© 2014 IJEDR | Volume 2, Issue 1 | ISSN: 2321-9939

Self-Tuning PI Control of Dynamic Voltage Restorer Using Fuzzy Logic

[1]Richa Agrawal, [2]Mahesh Singh, [3]Kushal Tiwari

[1] PG Research Scholar, [2] Sr. Assistant Professor, [3] Assistant Professor
[1] Electrical Engineering, SSTC, Bhilai, Chhattisgarh, India - 491001
[2]Electrical & Electronics Engineering, SSTC, Bhilai, Chhattisgarh, India – 491001
[3]Electrical & Electronics Engineering, CSIT, Durg, Chhattisgarh, India - 491001
[1]richaagrawal@csitdurg.in, [2]singhs004@gmail.com, [3]kushaltiwari@csitdurg.in

***Abstract* — In this paper DVR based Fuzzy Logic Controller is used for voltage sag mitigation. The term voltage sag is nothing but a problem which is associated with power quality. Voltage sag is originated from power system & can often damage/disrupt computerized process. The main occurrence of voltage sag in power quality is overcome by using DVR based Fuzzy Logic Controller. The DVR is installed between the source voltages and critical or three phase parallel RLC load. In this paper MATLAB/SIMULINK software is used for performance improvement of the DVR based Fuzzy Logic Controller. The performance of the DVR works on both in balance and in unbalance conditions of voltages.**

***Index Terms* — Power Quality, Dynamic Voltage Restorer (DVR), Fuzzy Logic Controller, Voltage Sag.**

I. INTRODUCTION

One of the most important power quality problems in the power distribution systems is Voltage sag. Mostly voltage sags are caused by single line- to-ground fault, double line to ground fault and three phase fault on the power distribution system. [3] Voltage sag is nothing but a slight decrease in voltage for a short duration of time. Now a day, power quality problems become very critical for industries due to the loss of money & time. Due to this, demand of good power quality results in reduction of power quality problems like voltage sag etc. In definite terms, it states that reduction in between 0.9 to 0.1 per unit (p.u) in r.m.s voltage or current at power frequency for duration of ½ cycles to 1 minute.

Now a day many of the industries are using heavy automation which requires high quality of power supply. There are many methods to overcome voltage sags. In my project I am using Dynamic Voltage Restorers with energy storage. The DVR is a power electronics device that is able to compensate voltage sags on critical loads dynamically. By injecting an appropriate voltage, the DVR restores a voltage waveform which ensures constant load voltage. The DVR consists of Voltage Source Converter (VSC), injection transformers, passive filters and energy storage (lead acid battery). The Dynamic Voltage Restorer (DVR) with the lead acid battery is an attractive way to provide excellent dynamic voltage compensation capability, & this is economical when compared to shunt-connected devices. The DVR is a custom power device that is connected in series with the distribution system. The DVR employs MOSFETs to maintain the voltage applied to the load by injecting three-phase output voltages whose magnitude, phase and frequency can be controlled. [1] Control unit works as the heart of the DVR. The main function of control unit is to detect the voltage sag in the system.

II. DYNAMIC VOLTAGE RESTORER (DVR)

Dynamic Voltage Restorer is a series connected device that injects voltage into the system in order to regulate the load side voltage. In other words, A DVR is a solid state power electronics switching device consisting of either MOSFET or IGBT, a capacitor bank as an energy storage device and injection transformers. It is normally installed in a distribution system between the supply and the load. Its main work is to rapidly boost up the load-side voltage to avoid any power disruption to that load. Apart from reducing voltage sag & swell, DVR also have some other features like: voltage harmonics compensation, voltage transients, reduction and fault current limitations. DVR consists of a voltage injection transformer, an output filter, an energy storage device, voltage source inverter (VSI), and a control system as shown in figure (A).

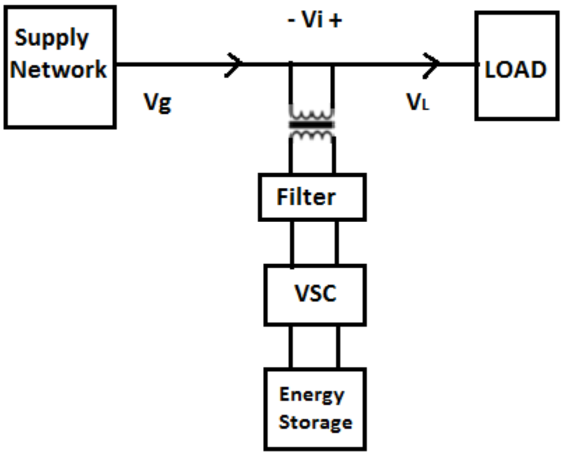


Figure (A): Structure of DVR

Voltage Injection Transformer

The main function of this transformer is to connect the DVR to the distribution network through the HV-windings and couples. The injected compensating voltages generated by the voltage source converted in to the incoming supply voltage. The injected voltage may consist of harmonics, switching harmonics and dc voltage components. If the transformer is not designed properly, the injected voltage may saturate the transformer and result in improper operation of the DVR.

Filter

The main function of the filter is to keep the harmonic voltage content by eliminating high frequency switching harmonics.

DC Energy Storage Device

The DC energy storage device provides the requirement of the real power of the DVR during compensation. Basically, there are many storage techniques such as: flywheel energy storage, superconducting magnetic energy storage and Super capacitors. Batteries are not suitable for DVR applications since it takes considerable time to remove energy from them. Now a day, conventional capacitors are also in use.

Voltage Source Inverter

A voltage source inverter is a power electronic system consists of switching devices (IGCTs, IGBTs, GTOs), it can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle. In the DVR, the voltage source inverter is used to replace the supply voltage or to generate the part of the supply voltage which is missing.

Controller

The main function of the control system is to maintain voltage magnitude constant at the point where a sensitive load is connected, as the disturbance occurs. The control system mainly consists of a voltage correction method which determines the reference voltage. This voltage is injected by DVR and the VSI control which in this method consist of PWM with PI controller. The controller input is an error signal obtained from the reference voltage and the value of the injected voltage as shown in figure (B).

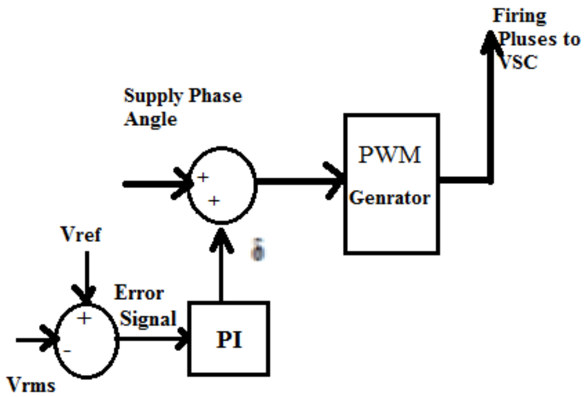


Figure (B): Phase Shift Controller

III. OPERATING PRINCIPLE OF DVR

The main function of the DVR is to inject a controlled voltage into the bus voltage with the help of voltage injection transformer. The amplitudes of the three injected phase voltages are controlled such as to eliminate any damaging effects of a bus fault to the load voltage V_L. It means that any differential voltages caused by disturbances in the ac feeder will be compensated by an equivalent voltage. The DVR works independently of the type of fault or any event that happens in the system. For many practical cases, a more economical design can be achieved by only compensating the positive and negative sequence components of the voltage disturbance seen at the input of the DVR.[1] The DVR operation of have two modes they are:-

1. Standby mode - At standby mode (V_{inj}=0), i.e. low voltage winding of the voltage injection transformer is shorted through the converter. In this mode of operation, No switching of semiconductors occurs.
2. Boost mode - In boost mode (V_{inj}>0), the DVR injects a compensation voltage through the voltage injection transformer, as it detects the supply voltage disturbance.

IV. PI CONTROLLER

The main aim of using proportional integral Controller is due to its effectiveness in controlling the steady state error of a control system. The disadvantage of this controller is its inability to improve the transient response of the system. From figure (c), the conventional PI controller forms an eq. 1, where, U is the control output which is fed to the PWM signal generator. K_P and K_I are the proportional and integral gains respectively, these gains depend on the system parameters. ε is the error signal, which is the difference between the injected voltage to the reference voltage.

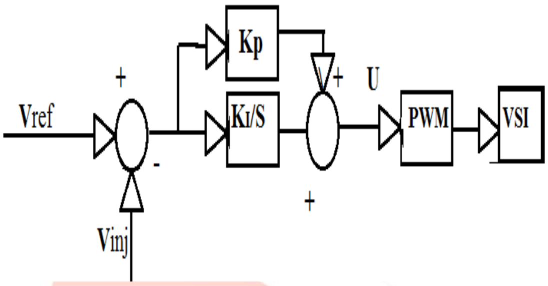


Figure (C): conventional PI controller for controlling the injected voltage

$$U(t) = K_P\, \varepsilon(t) + K_I \int \varepsilon(t)\, d(t) \qquad (1)$$

The PI controller introduces a pole in the entire feedback system, as shown in equation 1, by making a change in its original root locus. The pole introduces a change in the control system's response. The constants *KP* and *KI* determine the stability and transient response of the system.

V. FUZZY PI CONTROLLER

As we discussed earlier that, the disadvantage of PI controller is its inability to react to sudden changes in the error signal, ε, as it is only capable of determining the instantaneous value of the error signal without considering the change of the rise and fall of the error. So to overcome from this problem fuzzy PI CONTROLLER is used. The basic representation of the fuzzy logic controller (FLC) is shown in figure (D).

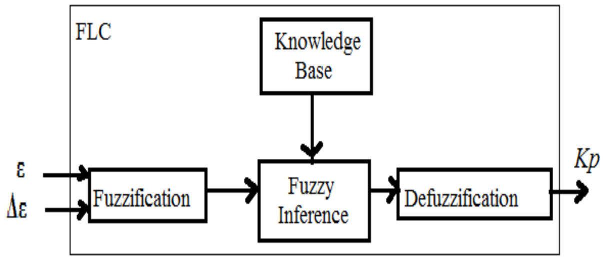


Figure (D): Block Diagram of FLC

The input of all the variables fuzzy subset are defined as, NB, NM, NS, Z, PS, PM, PB. Due to the coverage, sensitivity, robustness of universe, the fuzzy subsets of the membership functions use "Z"- shaped membership function in the left, triangular membership function in the middle, and "S"-shaped membership function curve in the right. The membership function is shown in figure (E), & a fuzzy control rule is shown in figure (F).

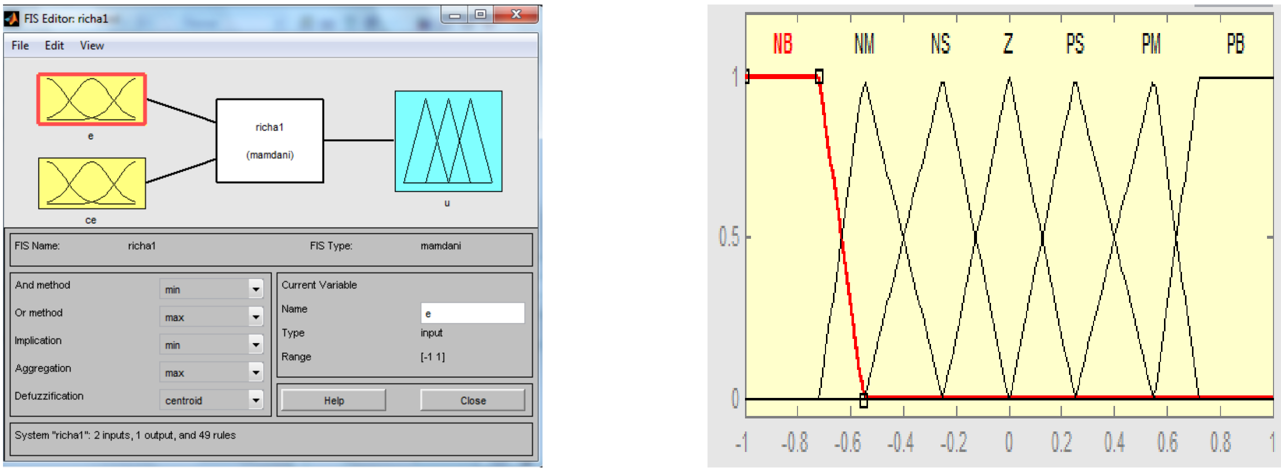
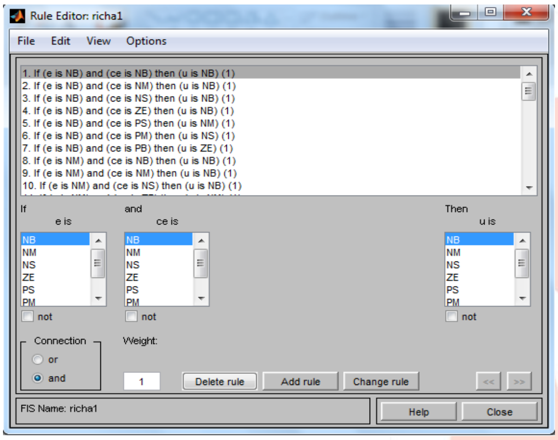


Figure (E): Membership function for FLC



ε / Δε	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NM	NM	NS	Z
NM	NB	NB	NM	NM	NS	Z	PS
NS	NM	NM	NS	NS	Z	PS	PS
Z	NM	NS	NS	Z	PS	PS	PM
PS	NS	NS	Z	PS	PS	PM	PM
PM	NS	Z	PS	PM	PM	PB	PB
PB	Z	NS	PS	NM	PB	PB	PB

Figure (F): FLC Rules

VI . SIMULATION

When the current commutates from one phase to another then, due to Line voltage Notching, dip in the supply voltage appears in the line voltage waveform during normal operation of power electronic devices. In this notching period, short circuit occurs between the two commutating phases, this reduces the line voltage. This reduction in voltage is limited only by the supply impedance. To show the Performance Improvement of DVR in voltage sag/swell mitigation using the proposed controller, a simple distribution network is simulated using MATLAB/SIMULINK software figure (G).

With the help of series transformer DVR is connected to the system with a capability to insert a maximum voltage of 100% of the phase to ground system voltage. In this simulation, the main characteristics of the DVR are set as: voltage source full-bridge IGBT based inverter controlled with PWM signal generator with commutation frequency of 12kHz, capacitor energy storage bank 8.6 mF, coupling transformer ratio 1:1, nominal dc link voltage 850V, LC output filter values C_f = 220 µF in series with a damping resistance R_d = 0.5Ω, L_f = 0.8mH, source voltage 220V_{rms} and source frequency of 50Hz. The load is a non linear load composed of a diode rectifier feeding an RL load where L= 40 mH and R=10/4 Ω connected to the DVR through a very small inductance L_{in} = 0.4mH. The power system (supply) is simulated as an ideal voltage source in series with impedance as shown in Figure (g). The impedance of the supply is considered to be a pure inductance Ls since in practical situation the supply resistance is very low compared to the inductance.

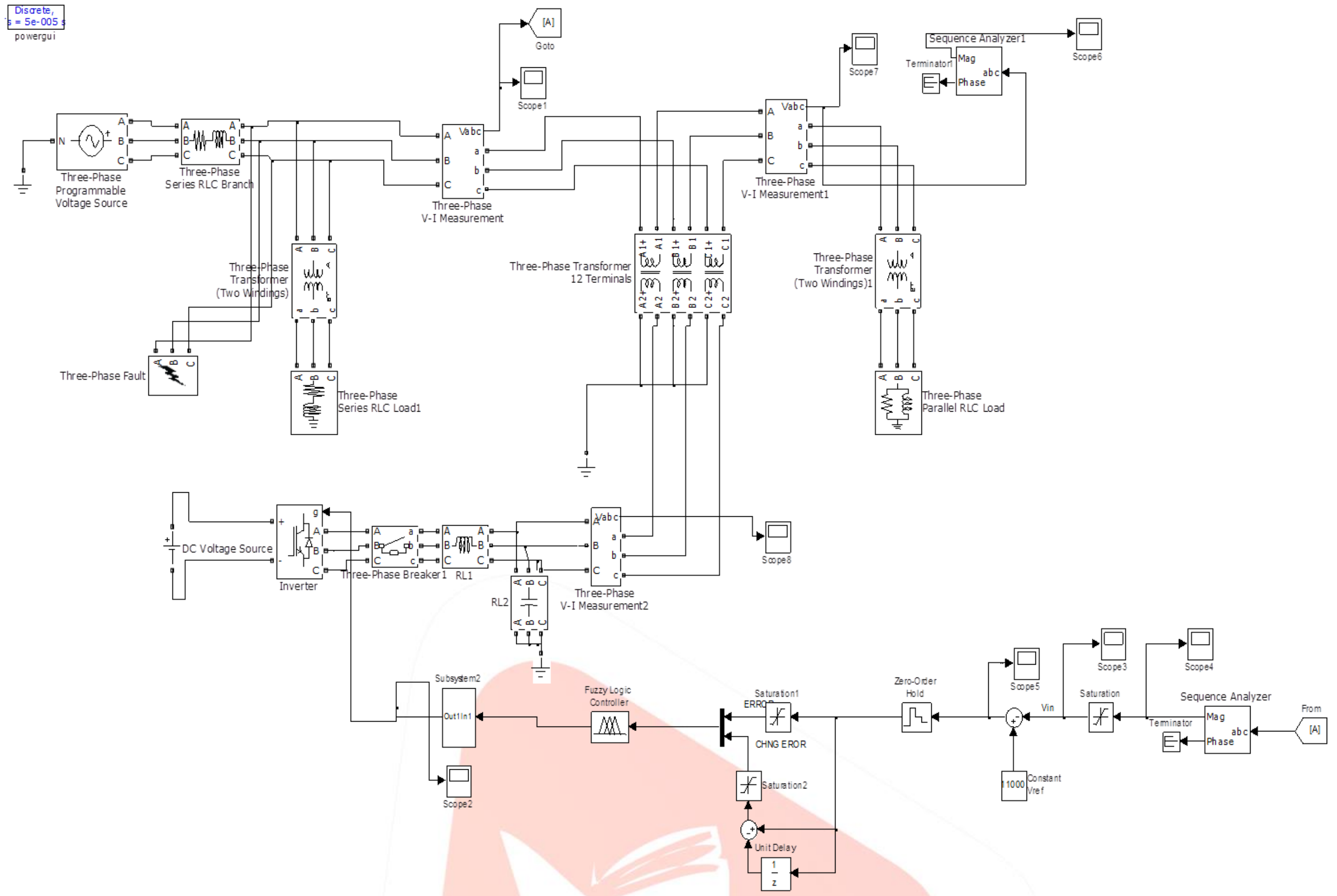


Figure (G): SIMULINK Model of the system

VII. RESULT

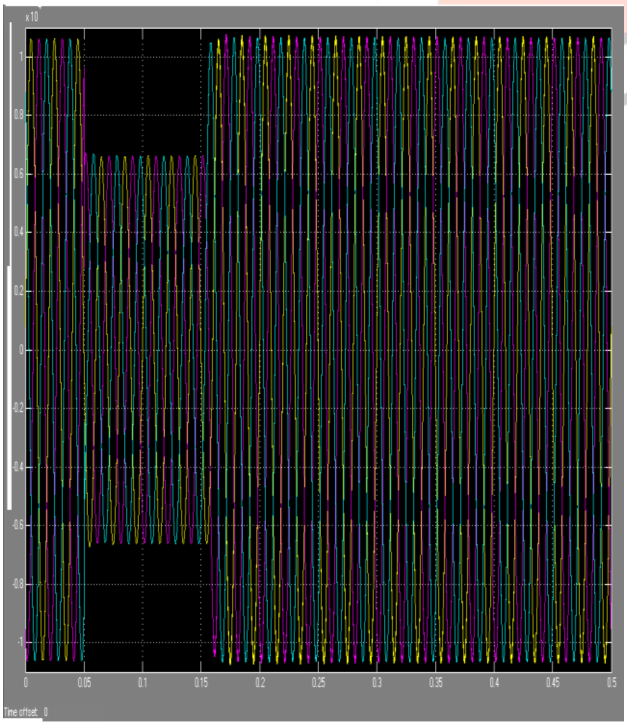


Figure (H): Main Input

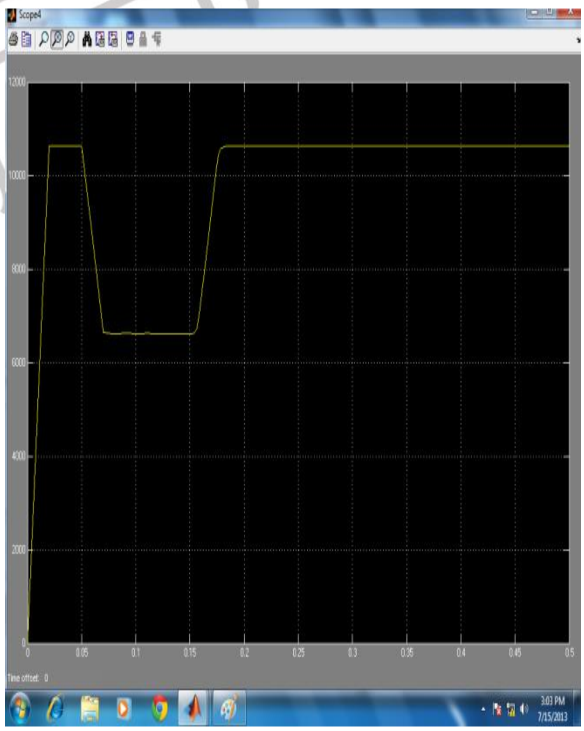


Figure (H.1): Main Input in PU

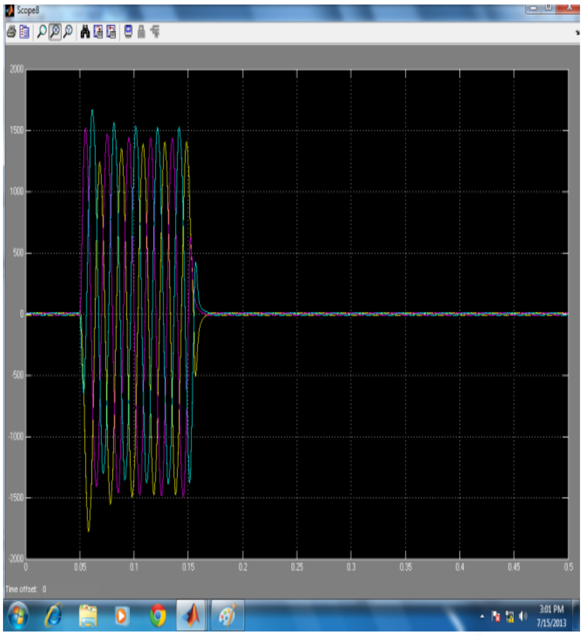


Figure (I): Injected V_g main

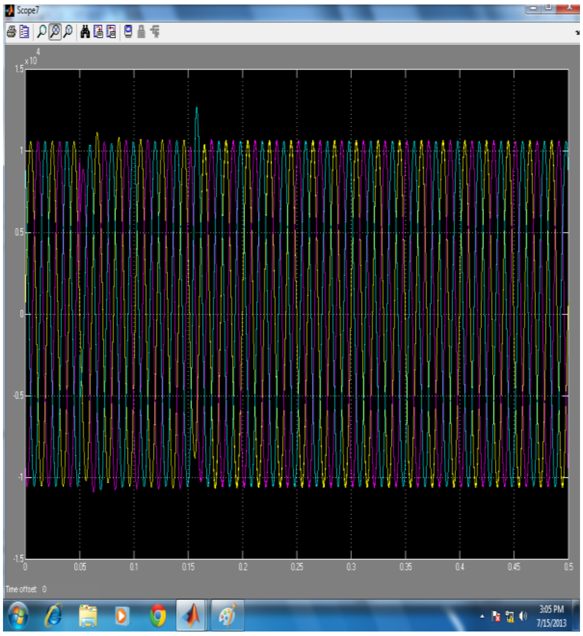


Figure (J): Final Output

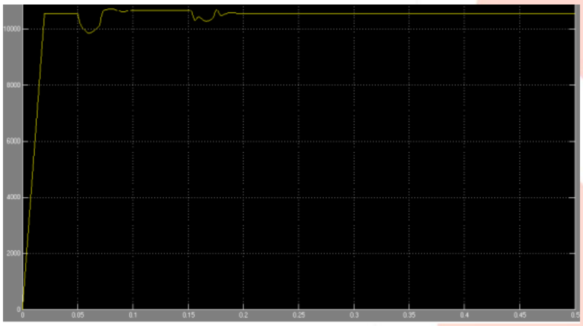


Figure (J.1): Final Output in PU

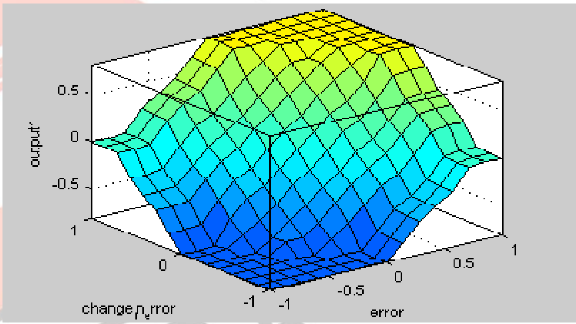


Figure (K): Surface

VIII. CONCLUSION

As DVR is very effective custom FACT device for voltage sag/swell mitigation, as it injects the required voltage to rapidly correct any abnormality in the supply voltage to keep the load voltage balanced & constant at the nominal value. The proposed PI controller combines with fuzzy logic controller to obtain the simulation results of voltage sag & swell in stiff & weak power system. The advantage of self – tuning fuzzy PI controller is its ability to compensate notching when DVR is connected to a weak power system.

REFERENCE

[1] S.Ezhilarasan, G.Balasubramanian "Dynamic Voltage Restorer For Voltage Sag Mitigation Using Pi With Fuzzy Logic Controller" , International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 3, Issue 1, January -February 2013, pp.1090-1095 1090 | P a g e.

[2] Sandesh Jain[1], Prof.Shivendra Singh Thakur[2], Prof. S.P.Phulambrikar[3], "Fuzzy Controller Based Dvr To Mitigate Power Quaity And Reduce The Harmonics Distortion Of Sensitive Load" , International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 1, Issue 5, November 2012.

[3] B. Ferdi, C. Benachaiba, S. Dib, R. Dehini, "Adaptive PI Control of Dynamic Voltage Restorer Using Fuzzy Logic" , Journal of Electrical Engineering: Theory and Application (Vol.1-2010/Iss.3) Ferdi et al. / Adaptive PI Control of Dynamic Voltage Restorer Using Fuzzy Logic / pp. 165-173.

[4] 1 Kartik Parmar 2 Pratik Kabrawala 3 Prof. Pinkal J.Patel, "Simulation And Analysis of DSTATCOM" , 2014 IJEDR | Volume 2, Issue 1 | ISSN: 2321-9939.

[5] R. H. Salimin, M. S. A. Rahim, "Simulation Analysis of DVR Performance for Voltage Sag Mitigation" , The 5th International Power Engineering and Optimization Conference (PEOCO2011), Shah Alam, Selangor, Malaysia : 6-7 June 2011.
[6] B.Panda, A.K. Mahapatra, D.P. Bagarty, & S. Behera, "Fuzzy Logic Controller-Based Dynamic Voltage Restorer For Mitigation Of Voltage Sag" , International Journal of Engineering Science and Technology (IJEST).
[7] Mahmoud A. El-Gammal1, Amr Y. Abou Ghazala2, and Tarek I. El-Shennawy3, "Dynamic Voltage Restorer (DVR) for Voltage Sag Mitigation" , International Journal on Electrical Engineering and Informatics - Volume 3, Number 1, 2011.
[8] K Hussain1, J Praveen2, "Voltage Sag Mitigation Using Distribution Static Compensator System" , International Journal of Engineering and Technology Volume 2 No. 5, May, 2012 ISSN: 2049-3444 © 2012 – IJET Publications UK.
[9] S.S. Mortazavi , M. Razaz, And E. Khavari , "Power Quality Improvement Using A Fuzzy Logic Control Of A Series Active Filter" , Journal Of Theoretical And Applied Information Technology.
[10] A. Teke K. Bayindir and M.Tu¨may"Fast sag/swell detection method for fuzzy logic controlled dynamic voltage restorer" IET Gener. Transm. Distrib., 2010, Vol. 4, Iss. 1, pp. 1–12.