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Modelling & Designing of FLC Based DVR with 5-Level Inverter for Voltage Compensation

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ABSTRACT: This paper describe the power quality trouble includes a wide range of phenomena. Voltage sag or swell, flicker, harmonics distortion, impulse transients and interruptions are a major few. These disturbances are responsible for problems ranging from malfunctions or errors to plant shut down and loss of manufacturing capability. In order to mitigate the simulated voltage sags and swells in the test system of each compensation technique, also to compensate voltage sags in useful application, a discrete PWM-based control scheme is implemented, with reference to fuzzy logic controller based DVR is used to mitigate voltage sag problem. [7][8].Fuzzy based DVR can provide the most commercial solution to mitigation voltage sag & swell by injecting voltage as well as power with the help of 5-level inverter into the system.[8][9][10].To validate the proposed technique for implementation of DVR with 5-level inverter a MATLAB simulation is carried out.

KEYWORDS: Dynamic Voltage Restorer(DVR), Fuzzy Logic Controller (FLC), Superconducting Magnetic Energy Storage(SMES), Pulse Width Modulation (PWM), 5-level inverter, In-phase Advanced Compensation Method (IACM).

I.INTRODUCTION

In recent years power systems have been experiencing extreme changes and disorder in electric power generation, Transmission, distribution, and end-user facilities. Power quality is one of the major important topics that electrical engineering have been noticed in recent years. . The voltage waves are disturbed from ideal waveform due to occurrence of instability like voltage sag, voltage swell, interruptions, flicker fluctuations etc. and also due to the use of non-linear loads. Power quality problems, such as voltage sag which occur due to a fault or a pulsed load, can cause interruption on critical load. [1][3].

DVR installed on a very sensitive load, restores the line voltage to its supposed value within the response time of a few milliseconds thus avoiding any power disturbance to the load. In this, 5 level inverter is used to produce the injection voltage during fault time which will then balance the system. Modern Pulse-Width Modulated (PWM) inverters are also able to generate the exact high quality voltage waveforms form the power electronic heart of the new Custom Power devices. Because the performance of the overall control system mostly depends on the quality of the applied control policy, a high performance - controller with fast quick response and excellent steady state characteristics is required [2].

SMES is very valuable for improving energetic performance of power system due to its large energy storage capacity, fast response and negligible losses. Superconductivity is a occurrence in which when the temperature goes less than a certain critical temperature of some material, the property of zero resistance occurs in the material. Due to the fast

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response of superconducting energy storage system, it may improve the stability of system frequency. [4][5][9][10][11].

II.RESEARCH METHOD

2.1 Basics of DVR

Figure 1 shows the Schematic representation of DVR with all blocks consists of Voltage source converter , a capacitor and storage unit Superconducting magnetic energy storage system which is used here as a basic configuration of DVR and has been taken from reference paper[4][6][20][14] . Series transformer is basically three single phase transformers which could be connected to distribution line star/open winding or delta/open winding. A voltage source converter is used for temporarily replacing the supply voltage or for producing a part of the supply voltage which is missing in this. The most popular three phase inverter topology is a two level inverter topology. [15][16].

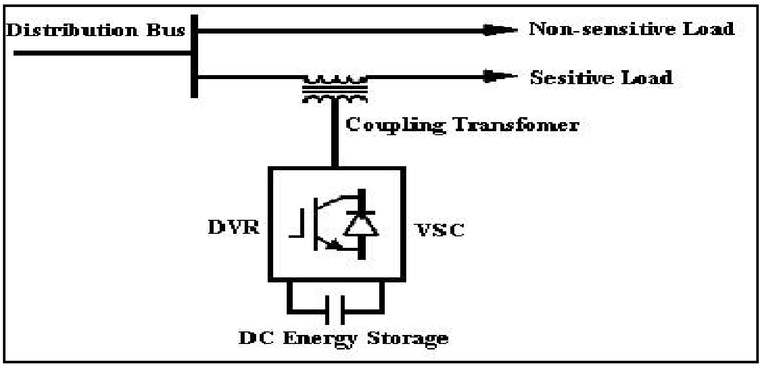

Figure 1. Schematic representation of a DVR

2.1.1 Compensation Techniques of DVR

The concept of techniques of compensation in DVR can be divided into two different categories which are as follows:

- Reactive power compensation
- Active and reactive power compensation

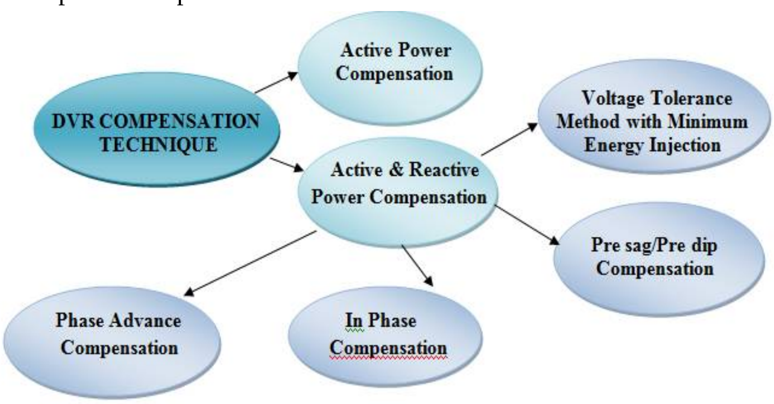

Figure 2. Compensation Techniques of DVR

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2.1.2 Compensation Technique Used in Project

In-phase Advanced compensation method: In this method, the real power spent by the DVR is decreased by minimizing the power angle between the sag voltage and load current. In case of pre-sag and in-phase compensation method the active power is injected into the system during disturbances. [14][15]The minimization of injected energy is achieved by making the active power component zero by having the injection voltage phasor perpendicular to the load current phasor.[17][18][20][5] In this method, the values of load current and voltage are fixed in the system. So we can change only the phase of the sag voltage. IPAC method uses only reactive power and unfortunately, not al1 the sags can be mitigated without real power, as a consequence, this method is only suitable for a limited range of sags. [5]

2.1.3 Control Method of DVR

The performance of the DVR depends upon the quality of applied control theory. Therefore, control techniques of DVR are important topic in this paper.

PI Controller: The PI parameters are determinable from simulink response optimization simulation program. The constraints or restrictions on the behavior of the response signals and the tuned parameters are set within the signal constraint blocks by keeping the above constraint in mind.
The modulated angle is then applied to the PWM generators which in phase A. The angles for phases B and C are shifted by 120^{o} and 240^{o}. In this PI controller, only the magnitude of the voltage is taken as a feedback parameter in the control scheme of this paper. [4][5]

Proportional-Integral (PI) control is the most commonly and widely used control algorithm in industry and has been universally accepted and used in industrial control. It is most popularly used because of its simple structure and robust performance in a wide range of operating condition. As PI control method is used to control transient state response of the system more efficiently than the any other one. The PI parameters are determinable easily from simulink response optimization simulation. One of the advantages of a proportional plus integral controller is that its integral term makes the steady-state error zero for a step input. PI controller input is an actuating signal which is basically the difference between the V_{ref} and $V_{in.}$

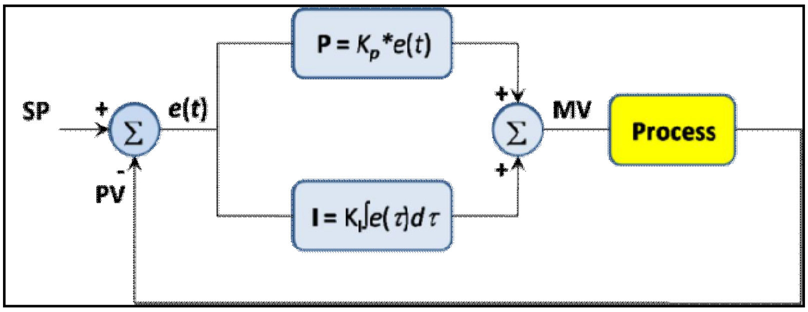

Figure 3 Proportional Integral controller

Figure 3 represents proportional integral controller with both proportional & integral controller part and it is taken from reference paper [20]. The input of the PI controller is an actuating signal which is basically the difference of the V_{ref} and V_{in}. Output of the controller block is in term of an angle δ, which produces additional phase-lag/lead in the three phase voltage [12][13][19]

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2.2 Five-Level Inverter Designing

Figure 4 shows the five-level cascade inverter used in the proposed system. As shown in figure 4, one phase of the cascade inverter consists of (5-1)/2 identity 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.

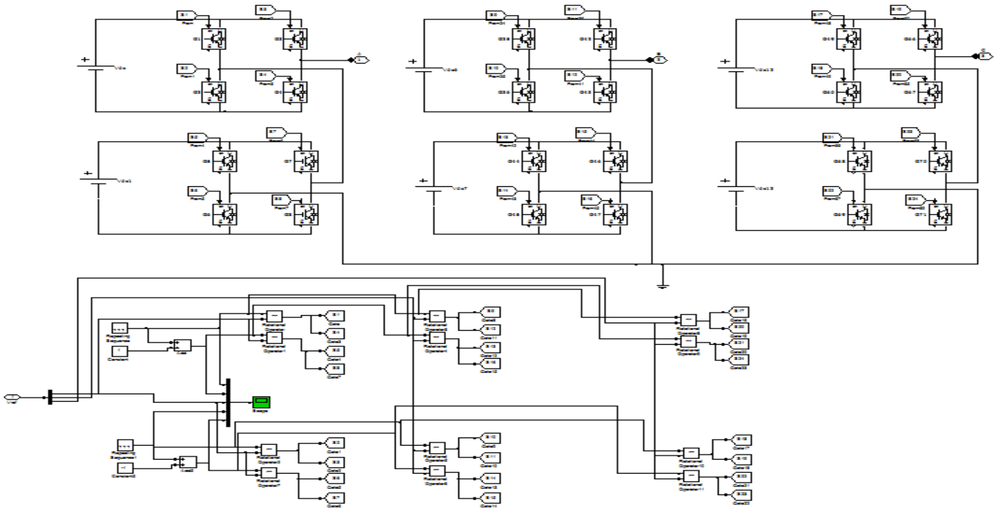

Figure 4.Five level Inverter

This inverter can:

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

III. SYSTEM MODEL AND ASSUMPTIONS

3.1 Proposed FLC Based DVR with 5 Level Inverter

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 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.

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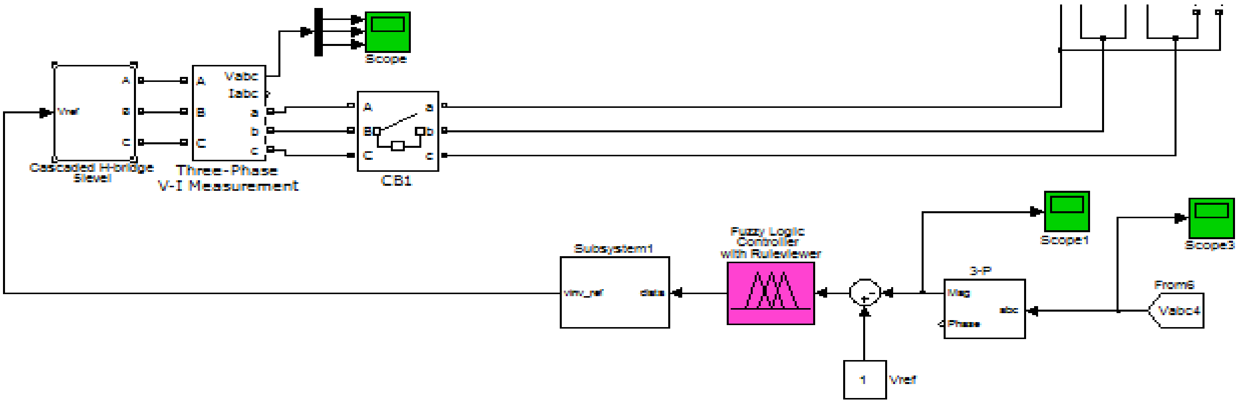

Figure 5. Fuzzy logic controller section of the proposed FLC based DVR with 5 level inverter

3.2 Simulation Model

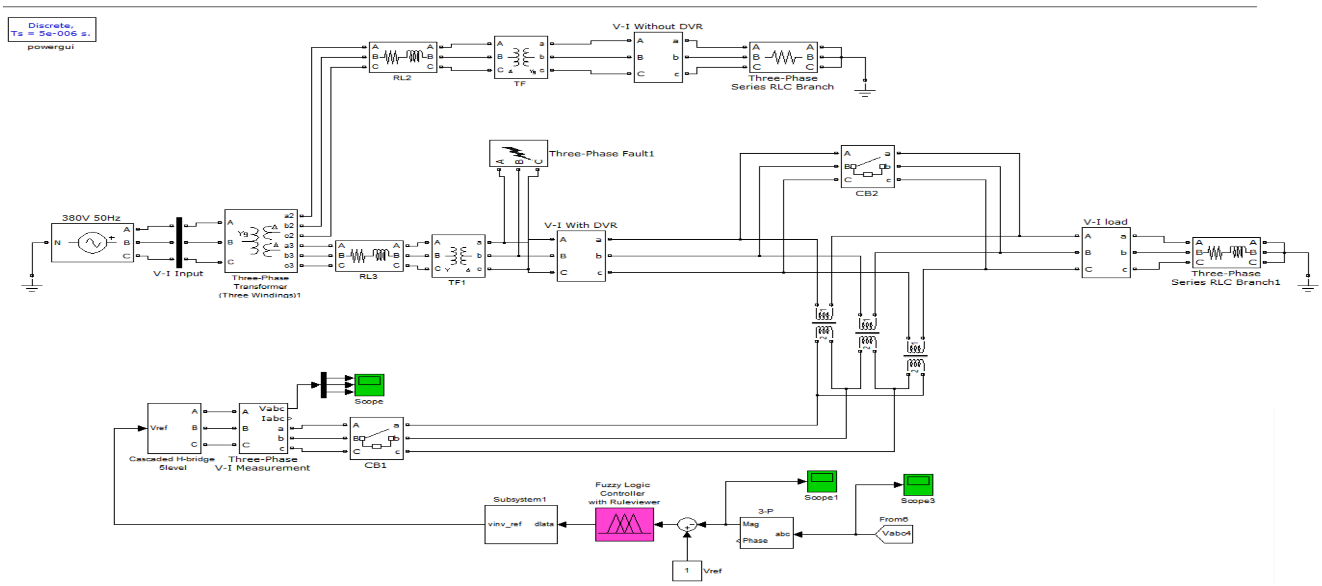

Figure 6.Proposed FLC based DVR model with 5-level Inverter

3.3 Rule Base Used

TABLE 1

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

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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

3.4 Simulation Parameters of DVR

Different parameter for proposed DVR simulation is tabulated in the table 2

TABLE 2 Simulation Parameter

S. No.	System Quantity	Specification
1	Fuzzy Controller	Fuzzy rule base is given in table 4.1
2	Inverter Specification	5-level based inverter, IGBT based, Carrier frequency = 1080 Hz. continuous simulation
3	Capacitance	10 micro farad
4	System voltage	22 KV(line to line)
5	System fault-three phase fault	R=0.01ohms (for 0.2- 0.7seconds transition time) L=0.005H
6	Load	10 KW RLC Load
7	Injection Transformer	22 KV /10 KV,10 MVA
8	PI Controller	KP=0.5, Ki=50, Sample time=50 µs

IV. RESULT AND DISCUSSION

In order to simulate the proposed fuzzy based DVR controller, first of all a simulink model of the DVR (Dynamic Voltage Restorer) is designed. 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 DVR a MATLAB simulation is carried out. A MATLAB simulation is carried out in some 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 0.001 ohm and for time duration for 0.4-0.6 Sec. 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 and the voltage injected by 5 level inverter at the time of three phase fault is analysed for symmetrical 3phase fault.

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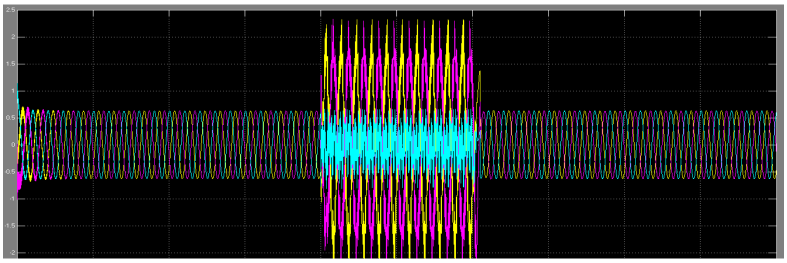

Figure 7 Voltage swell in system during three phase fault

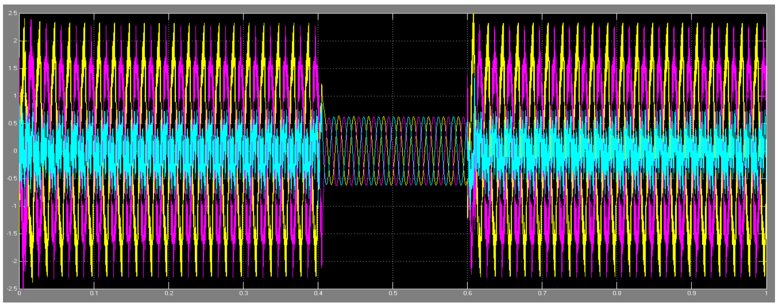

Figure 8 Voltage sag in system during three phase fault

Fig 7 & fig 8 represents the compensation without DVR with simulated three phase fault. This figure represents load sag & swell voltage in p.u. Though the actual supply line voltage is 22KV. From this figure it is clear that the sag in phase load voltage is created during the 0.4 second to 0.6 second and since there is no DVR in the circuit therefore this artificially generated sag & swell is not compensated which represent the actual sag & swell voltage condition in real time scenario.

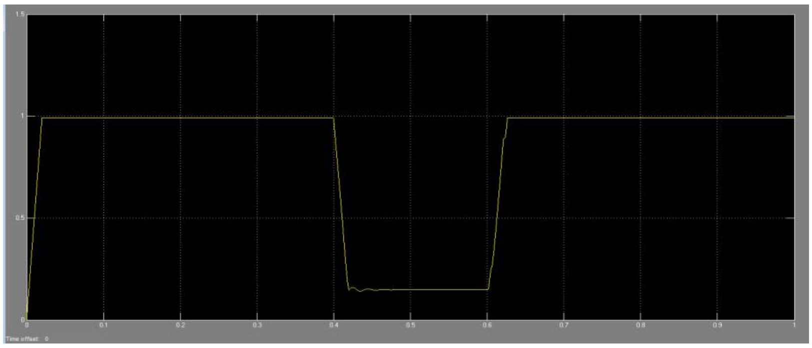

Figure 9 Voltage Sag Profile

Fig 9 showing the voltage sag profile of the system during three phase fault. The time duration of this voltage sag is taken 0.4-0.6 sec.

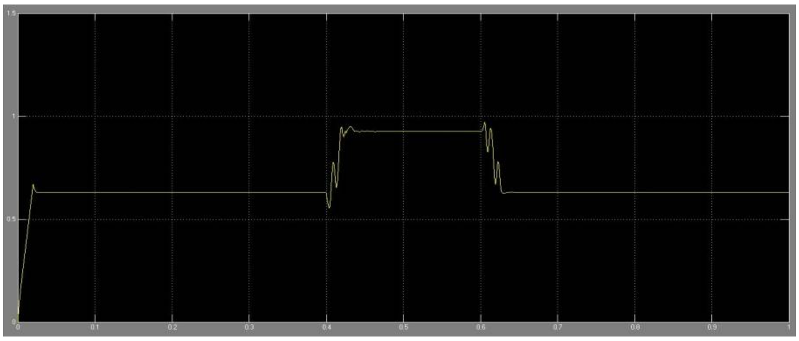

Figure 10 Voltage Swell Profile

Fig 10 showing the voltage swelling profile of the system during three phase fault. The time of duration for this profile has been taken 0.4-0.6 sec.

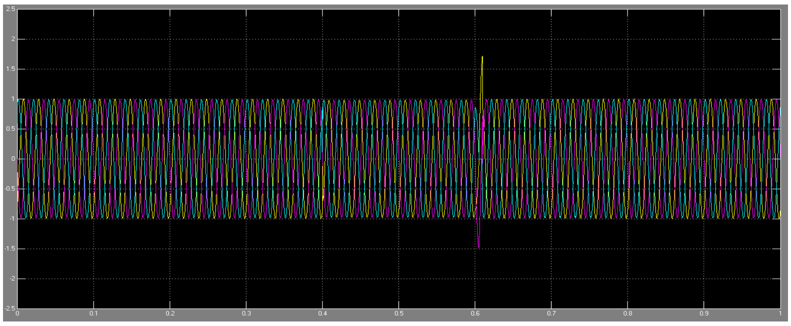

Figure 11 Load Voltage with Compensation using FLC based DVR with three phase fault.

Figure 11 represent the Load voltage after introducing the DVR is the main circuit. It is also in p.u. and showing that after introducing FLC based DVR in the system sag and swell voltage is mitigated successfully.

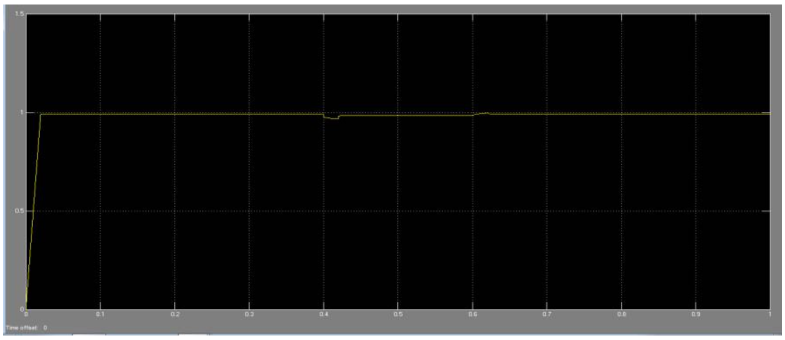

Figure 12 Sag & Swell Voltage Profile after applying DVR

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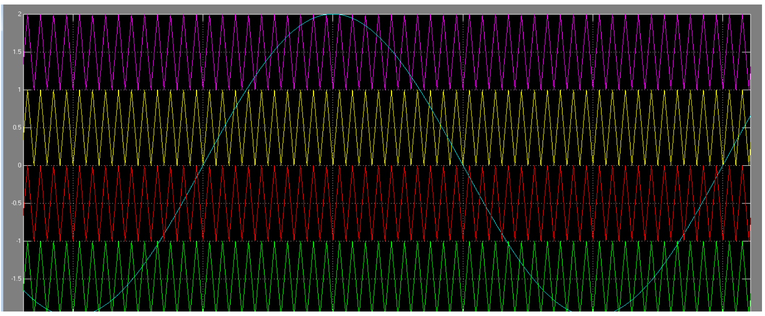

Figure 13 Output Pulse of the 5-level Inverter

Figure 12 represent the sag & swell voltage profile after applying the FLC based DVR in the system and it is clear from this figure that the compensation of the sag voltage is performed successfully by the FLC based DVR. Figure 13 shows the output pulse waveform of the 5-level inverter.

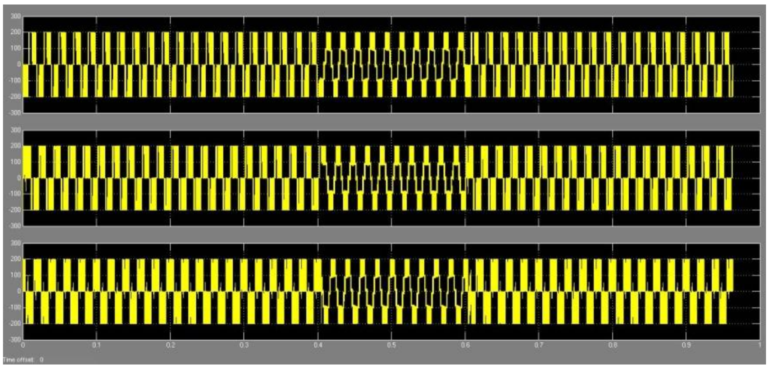

Figure 14 Output of multilevel inverter during voltage sag

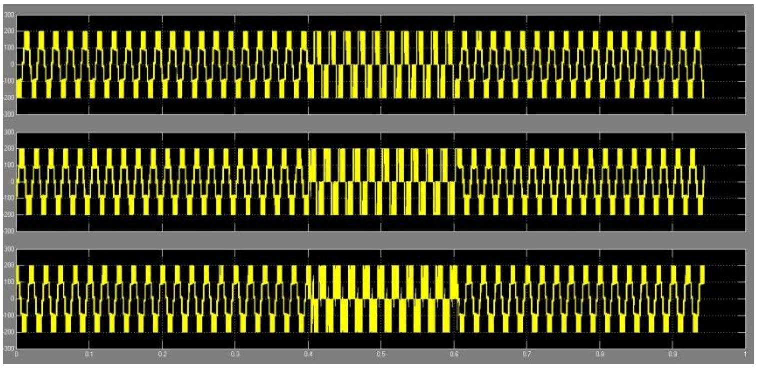

Figure 15 Output of multilevel inverter during voltage swell

Fig 14 & Fig 15 showing the output voltage of cascaded multilevel inverter which is applying to load for balancing the system voltage. The time duration of this is taken 0.4-0.6 second.

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V.CONCLUSION

This work presents a modelling and simulation of the DVR controller by incorporating the fuzzy logic controller in traditional method. Fuzzy logic being the most prominent concept in control theory has been used in this work to mitigate the voltage sag problem.MATLAB has been used in this work for modelling and simulation of the DVR. Simulation result shows that the proposed fuzzy logic controller based DVR is able to compensate the sag quickly and at the same time provide very good voltage regulation. Proposed DVR model is able to handle all types of balanced and unbalanced fault without any problem. Proposed DVR is able to inject sufficient amount of voltage to the main line in case of occurrence of the sag.

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