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Comparison of Minimising Total Harmonic Distortion with PI Controller, Fuzzy Logic Controller, BFO- fuzzy Logic Controlled Dynamic Voltage Restorer

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Abstract

This paper describes the minimisation of total harmonic distortions in a distribution line. DVR is used for this purpose. But the controlling of DVR voltage injection is done by three different controllers: PI, Fuzzy Logic and BFO-Fuzzy Logic. A comparison is shown amongst these three techniques. Every technique is checked for voltage sag and swell.

Keywords: voltage sag, voltage swell ,Dynamic voltage restorer(DVR), PI controller, Fuzzy controller, BFO-Fuzzy logic ,total harmonic distortion.

1. Introduction

Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. With the increase in the use of sensitive equipments and non linear loads in the domestic as well as industrial area, an enhanced awareness of power quality is developed amongst electricity consumers. However presence of non linear 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.[1,3] These disturbances create situations in which the waveform of the supply voltage (voltage 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 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 tackled by a series connected device named *Dynamic Voltage Restorer (DVR).* It is based on *pulse width modulated Voltage source inverter* ,which is capable of generating or absorbing real or reactive power independently.[3 6]

The DVR has two modes of operation which are, the standby mode and the boost mode. In the standby mode (VDVR=0), the booster transformer's low voltage winding is shorted through the inverter. No switching of semiconductors takes place in this mode of operation. Therefore, only the comparatively low conduction losses of the semi-conductors in this current loop contribute to the losses. In the boost mode (VDVR>0), the DVR will inject a compensation voltage through the booster transformer due to a detection of a supply voltage disturbance.

2. Proposed Algorithm

DVR is used to control injected voltage into distrubution line to compensate faults whether sag or swell. For this purpose IGBT controlled by pulse width modulator is used. The pulse width of PWM can be controlled and for this purpose some controllers like PI, fuzzy logic and BFO optimised 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 minimise steady state errors, membership function should be continuously changing with initial condition change. So position of membership functions is optimised. In our work this is done by bacterial foraging optimisation (BFO). BFO is discussed later in this paper. Time consumed in iterations to minimise the steady state error can be set by iteration number and number of bacteria's considered. Total number of positions in membership functions, decides searching space dimensions. In this work as shown in Fig. 2.1, 7 membership functions for each input and output are used. Positions of these are fixed initially. Two types of membership functions are used: trapezoidal and triangular. In error input, either one or two position vector of function coincides, this reduces the dimension of searching space to a great extent. Triangular function has three positions [x1, x2, x3], satisfying condition x1<x2<x3. As is seen in Fig. 2.1, the middle position of NM coincides with starting position of NS and similar other membership functions also have some common positions, reducing total of 4 positions to be optimised to minimise the steady state error for single input.

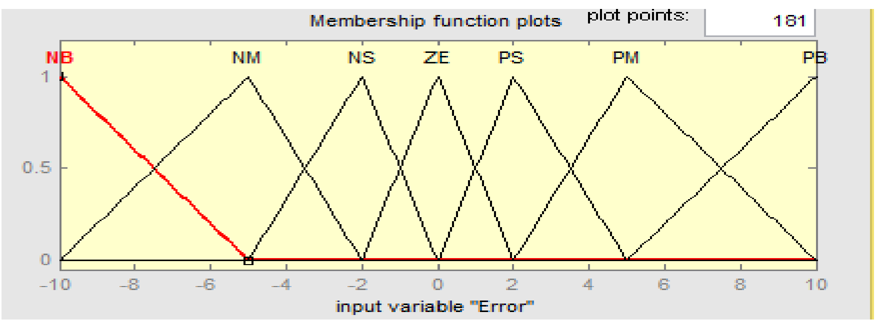

Fig. 2.1: Membership function of input 'error'

Since there are two inputs and one output, so total of 12 positions of membership functions are to be tuned by BFO algorithm. It means in BFO every single bacteria will search in twelve searching spaces for nutrition. During optimisation an objective function is decided which minimise the steady state error. For every bacteria twelve positions of membership functions are changed and new fuzzy logic is evaluated for given error. Here in this work integral square error (ISE) is taken to objective function and used as input for evaluation of fuzzy logic. After all complete iterations error is minimised and that instantaneous positions of membership functions are used as new positions in fuzzy logic.

3. Bacterial Foraging Optimisation

Bacteria Foraging Optimization Algorithm (BFOA), is a new comer to the family of nature-inspired optimization algorithms. For over the last five decades, optimization algorithms like Genetic Algorithms (GAs), Evolutionary Programming (EP), which draw their inspiration from evolution and natural genetics, have been dominating the realm of 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.. Bacteria search for nutrients in a manner to maximize energy obtained per unit time.. 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 .During foraging of the real bacteria, locomotion is achieved by a set of tensile flagella. When they rotate the flagella in the clockwise direction, each flagellum pulls on the cell. That results in the moving of flagella independently and finally the bacterium tumbles with lesser number of tumbling whereas in a harmful place it tumbles frequently to find a nutrient gradient.When they get food in sufficient, they are increased in length and in presence of suitable temperature they break in the middle to from an exact replica of itself. This phenomenon inspired Passino to introduce an event of reproduction in BFOA. Due to the occurrence of sudden changes, the chemotactic progress may be destroyed and a group of bacteria may move to some other places or some other may be introduced in the swarm of concern. This constitutes the event of elimination-dispersal in the real bacterial population, where all the bacteria in a region are killed or a group is dispersed into a new part of the environment.[2 ,4]

Thus search for food of E.Coli can be categorised into four steps: Chemotactic, Swarming, Reproduction and Killing/ Dispersion. Mathematically these can be represented step by step as:

Chemotactic:

$$\theta^i(j+1,k,l) = \theta^i(j,k,l) + c(i)\frac{\Delta(i)}{\sqrt{\Delta^t(i)\Delta(i)}}$$

Where $\theta^i(j,k,l)$ represents i-th bacterium at jth chemotactic, k-th reproductive and l-th elimination-dispersal step. C(i) is the size of the step taken in the random direction specified by the tumble (run length unit).

Swarming

$$J(i,j,k,l) = J(i,j,k,l) + J_{cc}(\theta(j,k,l), P(j,k,l)$$

where J (i, j, k, l) is the fitness function.[2, 4]

4. Results & Discussion

Before optimising fuzzy logic, rules and membership function have to be defined. In our case a ‘dvr.fis’ named fuzzy logic structure is designed in MATLAB whose decision table is shown in table1.

Table 1: Fuzzy Rule table[5]

CE\E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NM	NM	NS	Z
NM	NB	NB	NM	NM	NS	Z	PS
NS	NB	NM	NM	NS	Z	PS	PM
Z	NM	NM	NS	Z	PS	PM	PM
PS	NM	NS	Z	PS	PM	PM	PB
PM	S	Z	PS	PM	PM	PB	PB
PB	Z	PS	PM	PM	PB	PB	PB

Membership function defined in ‘dvr.fis’ are shown in Fig. 4.1 below.

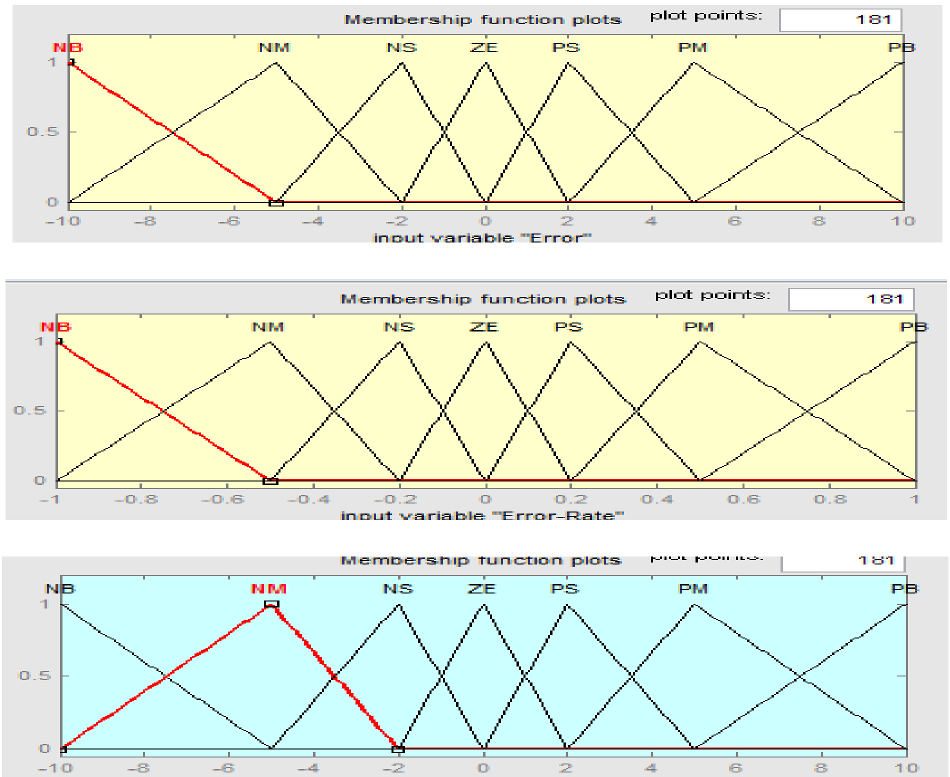

Fig. 4.1: Membership function (a) error signal (b) Error rate (c) Actuating Output Signal.

Fuzzy logic function takes two inputs: error and error rate and gives one output whose membership functions are shown in Fig. 4.1. In this paper total harmonic distortions are minimised and compared using PI, fuzzy logic and BFO trained fuzzy logic for voltage sag and swell. The proposed simulink model is shown in appendix. Fourier transform is applied on output signal to check THD (%). The output waveform and fft analysis of output in case of PI controller is selected by making constant value 3 for switch selection as shown in appendix. A voltage sag is applied by fault breaker within interval 0.1-0.3.

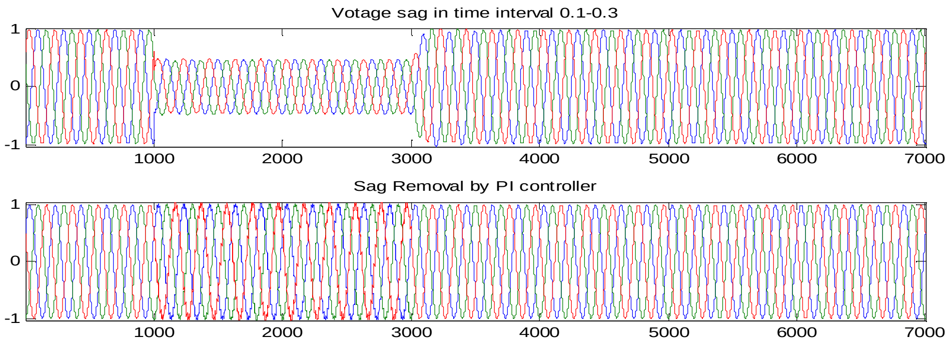

Fig. 4.2(a): Output of PI controlled sag.

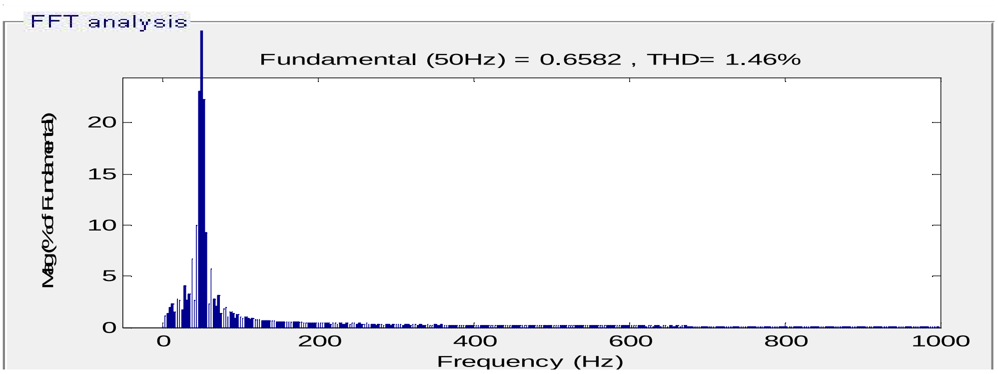

Fig. 4.2(b): THD after FFT analysis of sag introduced output.

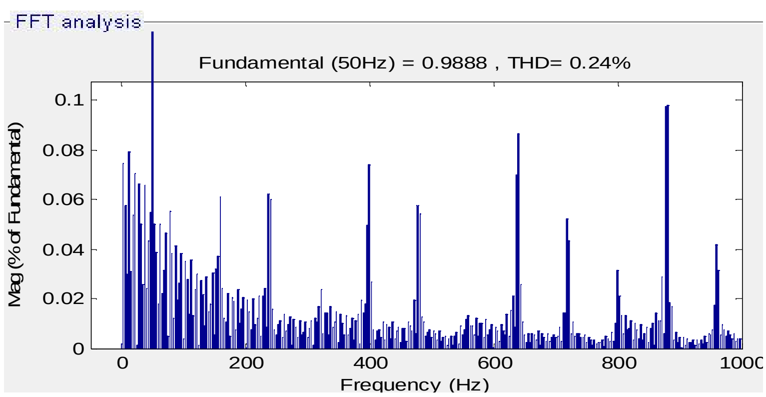

Fig. 4.2(c): THD after FFT analysis of sag compensated output

Similarly the compensation of voltage sag is done by fuzzy logic and bfo-fuzzy logic and THD by FFT analysis is noted down. The change in membership function after BFO optimisation is shown in Fig. 4.3. New positions of each membership function is obtained after optimisation satisfying condition for a triangular membership function as discussed above. A table showing the comparison of THD(%) for every case discussed is shown in table 2.

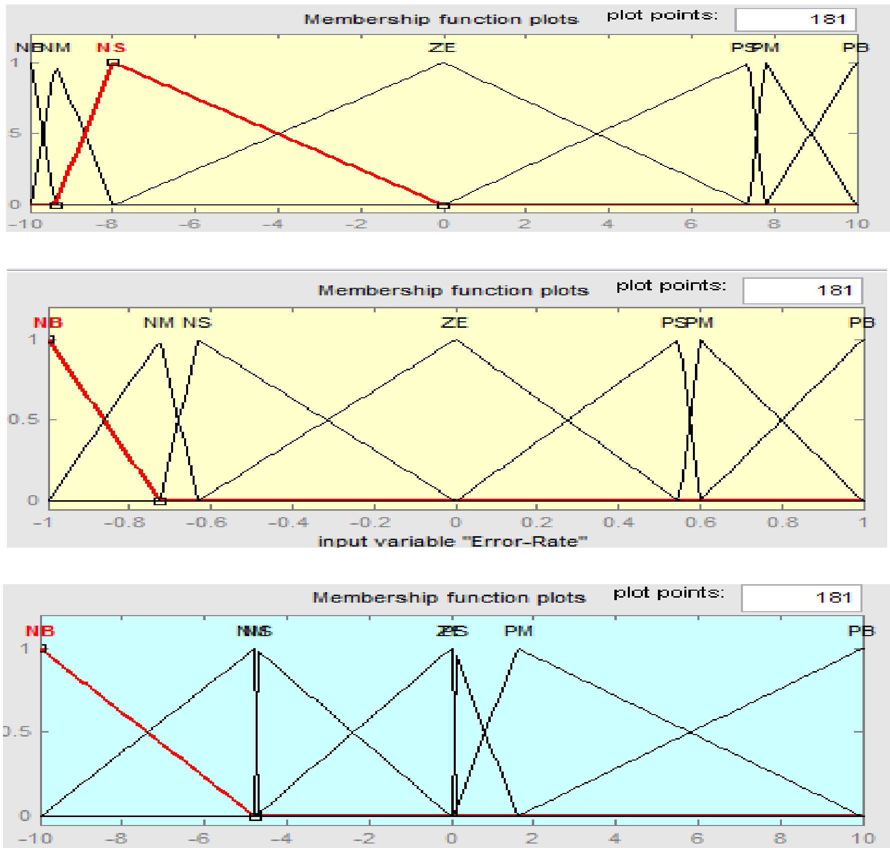

Fig. 4.3: Optimised Membership function (a) error signal (b) Error rate (c) Actuating Output Signal.

Table 2: Comparison of THD

	THD (%)
Without Control	1.46
PI	0.24
Fuzzy Logic	0.20
BFO- Fuzzy Logic	0.18

The compensation of voltage swell by proposed algorithm is shown in Fig. 4.4 below.

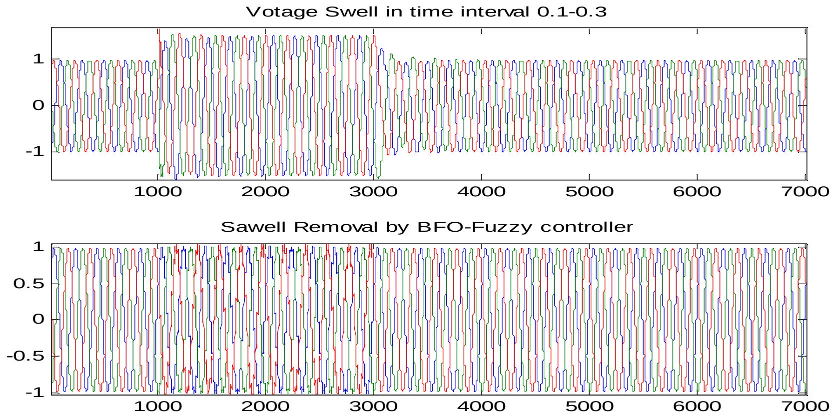

Fig. 4.4: Voltage Swell compensation.

5. Conclusion

The above shown results show that fuzzy logic minimisation of THD proves better than PI controller. Performance of fuzzy system is more increased if membership functions are optimised by any optimisation algorithm. In this paper bacterial foraging optimisation is used as trainer to membership functions. Table shown in results depicts clearly that after BFO optimisation THD is minimum as compared to others. Work described in this paper works well for both sag and swell compensation.

References

[1] 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

[2] 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

[3] 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

[4] 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.

[5] 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. 136-15

[6] 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

Appendix

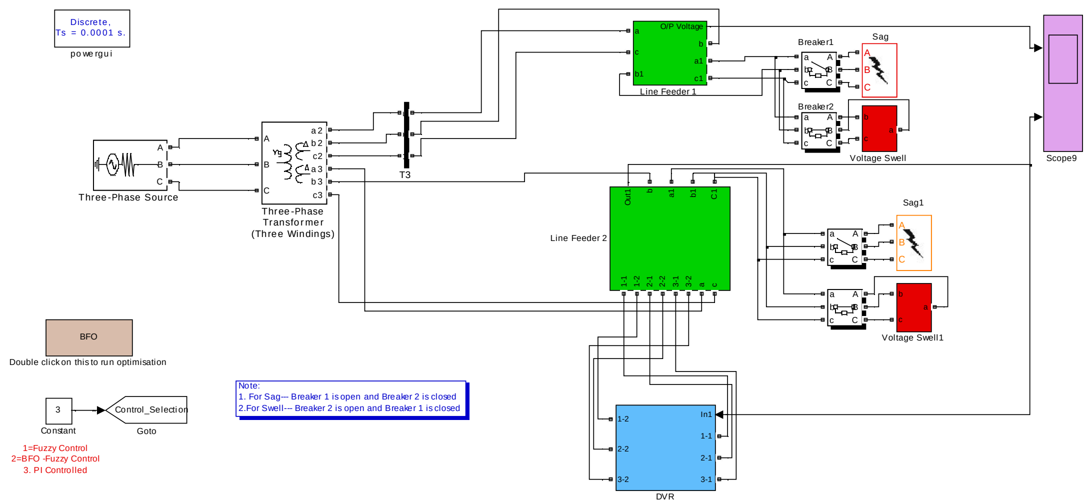

Fig. 5: Proposed Model for comparison of PI, Fuzzy Logic and proposed controller for THD reduction.

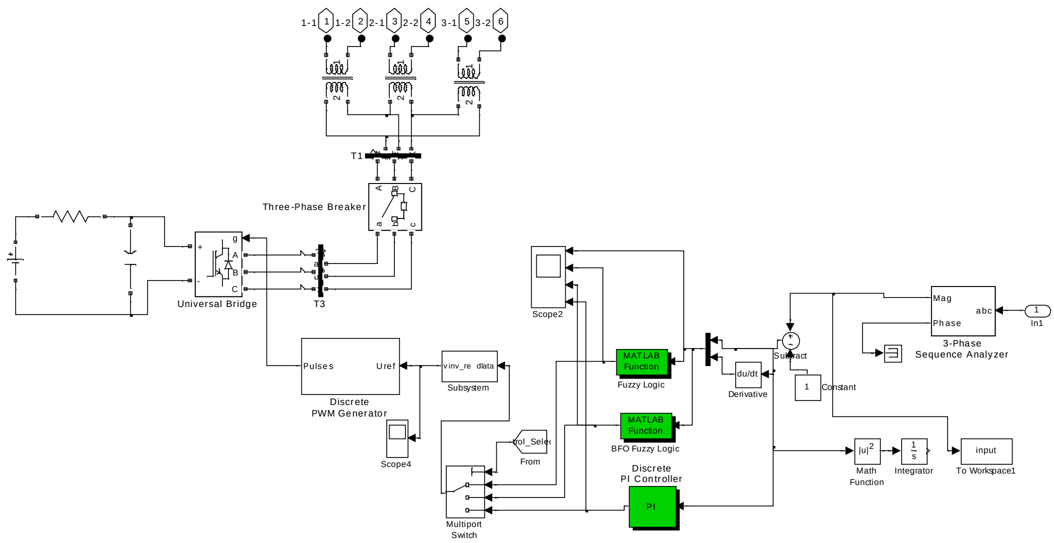

Fig. 6: DVR Model for proposed work having switch for PI, fuzzy Logic and BFO fuzzy logic