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Design and Development of DVR model Using Fuzzy Logic Controller for Voltage Sag Mitigation

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Abstract: **In this paper, A fuzzy logic based DVR model is presented and Modelled with the help of simulink block. Since from inception, fuzzy logic has been utilized in almost all the field but its application is mostly found very efficient in control system engineering. In this work Fuzzy logic controller is designed for DVR(Dynamic Voltage restorer) for mitigating the voltage sag and voltage swell problem. Simulation Result shows the compensation ability of this DVR is very effective.**

Keywords: **PI (Proportional Integration), VSC (Voltage Source Converter), DVR (Dynamic Voltage Restorer), SPWM (Sinusoidal Pulse Width Modulation).**

I. INTRODUCTION

In the recent years, power quality problem has become major concerned for the industries which causes massive loss for them in term of money and time. Therefore, it is need of the hours to design and develop some device which can improve the power quality in the industries. This will ensure the reduction in the problem of voltage sag, harmonics and flicker. Though in the literature various different kind of DVR has been presented. Controlling mechanism in all those DVR are different.

Voltage sag is one of the problems related to power quality. This phenomenon happens continuously in transmission and distribution systems. Power quality problems, such as voltage sag which arise due to a fault or a pulsed load, can cause interruption on critical load. [1][2]. Voltage sags are usually associated with system faults but they can also be generated by energization of heavy loads or starting of large motors which can draw 6 to 10 times its full load current during starting. Sag durations are subdivided into three categories, instantaneous, momentary, and temporary-all of which coincide with utility device operation times[3-4]. Voltage Swell is defined by IEEE 1159[4] as the increase in the rms voltage level to 110%-180% of nominal, at the power frequency for durations of ½ cycles to one minute. It is classified as a short duration voltage variation phenomena, which is one of the general categories of power quality problems.

Voltage sags are characterized by a reduction in voltage, but the load is still connected to the supply. Sags are in most cases considered less critical compared to interruptions, but they typically occur more frequently. Voltage sags have in several cases been reported as a threat to sensitive equipment and have resulted in shutdowns, loss of production and a hence a major cost burden [5][6].

Dynamic voltage restorer can provide the most cost effective solution to mitigate voltage sags by establishing the proper voltage quality level that is required by customer. When a fault happens in a distribution network, sudden voltage sag will appear on adjacent loads. DVR installed on a critical load, restores the line voltage to its nominal value within the response time of a few millisecond thus avoiding any power disruption to the load. [7].

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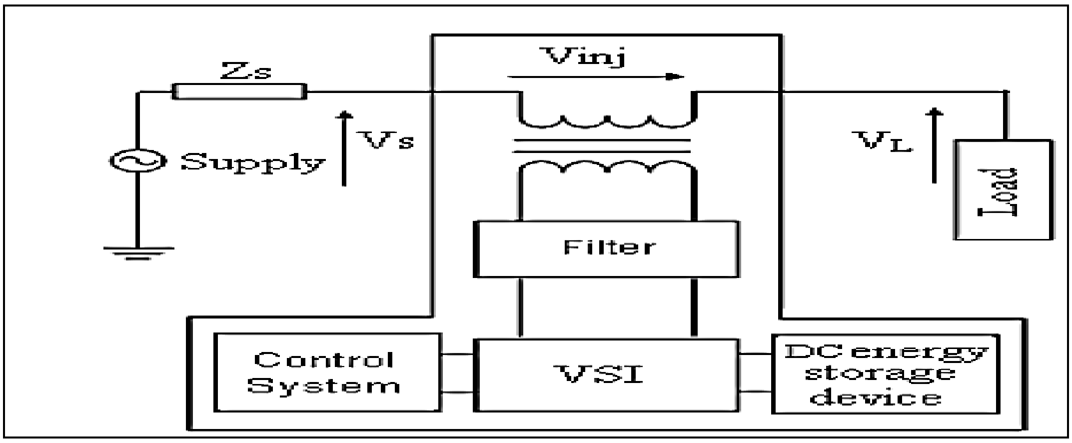

Figure1: Schematic Representation of DVR

In this paper, author proposes a novel dynamic voltage restore based on the fuzzy logic controller using 5-level inverter.

II. PROPOSED FUZZY LOGIC CONTROLLER BASED DVR

In the proposed DVR (Dynamic voltage restore), fuzzy logic is used for generating the error signal this error signal is then used to control the operation of the dynamic voltage restorer. In the proposed method a fuzzy logic controller is designed which takes the line voltage as input and then generate the d-error signal and q-error signal. A cascaded 5-level inverter is used to generate the compensating voltage which is then fed to the main line in series fashion.

A. Five Level Inverter Designing

Figure 2 shows the five-level cascade inverter used in the proposed system. As shown in figure 2, one phase of the cascade inverter consists of (5-1)/2 identicd H-bridges, in which each bridge has its own separate dc source, and all the capacitors, switches and diodes have the same voltage and current ratings. The required dc capacitors are far smaller and much more efficient than the conventional inverter.

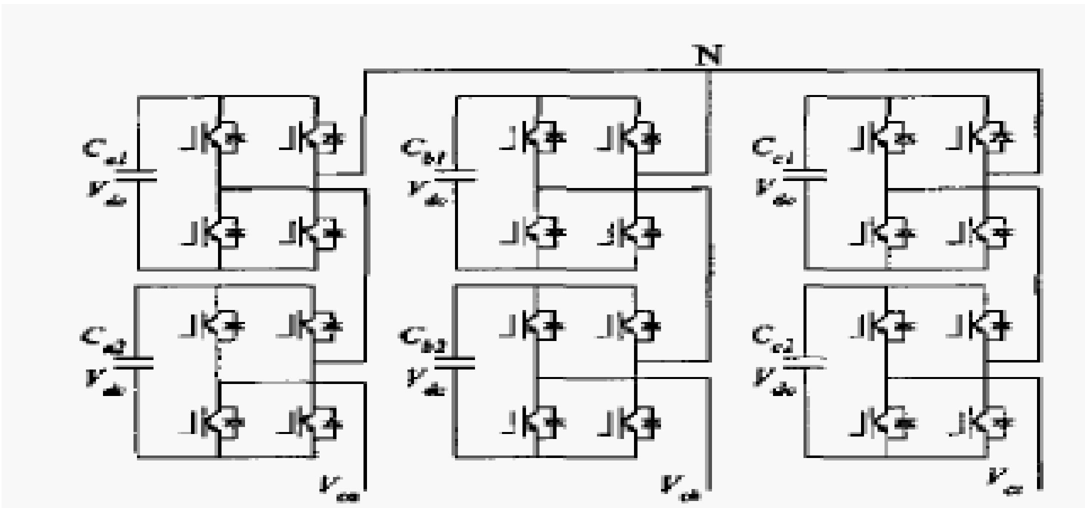

Figure 2: Five level Inverter

This inverter can

1. Generate sinusoidal waveform voltage with least harmonics.
2. Eliminate transformers used in conventional system.
3. Make possible direct connection to the distribution system without any additional transformers.

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Figure 3 represent the same inverter in simulink model

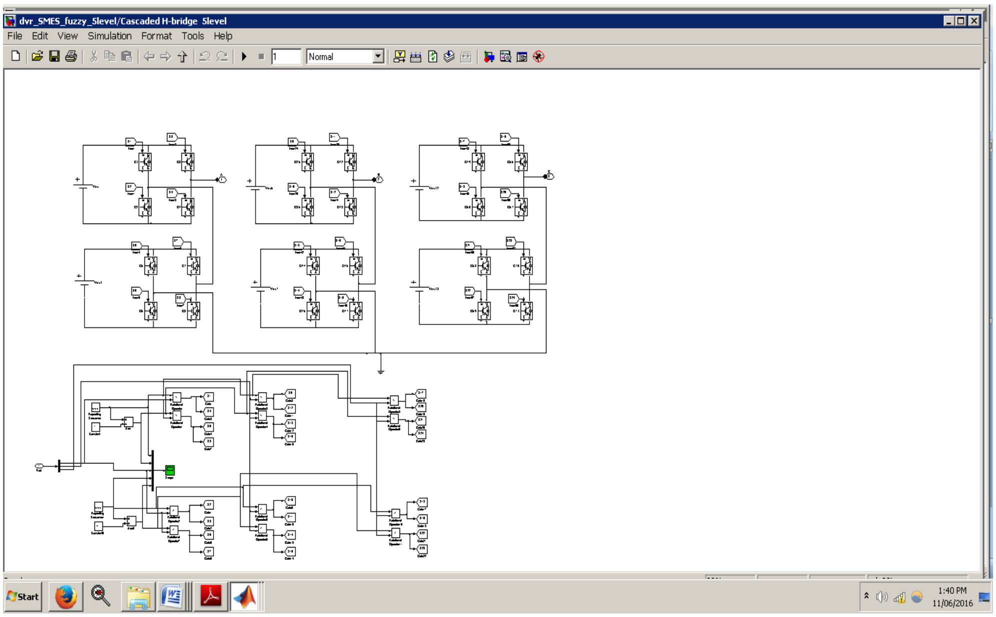

Figure 3: five-level H-Bridge Inverter model in simulink

B. Fuzzy Logic Controller

In the Boolean logic, there are two existing states i.e. 0 and 1 or true or false.

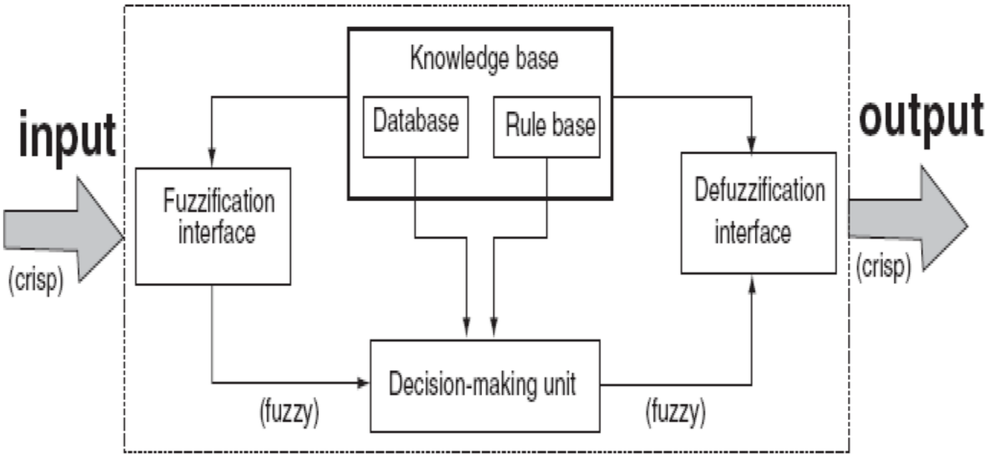

Figure 4: Block Diagram of Typical FLC

There is no other states are available in the Boolean logic other than these two values. On the other hand, fuzzy logic, unlike the Boolean logic can have number of different states (membership values) between 0 and 1. One of the most important features of the fuzzy logic is the, use of linguistic variables instead of numerical variables. In linguistic variables, variables are defined in natural languages sentence e.g. Big, small, High, low etc. These linguistic variables are represented by fuzzy sets [8].

Figure 4 represent the general block diagram of the Fuzzy logic Controller (FLC). From this figure, it is clear that it comprises of the four main blocks or components-

i. Fuzzification Interface- main function of this block is to convert the input data in to suitable linguistic variables.

ii. Knowledge Base- This block consists of database with the necessary linguistic definitions and fuzzy rule set.

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iii. Defuzzyfication Interface-Main function of this block is to convert the linguistic definitions and variables to the numerical values i.e. defuzzy-fication.

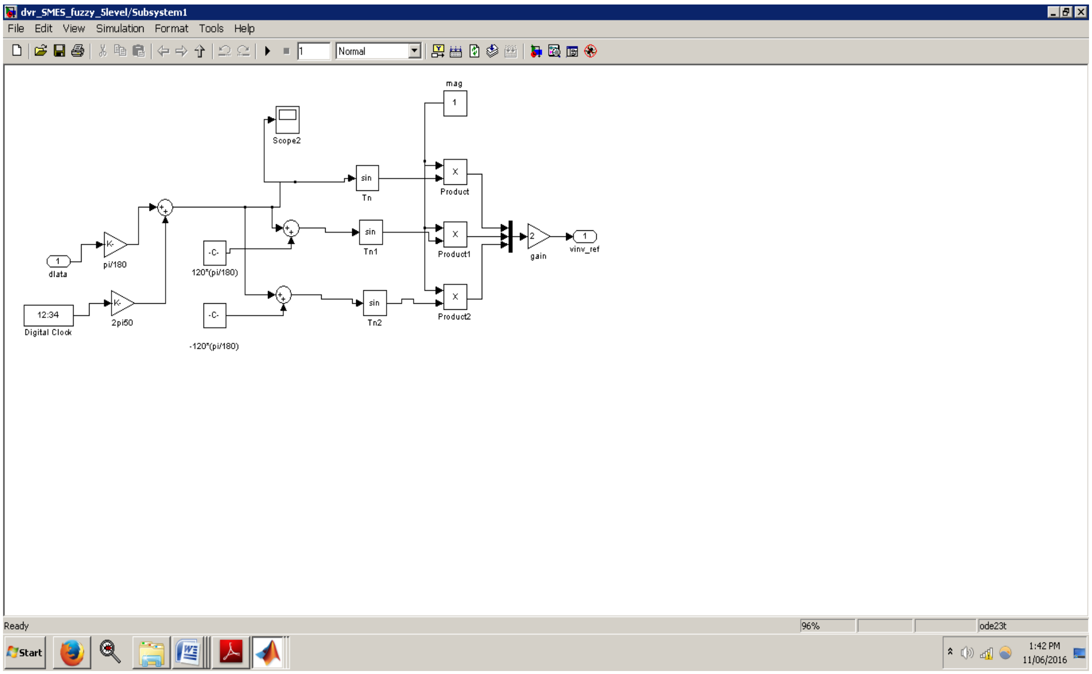

Figure 5: Reference Voltage Generation in Proposed DVR

In this work, controlling is accomplished through FL controller. As many as 5 different linguistic variables are used in the FL controller. These are High Negative (HN), Low Negative (LN), Zero (Z), Low Positive (LP); High Positive (HP).Figure 6 shows the various parameters from linguistic variable for error signal. There are two linguistic variables have been taken i.e. negative (N) and positive (P).

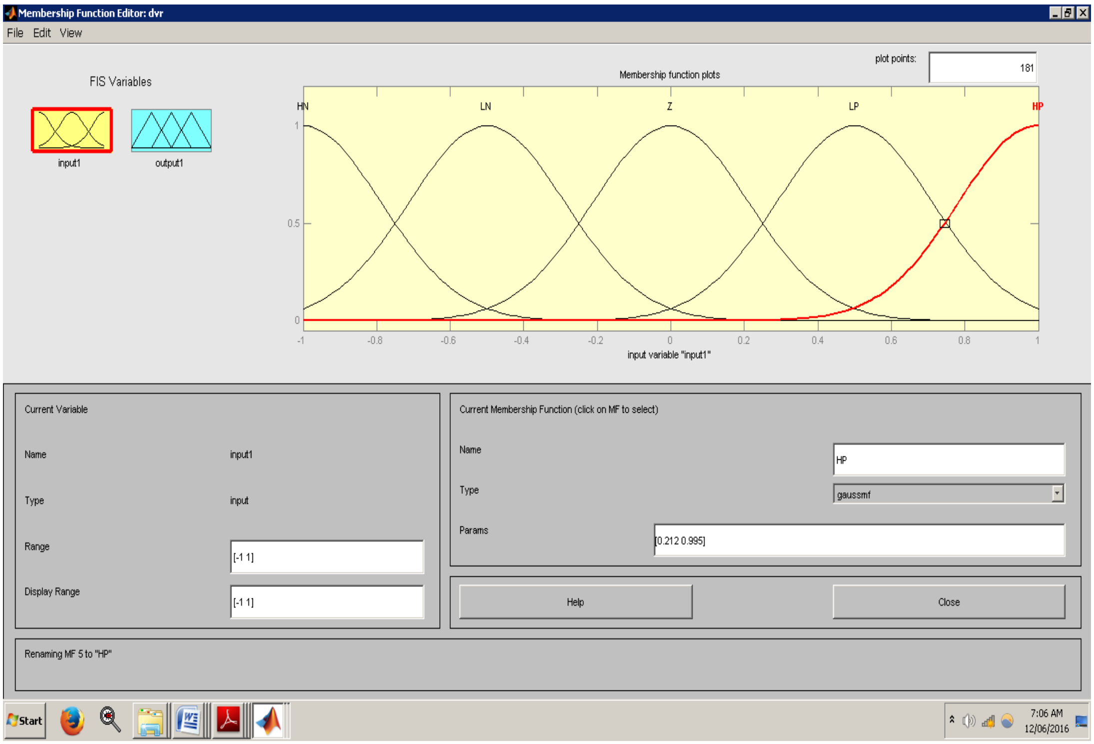

Figure 6: Linguistic variables from input

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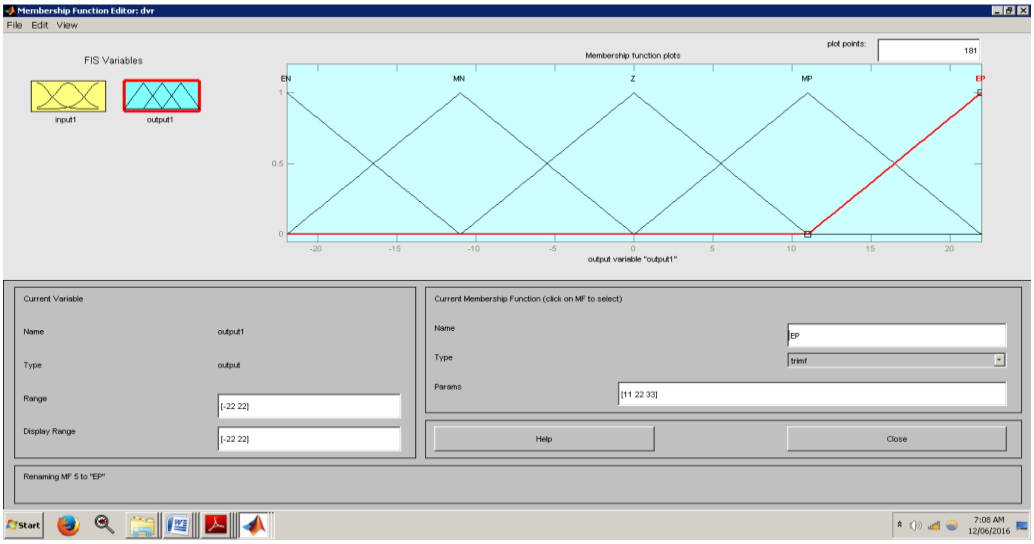

Figure 7: Linguistic variables from output signal

In order to perform the defuzzyfication process, 5 linguistic variables have been taken. These are named as Extreme Negative (EN), Mid negative(MN), zero(Z), Mid positive (MP) and Extreme Positive(EP). Figure 7 depicts the parameters for the output signal.

Table 1: Rule Base (Linear)

Input	Output
HN	EN
LN	MN
Z	Z
LP	MP
HP	EP

In the process of decision making, a rule base has been designed which is used to link the input signal(error signal) to the output signal. The rule base used in the project is shown in the table 1

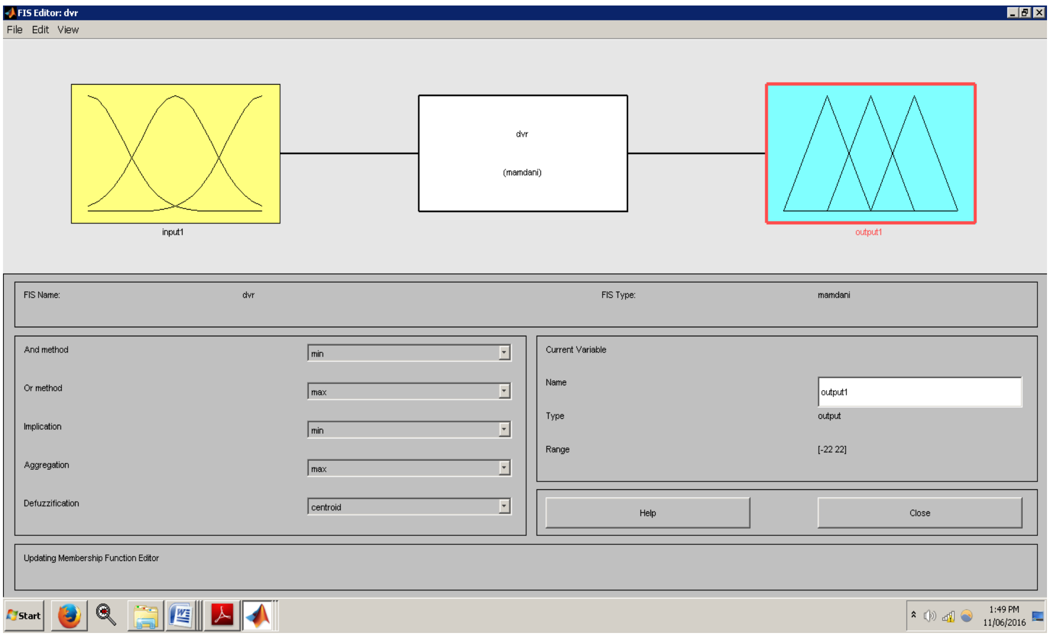

Figure 8: Fuzzy system Implementation

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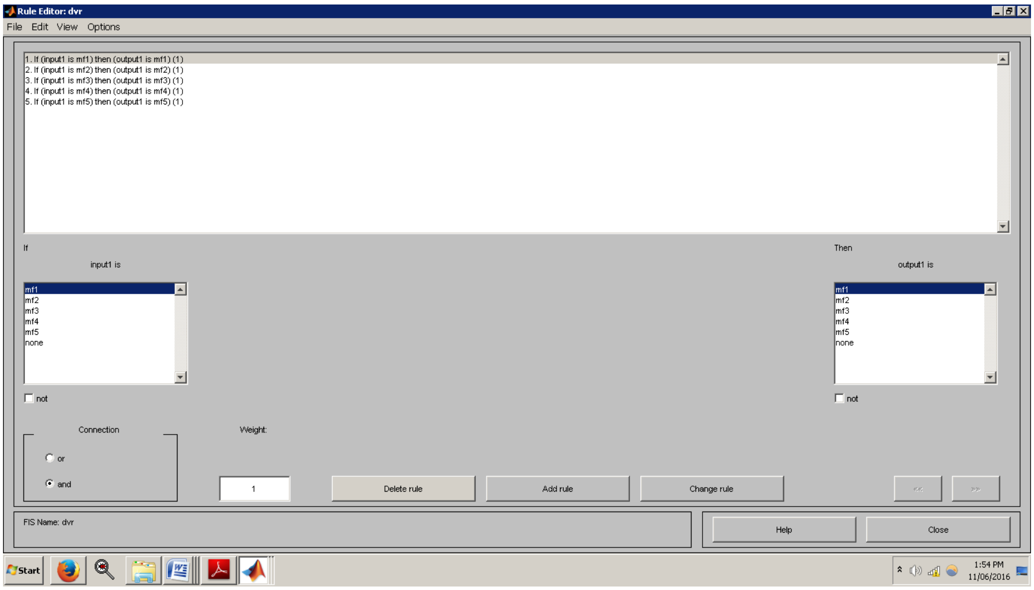

Figure 9: Fuzzy Rule Base

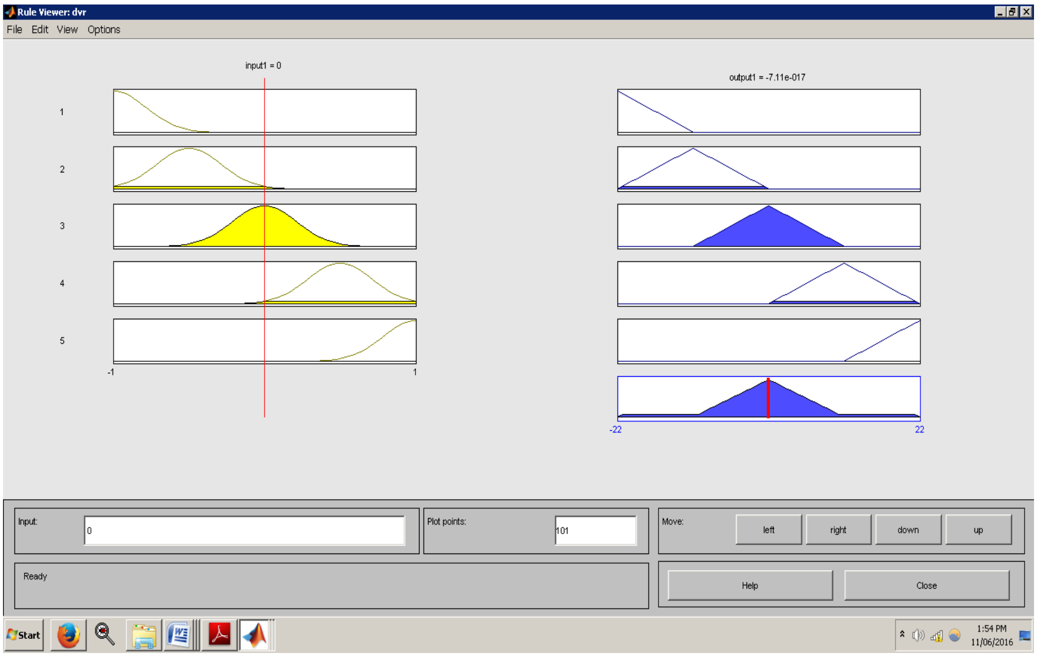

Figure 10: Fuzzy Rule Viewer

III. SIMULATION RESULTS

In order to simulate the proposed fuzzy based DVR controller, first of all a simulink model of the DVR (Dynamic Voltage Restorer) is designed. Which is shown in the figure given below. In this simulation, we have taken three phase AC voltage source with 230 v, 50 Hz specification.

To validate the proposed technique for implementation of SMES based DVR a MATLAB simulation is carried out. A MATLAB simulation is carried out in following steps for analysis purpose. The first simulation was done without DVR and a three phase fault is applied to the system at point with fault resistance of 0.001ohm and for a time duration for 0.2-0.7 secs The second simulation is carried out at the same scenario as above but Fuzzy based DVR is now introduced at the load side to compensate the voltage sag occurred due to the three phase fault applied.. The performance of Fuzzy based DVR is analysed for symmetrical 3phase fault.

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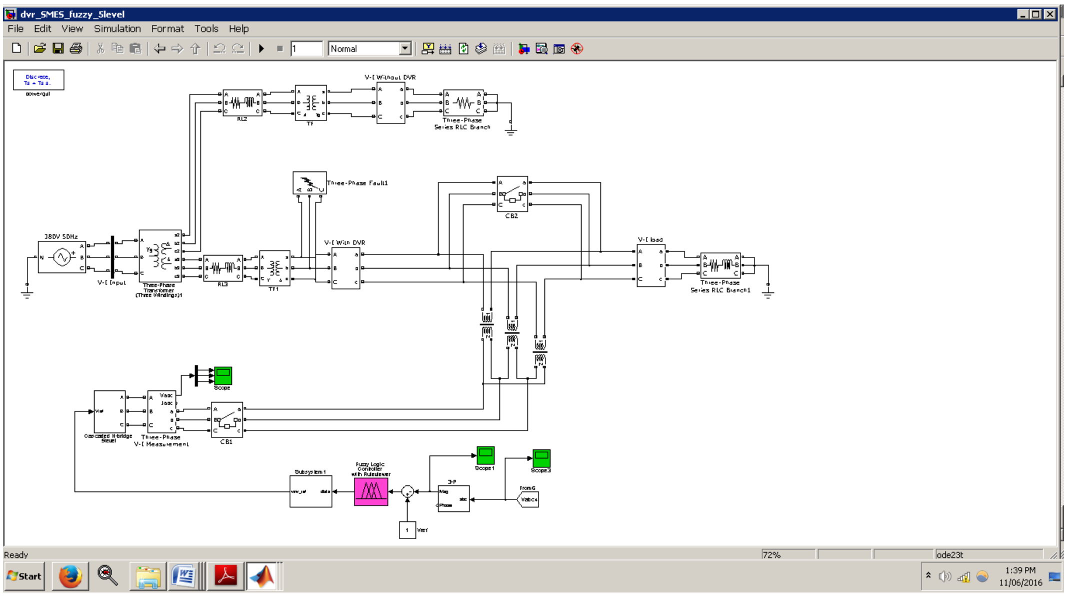

Figure 11: Proposed DVR model with Fuzzy logic controller

Step1. Generation of voltage sag due a three phase fault in the transmission line without fuzzy based DVR. Triple line to ground fault.

Step2. Design and Implementation of fuzzy set for input.

Step3. Design and Implementation of Fuzzy set for output.

Step4. Design and implementation of membership function for input as well as the Output.

Step5. Design and Implementation of Fuzzy inference system.

Step6. Design and Implementation of 5-level inverter in simulink as described in the last section.

Step7. Design and Implementation of Controller circuitry in simulink as described in the previous section.

Step8. Setting up a complete simulink model.

Step9. Creating a three phase fault in a setup without DVR, with the help of three phase fault model in Simulink.

Step10. Compensation of voltage sag by proposed fuzzy based DVR

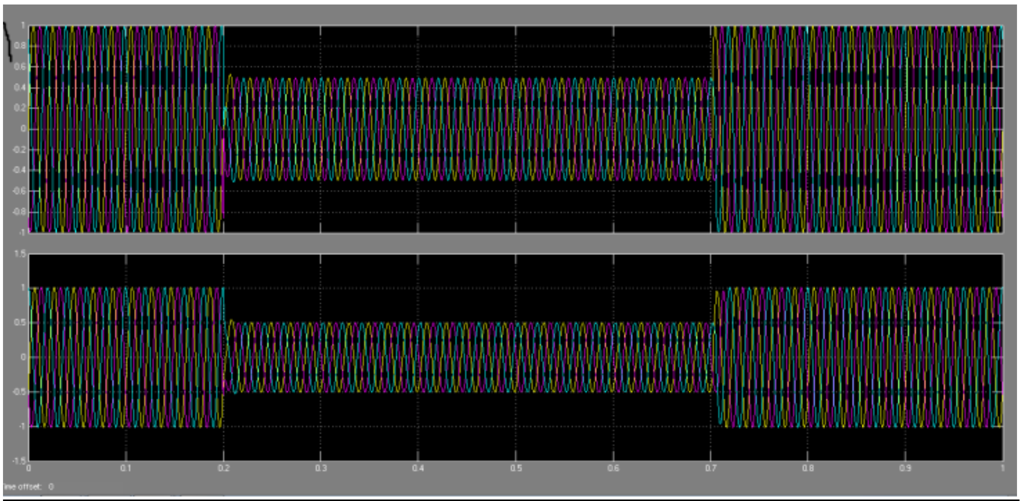

Figure 11.a: Simulation of three phase load voltage (above) & current (below) without DVR with three Phase fault

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Fig 11 represents the compensation without DVR with simulated three phase fault. Figure 5.2 (above) represent the voltage sag created during the transition time 0.2-0.7 seconds while figure 5.2 (below) represent the current sag during the transition time 0.2-0.7 seconds. This whole setup is created without introducing the DVR. Voltage and current profile for the setup after introducing the fuzzy based DVR is shown in the figure 12.

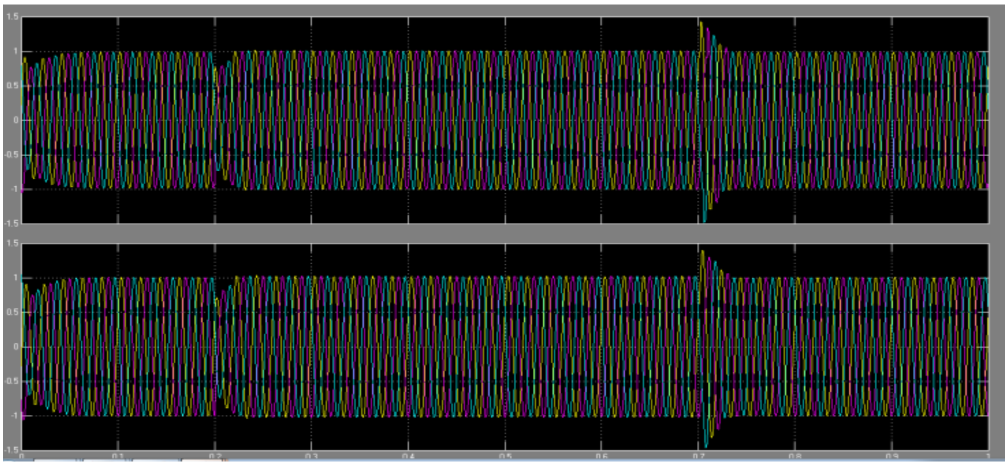

Figure 12: Load Voltage (above) and current (below) With Compensation using DVR with three phase fault.

Here transition time of 0.2-0.7 seconds of fault occurrence is taken with fault resistance of 0.001 ohm is taken. On occurrence of 3 phase fault the voltage profile of the system reduced from +1 pu to-1 pu then to 0.5 pu to -0.5 pu .

IV. CONCLUSION

This paper present the Fuzzy logic controller based Dynamic voltage Restorer (DVR) for mitigating the sag and swell in line voltage. In this model, Fuzzy logic controller is used for generating the control signal to the voltage source converter. 5-level inverter is used in this model for compensating voltage generation. Results obtained through the simulation model exhibit that the proposed system of DVR using fuzzy logic controller is able to mitigate the voltage sag and swell under balanced and un-balanced load condition.

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