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SIMULATION AND ANALYSIS OF MULTILEVEL INVERTER FOR DYNAMIC VOLTAGE RESTORER FOR VOLTAGE SAG AND SWELL MITIGATION

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ABSTRACT: Aim of this paper is to represents role of DVR is to compensate the load current and voltage is investigated during the fault condition. The paper proposes enhancement of power quality using DVR using multi level inverter design during voltage sag and swell conditions. Voltage dips and swells are the most common types of power-quality (PQ) disturbances. They represent a major concern for the industry because they lead to important economical losses and/or distorted quality of industrial products. Voltage dips being the most frequent PQ disturbance, the main research interests are focused on their analysis. The time duration where the dip occurs is determined by segmentation algorithms applied to the three phase voltages, Voltage sags and swells are characterized by their duration, magnitude and phase angle shift. The last two parameters determine their phase relation, which is also called dip/swell type or signature. A PI Controller based control strategy has been used for voltage sag mitigation and power quality improvement in this paper.

I. INTRODUCTION

Voltage dips and swells are the most common types of power-quality (PQ) disturbances. The problem of poor power quality like voltage sag for sensitive loads can be better dealt or solved by power electronics based Dynamic Voltage Restorer. Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute. Voltage swell, on the other hand, is defined as a swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min. typical magnitudes are between 1.1 and 1.8 pu. The DVR is connected in series with the sensitive load or distribution feeder and is capable of injecting real and reactive power.

The combination of the custom power devices DVR with PI controller is used for the power quality improvement in the distribution system. Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE1100 defines power quality as "the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment."

Categories		Typical Duration	Typical Magnitude
2.1 Instantaneous			
	Sag	0.5-30 cycles	0.1-0.9 pu
	Swell	0.5-30 cycles	1.1-1.8 pu
2.2 Momentary	Sag	0.5-3 seconds	0.1-0.9 pu
	Swell	0.5-3 seconds	1.1-1.8 pu
2.3 Temporary	Sag	3 sec-1 minute	0.1-0.9 pu
	Swell	3 sec-1 minute	1.1-1.8 pu

Table: 1 Classification of Voltage Sags and Swells according to IEEE.

A. Basic configuration of DVR

One of those devices most recognizable and good in performance is the Dynamic Voltage Restorer, which is the most efficient and effective modern custom power device used in power distribution networks. The general arrangement of the DVR is composition of Injection/ Booster transformer, Harmonic filter, Storage Devices, Voltage Source Converter (VSC), and DC charging circuit, Control and Protection system.

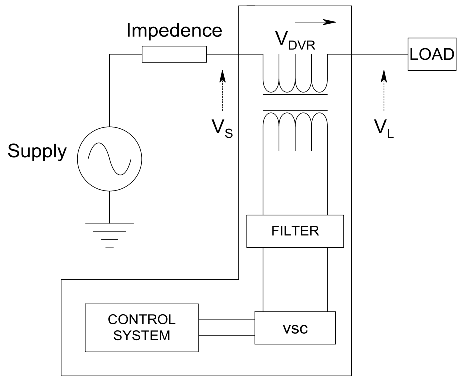

Fig. 1 Schematic diagram of DVR

The main function of a DVR is the protection of sensitive loads from voltage sags/swells coming from the network. A DVR is a solid state power electronics switching device consisting of whichever GTO or IGBT, a capacitor depository as a power storage device and inoculation transformer. It is linked in series between a distribution and a load

II. CONTROL STRATEGY

A. 3-Phase sequence analyzer

The Three-Phase Sequence Analyzer block outputs the magnitude and phase of the positive- (denoted by the index 1), negative- (index 2), and zero-sequence (index 0) components of a set of three balanced or unbalanced signals. The signals can contain harmonics or not. The three sequence components of a three-phase signal (voltages V1 V2 V0 or currents I1 I2 I0) are computed as follows:

$V_1 = (V_a + aV_b + a^2V_c)/3$

$V_2 = (V_a + a^2V_b + aV_c)/3$

$V_0 = (V_a + V_b + V_c)/3$ where V_a, V_b, V_c = three voltage phasors at specified frequency

$a = e^{j2\pi}/3 = 1\angle 120°$ complex operator

III. PI CONTROLLER

PI controller is a closed loop controller, which drives the plant to be controlled with a weighted sum of the error and the integral of that value. An advantage of a proportional plus integral controller is that the integral term in a PI controller causes the steady state error to be zero for a step input. The aim of the control scheme is to maintain a constant voltage magnitude at the sensitive load point, under the system disturbance. The control system only measures the RMS voltage at load point; for example, no reactive power measurement is required in the DVR controller scheme implemented in MATLAB/SIMULINK.

Fig. 4.5 shows that there is an error signal applies to proportional gain (Kp) and integral gain (Ki). Proportional gain (Kp) is applied to zero order hold, the Zero-Order hold block samples and holds its input for the specified samples period.

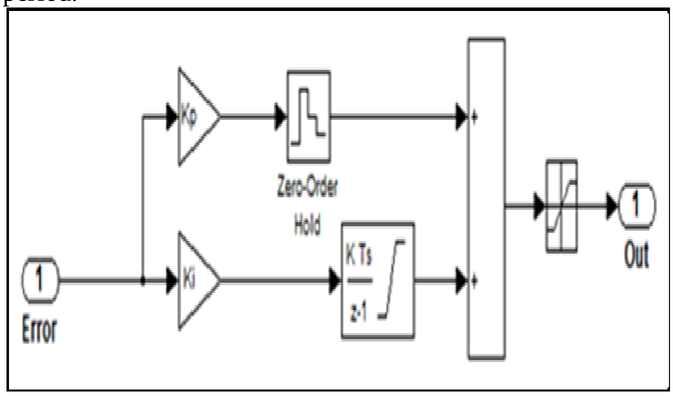

Fig. 4.5 Discrete PID Controller

A. Control Algorithm

The basic functions of a controller in a DVR are the detection of voltage sag/swell events in the system; computation of the correcting voltage, generation of trigger pulses to the sinusoidal PWM based DC-AC inverter, correction of any anomalies in the series voltage injection and termination of the trigger pulses when the event has passed.

The dqo transformation or Park's transformation is used to control of DVR.

Vd =2/3(Va*sinwt + Vb*sin(wt-2pi/3) + Vc*sin\(wt+2pi/3)

Vq =2/3(Va*coswt + Vb*cos(wt-2pi/3) + Vc*cos\(wt+2pi/3)

V0 = 1/3(Va + Vb + Vc)

IV. MATLAB MODEL FOR SAG CONDITION

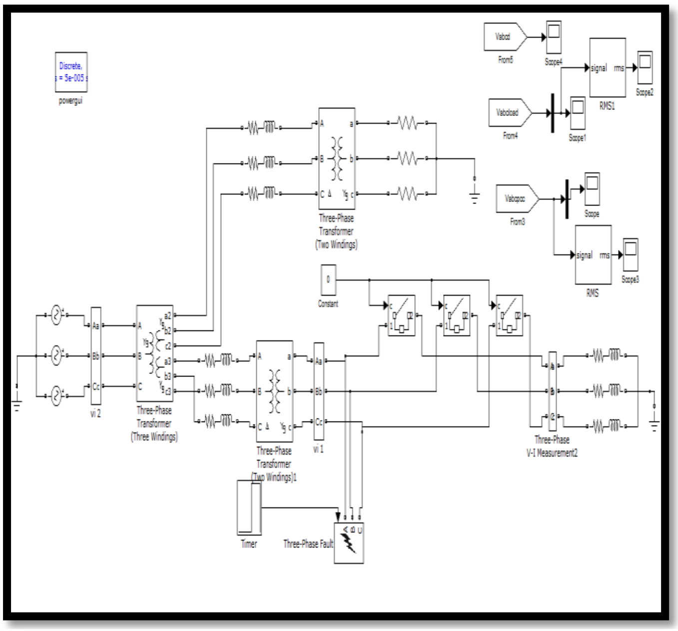

Fig 2- MATLAB model of system without DVR during SAG condition

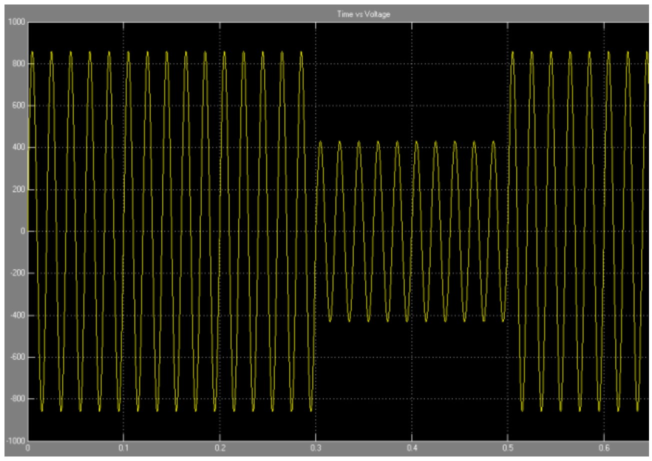

Fig 3- Waveform for without DVR during SAG condition

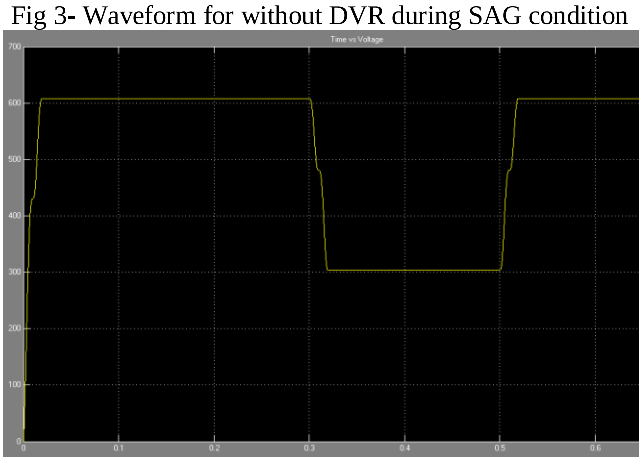

Fig 4- Waveform for RMS Value without DVR during SAG condition

A. MATLAB model of MV inverter for Sag Mitigation

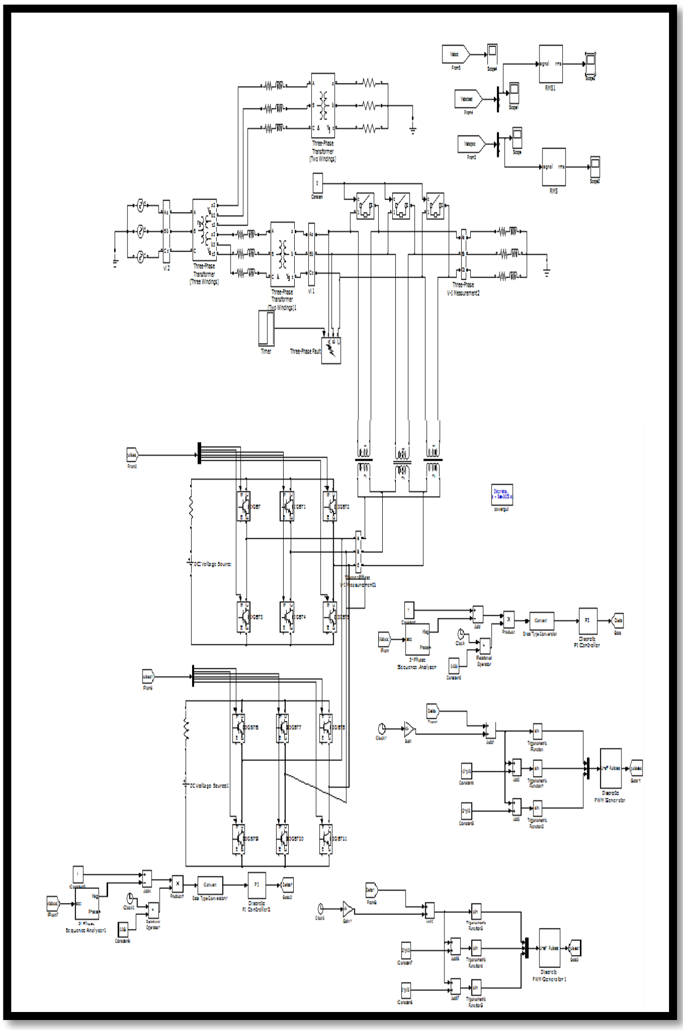

Fig 5- MATLAB model of multilevel inverter system with DVR for SAG Mitigation

Now the DVR Control Strategy is also apply with the multi level inverter for voltage sag condition mitigation in the system. The Multilevel inverter based topology of DVR control Strategy is shown in the fig 5

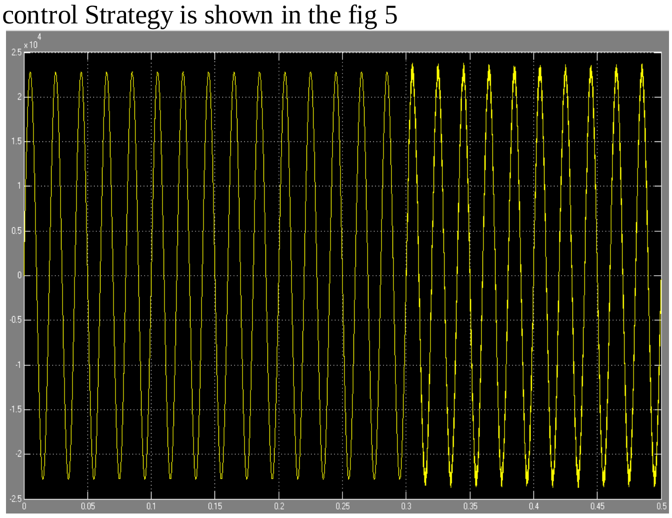

Fig 6- Waveform for Voltage Mitigation with DVR for Multilevel Inverter

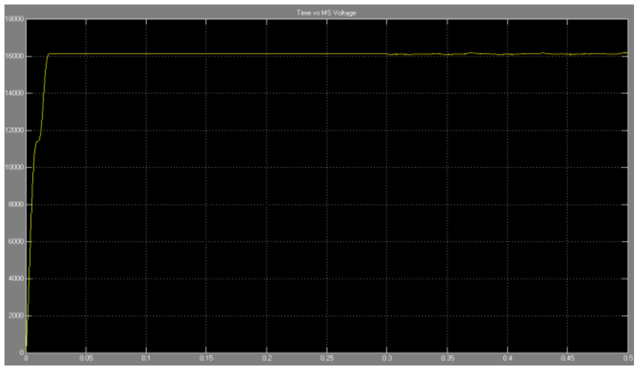

Fig 7- Waveform for RMS Value of Voltage with DVR for Multilevel Inverter

Voltage Swell Mitigation Using PI Controller

The voltage swell mitigation using PI controller is easily done. The MATLAB- SIMULINK model of voltage swell mitigation using PI Control Strategy is shown in fig below:-

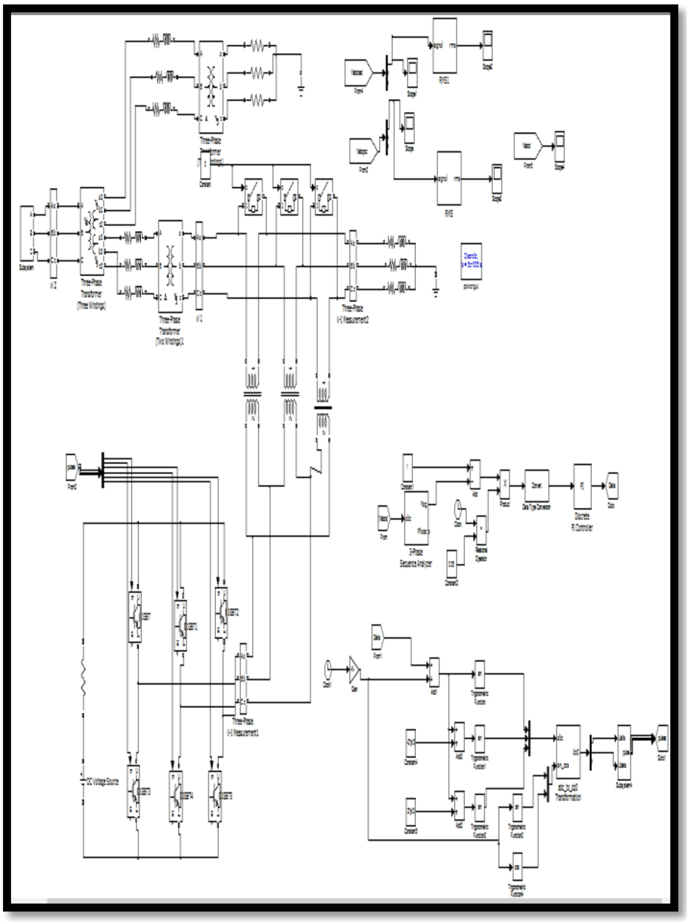

Fig 8- Voltage Swell mitigation Using PI Controller

The PI controller is provided for comparison and relation development between the reference value and running condition value. The PI Controller calculates the value of power angle which is given to trigonometric function calculation of sine and cosine angle value after that it is given for dqo-transformation which compare with the reference value or carrier signal for generating the pulses for IGBT Devices for mitigation of voltage sag condition. The injecting transformers are provided for the distribution line control for compensation using DVR. The Subsystems for voltage swell condition in the system without DVR Control Strategy is shown in the fig below with their simulation results:-

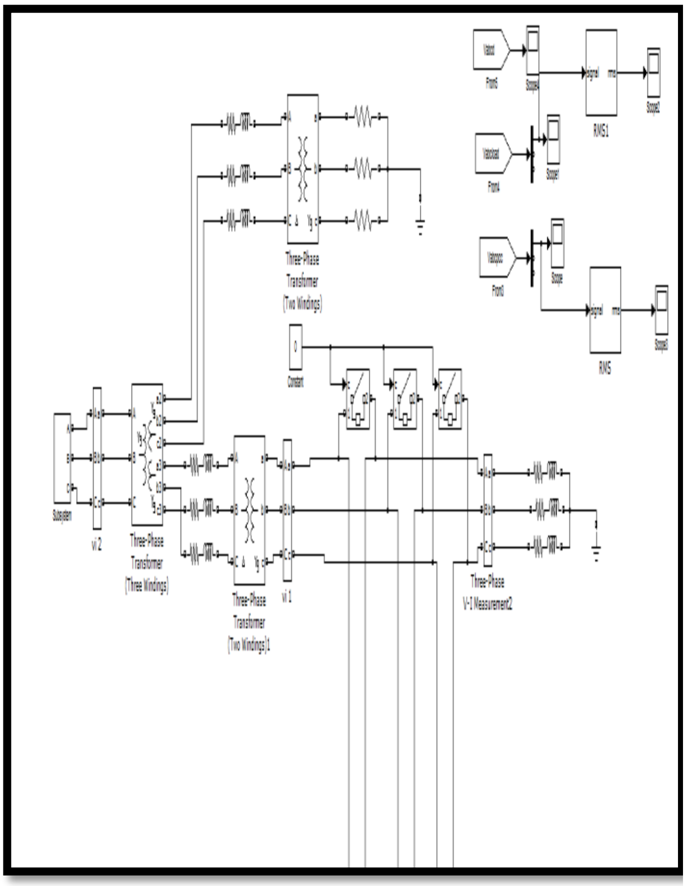

Fig. 9- Voltage Swell condition without DVR Control Strategy

The Simulation of this model shows that voltage Swell condition occurs at the point of common coupling. The simulation results of these conditions are shown in the fig below:-

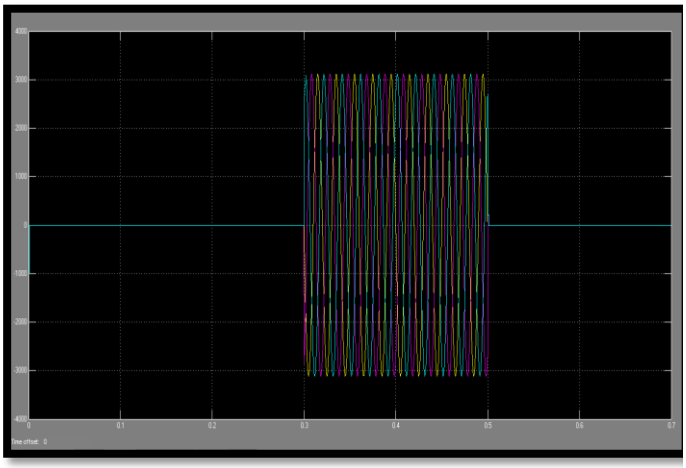

Fig.10- Voltage SWELL Condition at input Side

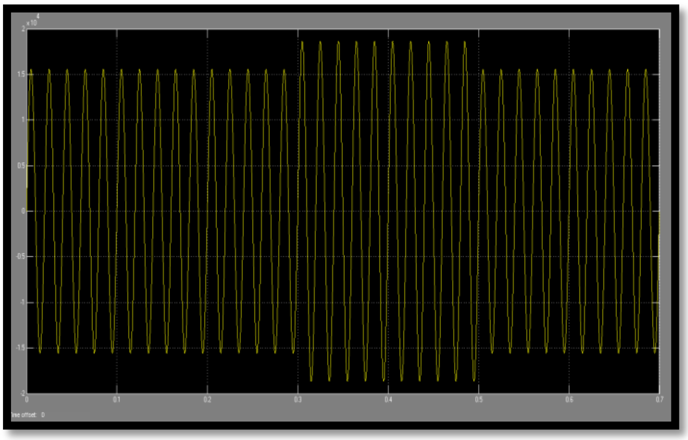

Fig.11- Voltage Swell condition at PCC (Point of Common Coupling) point

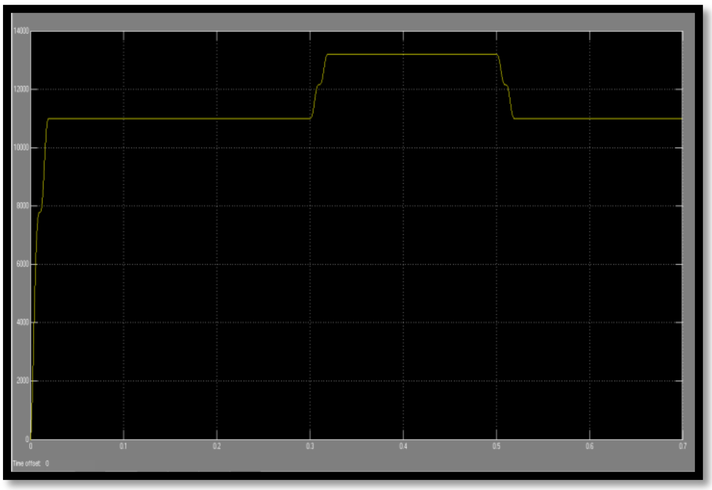

Fig 12-R.M.S value of Voltage Swell condition at point of common coupling

Now the PI control Strategy is apply in this system for voltage swell mitigation as discussed above. The Model of this system is shown in the fig below:-

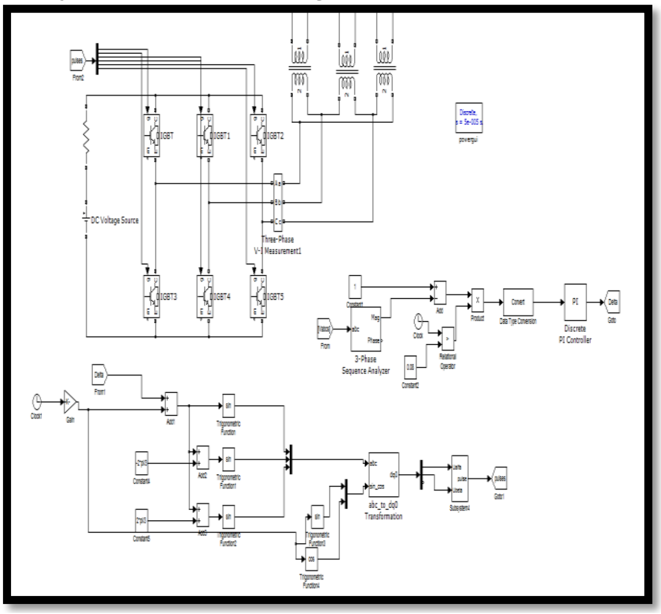

Fig 13- DVR Control strategy for Voltage Swell mitigation

After applying the PI control Strategy the voltage swell condition is mitigated as shown in fig below:-

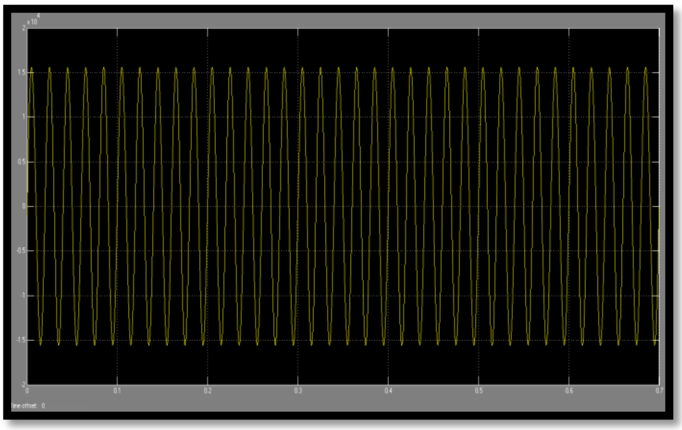

Fig 14- Voltage Swell mitigated and pure sinusoidal output waveform

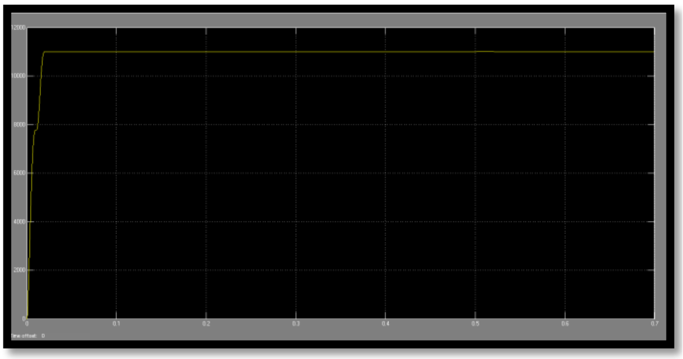

Fig 15- R.M.S value of Load side mitigated voltage sag condition waveform

V. CONCLUSION

This paper has proposed and modeled multilevel inverter for Dynamic Voltage Restorer (DVR) Based on PI control strategy for voltage sag mitigation. The steps of developing the model of the DVR have been explained in details. The ability of the DVR to maintain the load voltage under different voltage sags and swells has been verified using time domain simulations. The model of the DVR with the PI control can be further enhanced by having fixed frequency hysteresis voltage controller. In addition, a faster sag/swell detection technique can be also developed and modeled to improve the response of the DVR. From the simulation results we can say that we can easily mitigate the sag and swell condition using DVR.

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