Sulaiman," Dynamic Voltage Restorer Application for Power Quality Improvement in Electrical Distribution System: An Overview" Australian Journal of Basic and Applied Sciences, 5(12): 379-396, 2011

[8]. Sushree Sangita Patnaik and Anup Kumar Panda," Particle Swarm Optimization and Bacterial Foraging Optimization Techniques for Optimal Current Harmonic Mitigation by Employing Active Power Filter" Hindawi Publishing Corporation Applied Computational Intelligence and Soft Computing Volume 2012, Article ID 897127, 10 pages

