Utilization of DVR with FLC to Inject Voltage in a Transmission Line

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ABSTRACT: *In this paper a Dynamic Voltage Restorer (DVR) is used for power quality improvement on transmission side for the voltage regulation, grid stabilization and efficient utilization. The DVR normally installed between the source voltage and critical or sensitive load. The vital role of DVR depends on the efficiency of the control technique involved in switching circuit of the inverter. The DVR is controlled by using PI with fuzzy logic controller. The Fuzzy logic controller based on fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into automatic control strategy. This paper presents a Digital validation conducted for different cases of fault conditions using the Mat lab/Simulink/Sim-Power software environment with the Dynamic Voltage Restorer scheme with fuzzy controller for effective voltage compensation, in rush current conditions and transmission line loss reduction.*

***KEYWORDS*:** *Dynamic Voltage stabilization, PI with fuzzy controller, Phase detection, voltage source converter, voltage sag.*

I. INTRODUCTION

The various power quality problems are due to the increasing use of non linear and power electronic loads. Harmonics and voltage distortion occur due to these loads. The power quality problems can cause malfunctioning of Sensitive equipments, protection and relay system [1]. These problems include a variety of electrical disturbances, which may originate in several ways and have different effects on various kinds of sensitive loads. As a result of this vulnerability, increasing numbers of industrial and commercial facilities are trying to protect themselves by investing in more sophisticate equipment to improve power quality [2]. Voltage magnitude is one of the major factors that determine the quality of power supply. Loads at distribution level are usually subject to frequent voltage sags due to various reasons. Voltage sags are highly undesirable for some sensitive loads, especially in high-tech industries. It is a challenging task to correct the voltage sag so that the desired load voltage magnitude can be maintained during the voltage disturbances. The effect of voltage sag can be very expensive for the customer because it may lead to production downtime and damage. Voltage sag can be mitigated by voltage and power injections into the distribution system using power electronics based devices, which are also known as custom power device. Different approaches have been proposed to limit the cost causes by voltage sag. One approach to address the voltage sag problem is dynamic voltage restorer (DVR). It can be used to correct the voltage sag at distribution level [3].

Distribution system is mainly affected by voltage sag and Swell power quality issue. Short circuits, lightning strokes, faults and inrush currents are the causes of voltage sags. Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers, single line to ground fault on the system lead to voltage swells. Voltage sag is a decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0.5 cycle to 1 minute. Voltage swells are momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds [4]. The Dynamic Voltage Restorer (DVR) are now becoming more established in industry to mitigate the impact of voltage disturbances on sensitive loads [5].The Dynamic Voltage Restorer (DVR) is a device that detects the sag or swell and connects a voltage source in series with the supply voltage in such a way that the load voltage is kept inside the established tolerance limits [6].Other than voltage sags and swells compensation, DVR also has added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

This paper explores design and analysis of a novel Dynamic Voltage Restorer along with fuzzy controller (mamdani rule base) for efficient stabilization and utilization. Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision [7], [8]. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, and fuzzy logic controllers [9]. The Mamdani rule base is a crisp model of a system, i.e. it takes crisp inputs and produces crisp outputs. It does this with the use of user-defined fuzzy rules on user-defined fuzzy variables. The idea behind using a Mamdani rule base to model crisp system behavior is that the rules for many Systems can be easily described by humans in terms of fuzzy variables. Thus we can effectively model a complex non-linear system, with common-sense rules on fuzzy variables [10], [11]. The proposed scheme proved success in improving the power quality, enhancing power factor, reduce transmission losses and limit transient over voltage and inrush current conditions. The paper is organized in seven sections. Section II deals with the Dynamic Voltage Restorer. Section III Proposed DVR with fuzzy controller with mat lab models. Section IV presents the Digital simulation results when different faults occur, Section VI concludes the work.

II. DYNAMIC VOLTAGE RESTORER

A DVR is a solid state based power electronics switching device consisting of either MOSFET or IGBT, a capacitor bank as an energy storage device and injection transformers. It is linked in series between a distribution system and a load that shown in Figure.1. The basic idea of the DVR is to inject a controlled voltage generated by a forced commuted converter in a series to the bus voltage by means of an injecting transformer.

A DC to AC inverter regulates this voltage by sinusoidal PWM technique. All through normal operating condition, the DVR injects only a small voltage to compensate for the voltage drop of the injection transformer and device losses. However, when voltage sag occurs in the distribution system, the DVR control system calculates and synthesizes the voltage required to preserve output voltage to the load by injecting a controlled voltage with a certain magnitude and phase angle into the distribution system to the critical load [12].

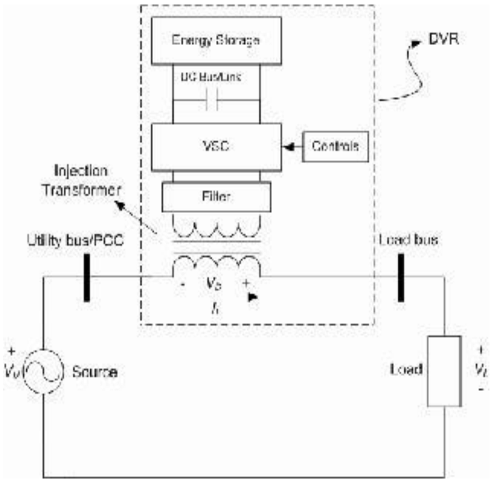


Fig. 1: DYNAMIC VOLTAGE RESTORER

III. PROPOSED DVR WITH FUZZY CONTROLLER WITH MAT LAB MODELS

Discrete PI Controller shown in Fig.2 is a feedback controller which drives the plant to be controlled with a weighted sum of the error and the integral of that value. The proportional response can be adjusted by multiplying the error by constant K_p, called proportional gain. The contribution from integral term is proportional to both the magnitude of error and duration of error. The error is first multiplied by the integral gain, K_i and then was integrated to give an accumulated offset that have been corrected previously.[13]

A. Proportional-Integral (PI) Controller

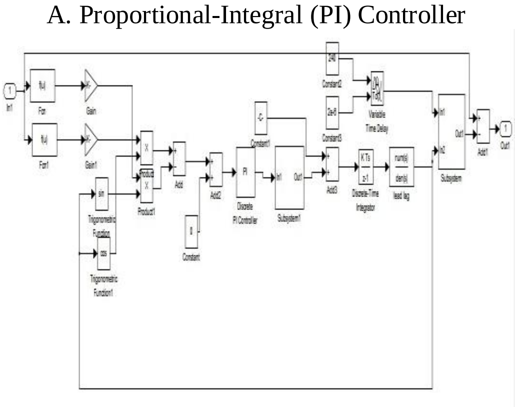


Fig. 2 Discrete PI controller

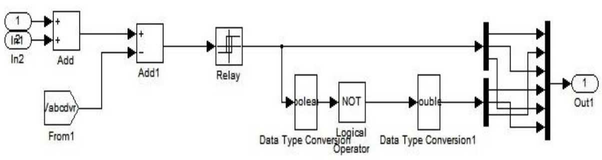


Fig. 3: Control circuit using PI with fuzzy logic controller

Fig.3 shows the control circuit designed in Matlab/Simulink software. The input of the controller come from the output voltage, V3 measured by three-phase V-I measurement at Load in pu. V3 is then transformed in dq term (expressed as instantaneous space vector). The voltage sag is detected by measuring the error between the dq- voltage and the reference values. The d-reference is set to rated voltage whilst q reference is set to zero. The dq components of load voltage are compared with the reference values and the error signal is then entering to PI controller. Two PI controller block are used for error signal-d and error signal-q separately. For error signal-d, K_p is set to 40 and K_i is set to 100 whilst for error signal-q, K_p is set to 30 and K_i is set to 150 respectively. All the gains selected use to tune up the error signal d and q so that the signal is stable and well responses to system disturbances. The outputs of the PI controller then are transformed back into V_{abc} before forwarded to PWM generator. B. Fuzzy Logic Controller (FLC)

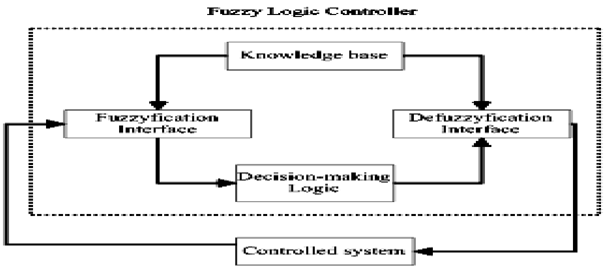


Fig. 4: Basic configuration of FL controller

Unlike Boolean logic, fuzzy logic allows states (membership values) between 0 or 1. Its major features are the use of linguistic variables rather than numerical variables. Linguistic variables, defined as variables whose values are sentences in a natural language (such as small and big), may be represented by fuzzy sets [14]. The general structure of an FLC is represented in Fig.4 and comprises four principal components:

• a fuzzyfication interface which converts input data into suitable linguistic values;

• a knowledge base which consists of a data base with the necessary linguistic definitions and control rule set;

• a decision making logic which, simulating a human decision process, infers the fuzzy control action from the knowledge of the control rules and the linguistic variable definitions; and

• a defuzzyfication interface which yields a nonfuzzy control action from an inferred fuzzy control action.

In this paper, two FL controller block are used for error signal-d and error signal-q as shown in Fig.3. The process also same as before except the controller now is Fuzzy Logic. For both blocks (error signal-d and q) the FL controller consists of three linguistic variables from input which is; Negative (N), Zero (Z) and Positive (P). Each parameter from linguistic variables for error signal is shown in Fig.5.

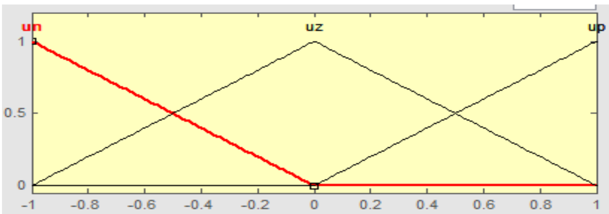


Fig. 5: Linguistic variables from error

For delta error, there are three linguistic variables, Negative (N), Zero (Z) and Positive (P). Both variables can be depicted as in Fig.6.

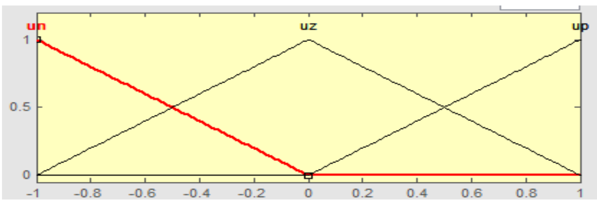
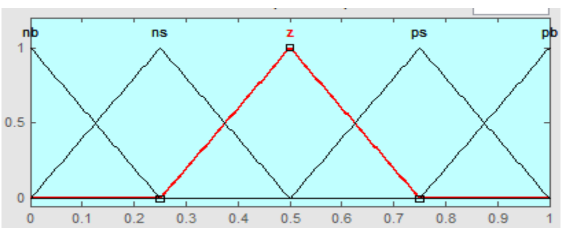


Fig. 6: Linguistic variables from delta error



Negative Big (NB), Negative Small(NS), Positive Big(PB), Positive Small (PS), Fig.7. Shows each parameter for output signal.

Table 1: Rule Base

E /DE	N	Z	P
N	NB	NS	Z
Z	NS	Z	PS
P	Z	PS	PB

In the decision-making process, there is rule base that linking between input (error signal) and output signal. Table 1 show the rule base used in this FL controller.

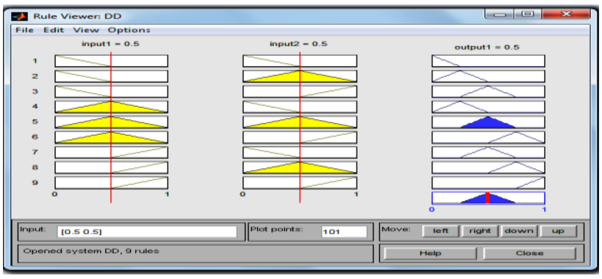


Fig. 8: Rule viewer of d reference

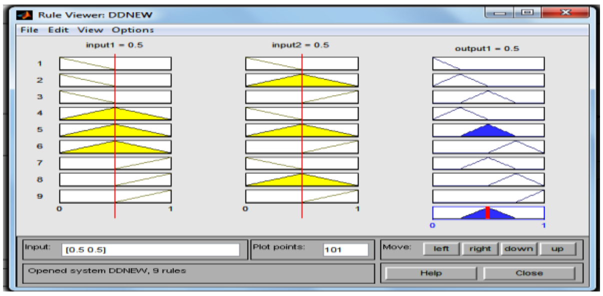


Fig. 9: Rule viewer of q reference

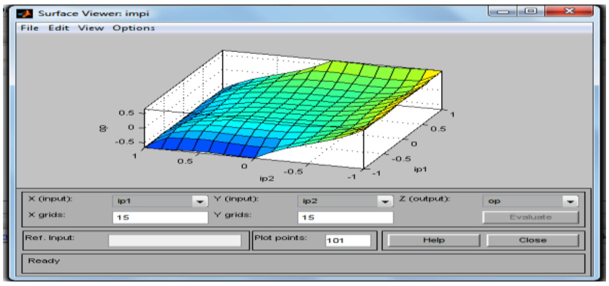


Fig. 10: Surface viewer

IV. SIMULATION RESULTS

In order to understand the performance of the DVR along with control, a simple distribution network as shown in Fig.11 is implemented. There are different fault conditions like normal system, single line to ground fault, double line to ground fault, three phase fault and voltage sag simulated using MATLAB/SIMULINK software. PI with fuzzy logic controller is used for the control purpose. The DVR system connected to the distribution system using a booster transformer.

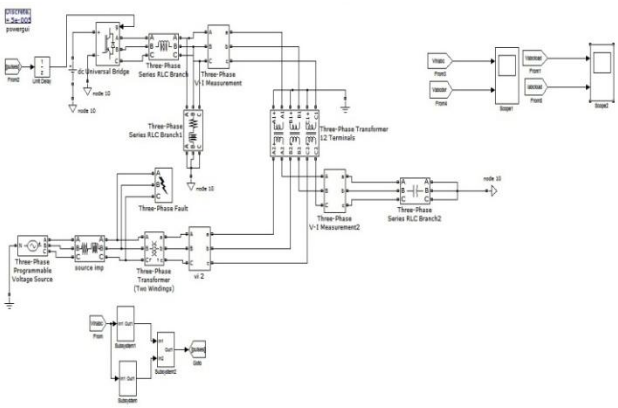
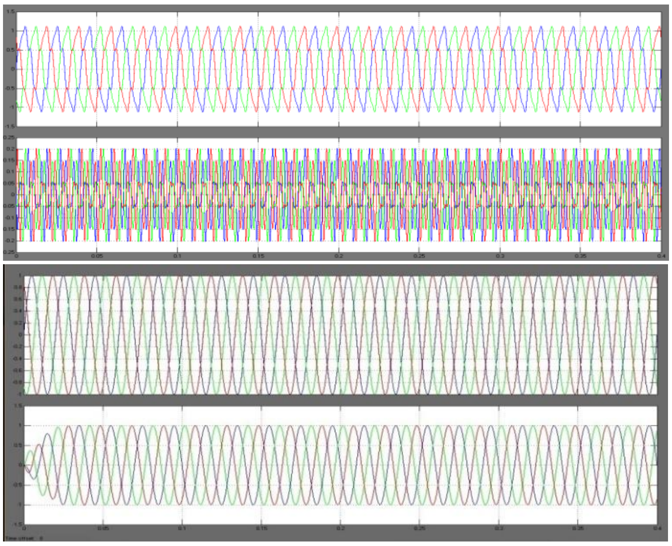


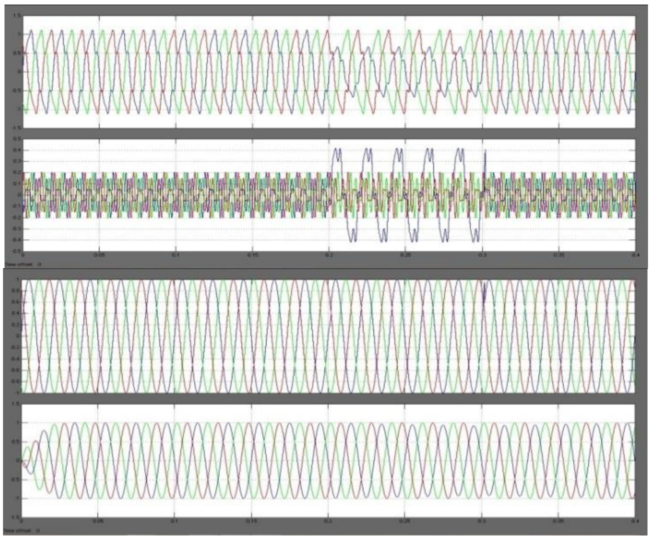
Fig. 11: Simulink Model of DVR Test System

In this system different fault conditions like normal system, single line to ground fault, double line to ground fault, three phase fault and voltage sag with feeder for the duration of 0.2s to 0.3s with fault resistance is 20 ohms and the ground resistance is 0.001 ohms. The output results for the above system are shown below.



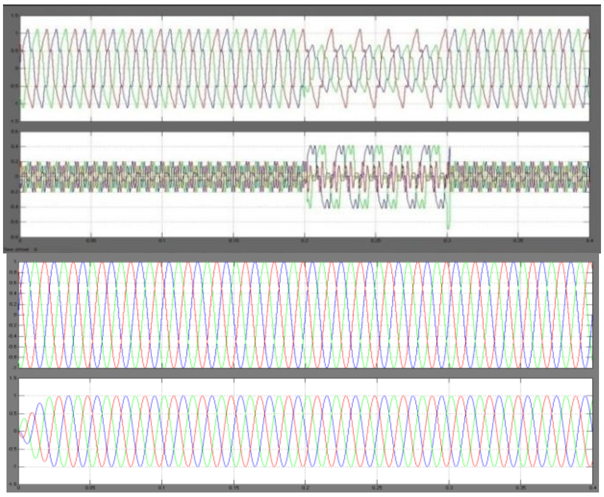
Time (s)

Fig. 12: Normal system (a) Supply voltage, (b) Injection voltage, (c) Load voltage and (d) Load current



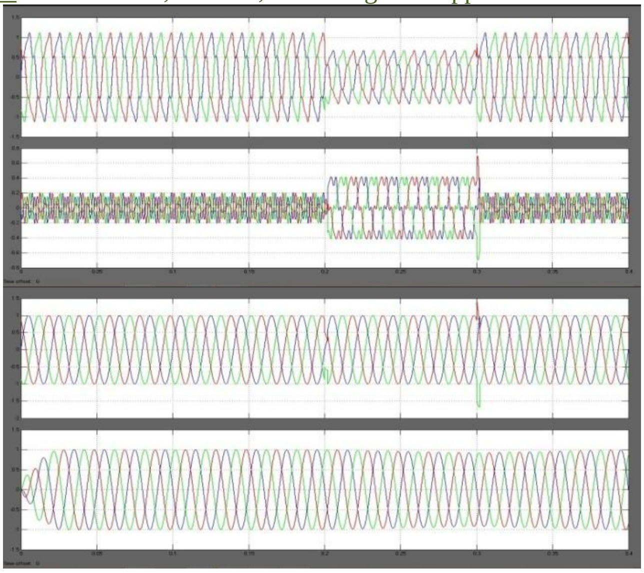
Time (s)

Fig. 13: Single line to ground fault; (a) Supply voltage, (b) Injection voltage, (c) Load voltage and (d) Load current



Time (s)

Fig. 14: Double line to ground fault; (a) Supply voltage, (b) Injection voltage, (c) Load voltage and(d) Load current



Time (s)

Fig. 15: Three phase fault; (a) Supply voltage, (b) Injection voltage, (c) Load voltage and (d) Load current

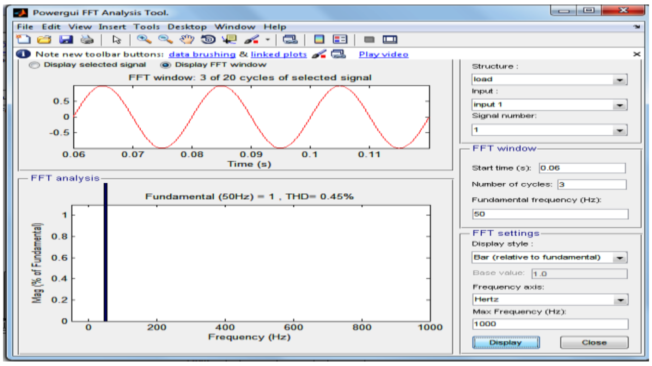


Fig. 17: THD for load voltage using PI with Fuzzy Logic controller

Table 2: THD for V_{dc}

Sl.No.	V_{dc} (V)	
1.	250	0.45
2.	200	0.39
3.	150	0.30
4.	100	0.19
5.	50	0.08

V. CONCLUSION

This project thesis examined the problems of power quality in the distribution systems and the need for the mitigation of these problems using the effective and efficient power quality equipment. The Voltage sag was created in a sampler power system by a three phase symmetrical fault in Simulink and a prototype of Dynamic Voltage Restorer was constructed in Simulink. The corresponding Injected voltage was generated for the appropriate Sag voltage occurred in the line.

Finally DVR model can able to mitigate the voltage sag dynamically without any change in the parameters of the internal system and the corresponding compensating voltage is also generated in the distribution system. The simulations carried out showed that the DVR provides relatively better voltage regulation capabilities. There are some limitations; those are the voltage limit, power limit, and energy limit.

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