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Fuzzy Logic Controlled Less Storage Dynamic Voltage Restorer for Voltage Sags/Swells Mitigation

Yadagiri Ukondi [1], A Ram Reddy[2]

PG Scholar, Dept. of EEE, Siddahrtha Institute of Engineering & Technology, Ibrahimpatnam, Telangana, India[1]

Associate Professor, Siddhartha Institute of Engineering & Technology, Ibrahimpatnam, Telangana, India[2]

ABSTRACT: Power quality is one of major concerns in the present era. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipment. One of the major problems dealt here is the voltage sag and voltage swell.To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (DVR). Its appeal includes lower cost, smaller size, and its fast dynamic response to the disturbance. Since no storage device is employed, these topologies require improved information on instantaneous voltages at the point of common coupling and need flexible control schemes depending on these voltages. The control for DVR based on Fuzzy Logic Control is discussed. The proposed control scheme is simple to design. Simulation results carried out by MATLAB/SIMULINK verify the performance of the proposed method.

KEYWORDS: sag, swell, DVR, Fuzzy logic control

I. INTRODUCTION

1.1.1 Power quality problems

A North American analysis of power quality included data collection from 1057 site-months at 112 locations from 1990 to 1994. The measured data were analysed and classified according to the standards of ANSI C84.1-1989 and the Computer and Business Equipment Measurement Association (CEBEMA) curve, illustrated in Fig. 1.1. More than 160,000 power disturbances were recorded over the four monitoring periods, which showed the unavailability of commercial power with an estimated mean value of 6.17 hour per site, per year. The power disturbances were categorized into four major events; low RMS events, high RMS events, transients and interruptions. The transient events took a major part with around 60 %, while the interruption took minor part with around 1 %. The transients mainly came from capacitive switching operations, when the utility applies a large bank of capacitors on a high voltage power line to help to regulate voltage and to compensate for a poor power factor. More than 26 % of the power disturbances came from the low RMS events, while 13 % of that came from the high RMS events. Some of the high RMS events were suspected to come from the incorrect setting of the transformers. The majority of the low RMS events (90 %) lasted less than one minute, while 4 % lasted more than thirty minutes. Voltage dips can cause tripping of sensitive loads and the cost associated with short duration voltage dips can in some cases justify the insertion

II. POWER QUALITY AND CONTROLLER FOR VOTLAGE SAG/SWELL MITIGATION

This chapter explains different issues of power quality with emphasis put on voltage sag/swell and power quality issues, which are relevant for the dynamic voltage restorer. At the end of the chapter basic power electronic controllers for voltage sag/swell mitigation are presented.

2.2Voltage Quality

The voltage quality has an impact on the control and design of a DVR and the DVR performance depends on the voltage quality at the location the DVR is inserted. In this section voltage harmonics, non-symmetry and voltage dips are treated to give a basic introduction to key voltage parameters for a DVR.

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2.2.1 Voltage harmonics

Non fundamental voltage harmonics often appear at all levels in the electrical system. In relation with the DVR the harmonic content of the voltage before and after the DVR has major interest. Before the DVR, during no-load conditions the so called background distortion level can be measured and the level of distortion may influence the control of the DVR. The DVR can inject some harmonics and a vectorial addition with the background harmonics gives the resulting load voltage harmonics. The load voltage harmonics and the resulting load voltage distortion is an important evaluation parameter of the DVR performance. Sources to the distortion of the load voltages vary and the three main sources are:

- Background voltage harmonics: Background harmonics can easily be transferred to the load voltage side. During voltage injection harmonics from background distortion can be amplified or damped in the DVR control system. A supply voltage with a high harmonics content can complicate the synchronization to the supply and interfere with the DVR control.
- Harmonics injected by the DVR: The THD of the injected series voltage depends on the DVR hardware Eg.Converter topology, switching frequency, modulation method, modulation index and filtering. Non-linear effects in the converter can even be a pure fundamental reference voltage inject harmonics, caused by non-linear effects in the DVR such as dead-time, transistor and diode voltage drop.
- Non-linear load currents: A non-linear load current distorts the load voltage, which depends on the strength of the grid, the inserted DVR and the resulting impedance seen by load. This will include impedance in the DVR and the grid.

The voltage distortion U_{dis} can be calculated by a summation of the harmonic components, according to:

$$\boldsymbol{U_{dis}} = \sqrt{\sum_{h=2}^{\infty} U_h^2} \quad eq.\,2.1$$

and the total harmonics distortion (THD) in percent can be calculated by:

$$U_{THD,\%} = \frac{U_{dis}}{U_1} \times 100\,\% \qquad eq.\,2.2$$

The DVR has the potential of improving the load voltage with respect to harmonic distortion, which means both to compensate for background harmonics and to compensate for the distorted load voltage caused by a distorted load current. This type of control is often termed as a harmonic blocking control or series harmonic filtering. In this thesis the main focus is on the control of the fundamental voltage, but still the load voltage THD has to be within acceptable limits.

III. DYNAMIC VOLTAGE RESTORER

3.1Introduction

First the chapter describes the basic elements of a DVR and the expected location of a DVR. Thereafter, different DVR system topologies are presented with respect to topologies and methods to have active power access during voltage dips. Finally protection issues are discussed.

3.2The basic elements of DVR

Fig. 3.1 illustrates some of the basic elements of a DVR, which are: Converter: The converter is most likely a Voltage Source Converter (VSC), which Pulse Width modulates (PWM) the DC from the DC-link/storage to AC-voltages injected into the system. Line-filter: The line-filter is inserted to reduce the switching harmonics generated by the PWM VSC.Injection transformer: In most DVR applications the DVR is equipped with injection transformers to ensure galvanic isolation and to simplify the converter topology and protection equipment. DC-link and energy storage: A DC-link voltage is used by the VSC to synthesize an AC voltage into the grid and during a majority of voltage dips active power injection is necessary to restore the supply voltages. By-pass equipment: During faults, overload and service a bypass path for the load current has to be ensured. Illustrated in Fig. 3.1 as a mechanical bypass and a thyristor bypass is-connection equipment: To completely disconnect the DVR during services.

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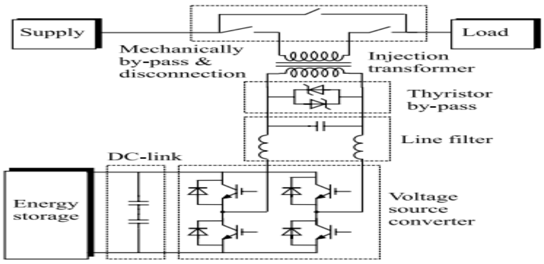

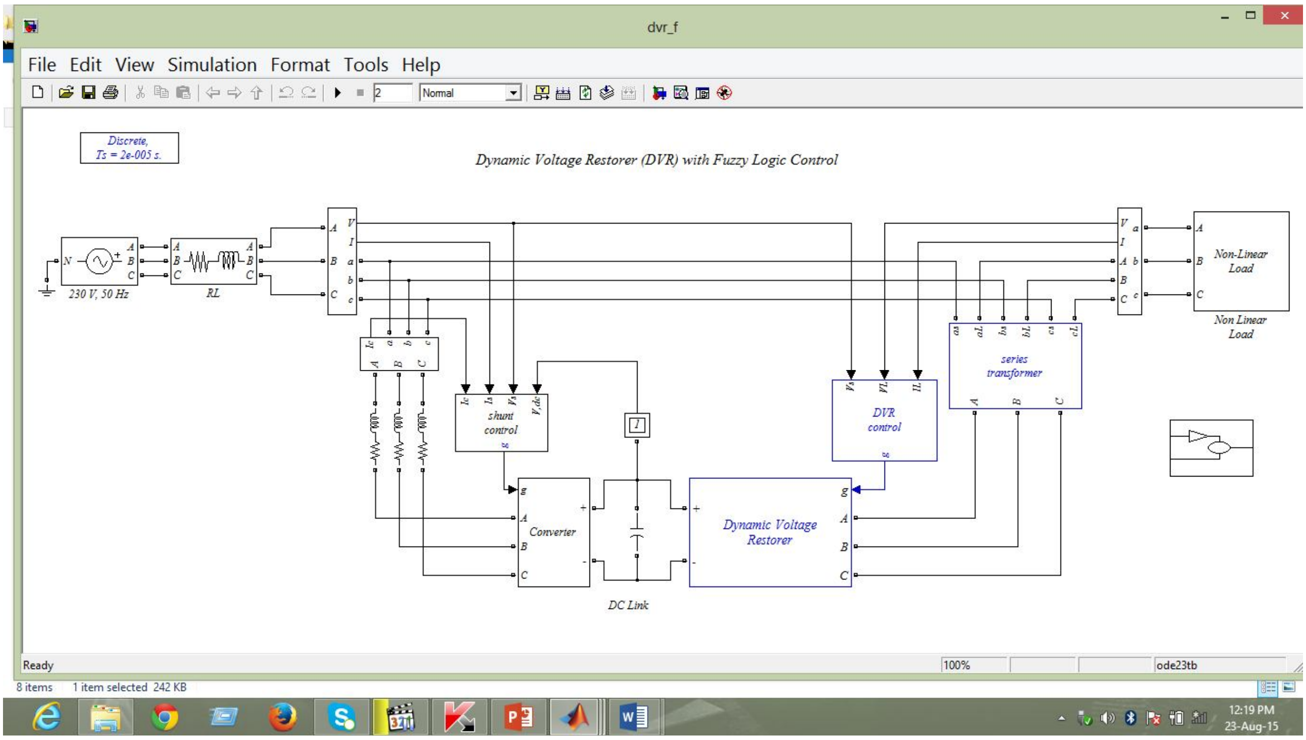

Fig.1. Basic circuit of the proposed Dynamic Voltage Restorer in MATLAB/SIMULINK

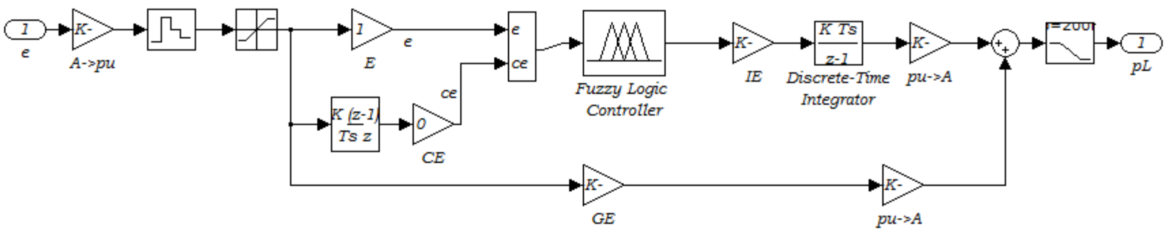

Fig.3.Control scheme of the proposed Dynamic Voltage Restorer in MATLAB/SIMULINK

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V. INTRODUCTION TO FUZZY LOGIC CONTROLLER

A new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of dc-to-dc converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in Fig 5 and consists of four principal components such as: a fuzzy fication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

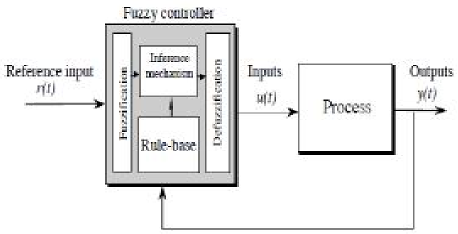

Fig.5. General Structure of the fuzzy logic controller on closed-loop system

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [10]. Simulation is performed in buck converter to verify the proposed fuzzy logic controllers.

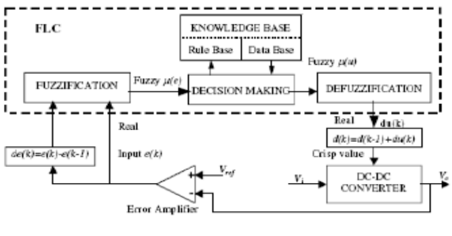

Fig.6. Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters

Fuzzy Logic Membership Functions:

The dc-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of boost converters. Fuzzy controllers do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the output of boost dc-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.

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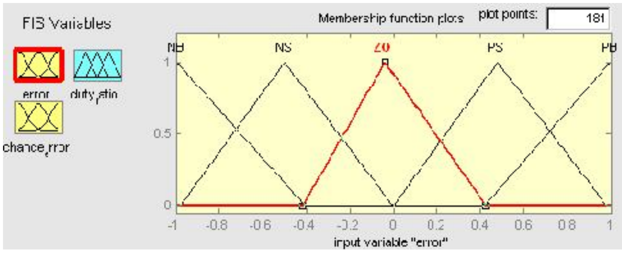

Fig. 7.The Membership Function plots of error

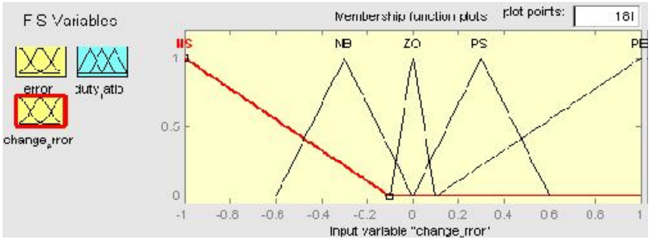

Fig.8. The Membership Function plots of change error

Fuzzy Logic Rules:

The objective of this dissertation is to control the output voltage of the boost converter. The error and change of error of the output voltage will be the inputs of fuzzy logic controller. These 2 inputs are divided into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive small and PB: Positive Big and its parameter [10]. These fuzzy control rules for error and change of error can be referred in the table that is shown in Table II as per below:

Table II
Table rules for error and change of error

(de) \ (e)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

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VI.MATLAB/SIMULINK RESULTS

Case 1: Dynamic Voltage Restorer in MATLAB/SIMULINK with fuzzy

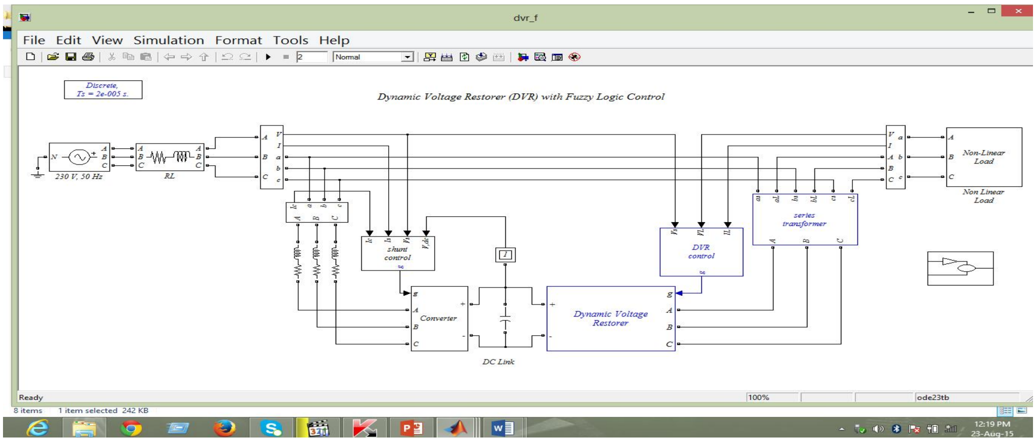

Fig.10.Simulink circuit for SHPF-TCR under harmonic generated load with fuzzy

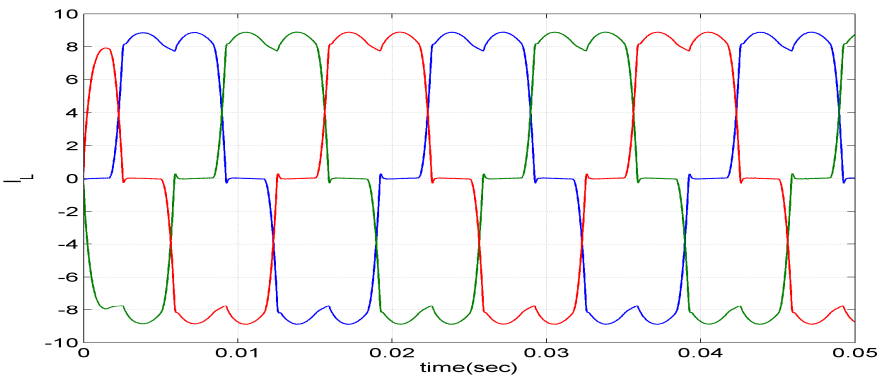

Figure 6.1 Load Current of Sensitive Load (Non Linear)

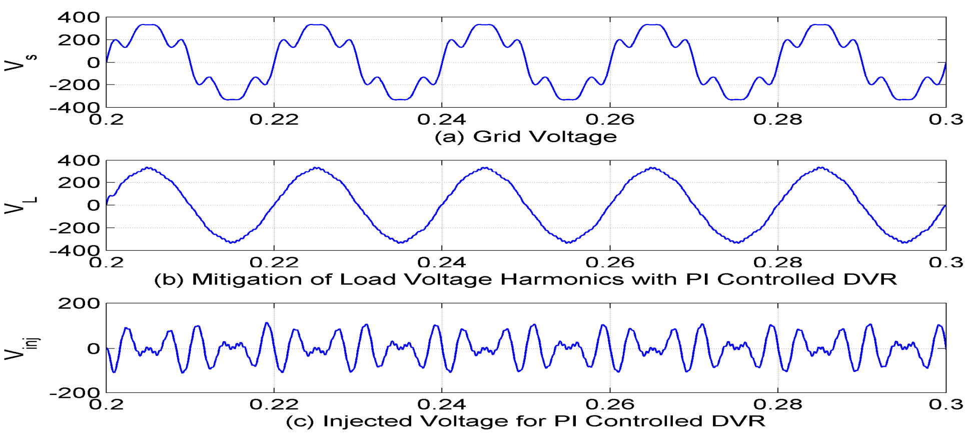

Figure 6.3 Mitigation of load voltage harmonics with Fuzzy Logic Controlled DVR

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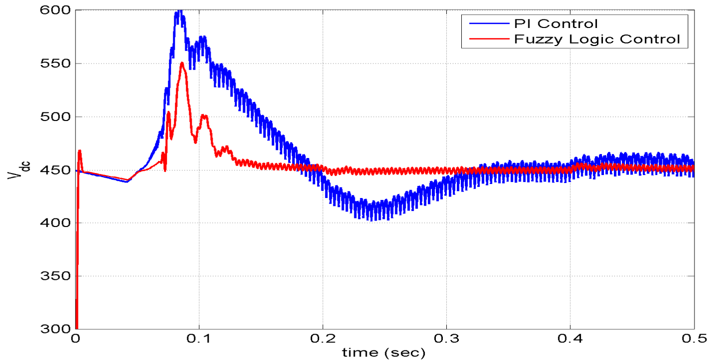

Figure 6.4 DC link Voltage

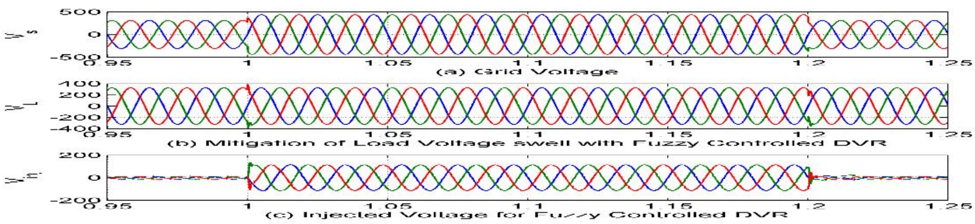

Figure 6.9 Mitigation of Load Voltage swell with Fuzzy controlled DVR

VII. CONCLUSION

This thesis has presented the power quality problems such as voltage dips, swells, distortions and harmonics. Compensation techniques of custom power electronic devices DVR was presented. The design and applications of DVR for voltage sags and comprehensive results were presented. A PWM-based control scheme was implemented. The DVR is modelled in MATLAB Simulink with PI control and Fuzzy logic control. Fuzzy logic controlled DVR reduced the noise the DC link and hence the %THD is reduced and hence the performance and power quality of the system is improved with proposed control than conventional control.

FUTURE SCOPE

A series connected voltage controller like the DVR is expected to experience an increased attention in the future, because it can be an effective and relative inexpensive solution to stabilize the voltage compared to high power rated UPS systems.

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