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Modeling of Dynamic Voltage Restorer

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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's. One of the major problems dealt here is the power sag. Sensitive industrial loads and utility distribution networks all suffer from various types of outages and service interruptions which may result in a significant financial 1oss. To improve the power quality, custom power devices are used. The device considered in this work is DVR. This thesis presents modeling, analysis and simulation of a Dynamic Voltage Restorer (DVR) test systems using MATLAB. In this work, PI controller and Discrete PWM pulse generator are used for the control purpose. Here, different fault conditions are considered for linear as well as induction motor load. The role of DVR to compensate load voltage is investigated during the different fault conditions like voltage sag, single phase to ground, double phase to ground faults. In addition, the application of DVR to compensate the problem of starting voltage dip for induction motor is also investigated.

Keywords : Dynamic Voltage Restorer, Voltage Sags, Powerquality, Injection Methods.

I. INTRODUCTION

Nowadays, modern industrial devices are mostly based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. The common method for this is to install mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching may be on a schedule, via signals from a supervisory control and data acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage is that, high speed transients cannot be compensated. Some sags are not corrected within the limited time frame of mechanical switching devices. Transformer taps may be used, but tap changing under load is costly. Another power electronic solution to the voltage regulation is the use of a dynamic voltage restorer (DVR). DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

II. EXPERT GUIDELINES

Sabin presents voltage deviations, commonly in the form of voltage sags, can cause severe process disruptions and result in substantial production loss. Several recent surveys attribute that 92% of the all disturbances in electrical power distribution systems are due to voltage sags [2].

Gosh and Ledwich been proposed the Dynamic Voltage Restorer (DVR) to protect sensitive loads from such voltage sags. The DVR is connected in series with the sensitive load or distribution feeder and is capable of injecting real and reactive power demanded by the load during voltage sag compensation. The output of the DVR inverter is usually provided with an output LC filter to attenuate the harmonic contents appearing in injected voltage. The filter parameters are designedaccording to certain designed aspects such as depth of the sag to be mitigated and the load voltage [3].

Carl N. M. Ho, Henery, and S. H. Chaung proposed a method; when a disturbance occurs (abnormal condition) and supply voltage deviates from nominal value, DVR supplies voltage for compensation of sag and is said to be in transient state. The DVR is connected in series between the load and the supply voltage [4].

KasuniPerera, Daniel Salomon son and Arulampaiam presented a DVR which basically supplies the voltage difference (difference between the pre sag and sag voltage) to transmission line and maintains the pre sag values condition in the load sides [5].

Yun Wei Li. Poh Chiang Loh proposed that a DVR is used proposed in low and medium voltage distribution network to protect sensitive load from sudden voltage dips/sag [6].

V. K. Ramachandramurthy et al. present a pulse width modulated inverter that is used to vary the amplitude and the phase angle of the injected voltages, thus allowing the control of both real and reactive power exchange between the distribution system and the load [7].

D. Mahind proposed a method for proper voltage sag compensation, it is necessary to derive suitable and fast control scheme for inverter switching. The general requirement of a control scheme is to obtain an AC waveform with minimum total harmonic distortion (THD) and best dynamic response against supply and load disturbance when the DVR is operated for voltage sag compensation [8].

III. DYNAMIC VOLTAGE RESTORER

Among the power quality problems (sags, swells, harmonics etc.) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of these devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. DVR is a recently proposed series connected with solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply

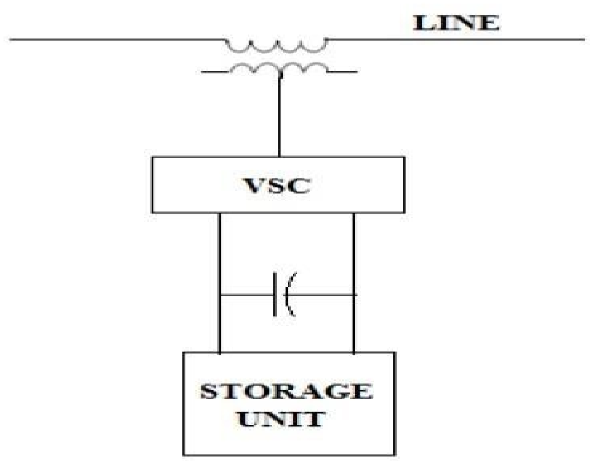

Figure.(a)- DVR [1]

and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also be added with other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations [9]. DVR consists of rectifier, energy storage device, PWM inverter, filter, and injection transformer.

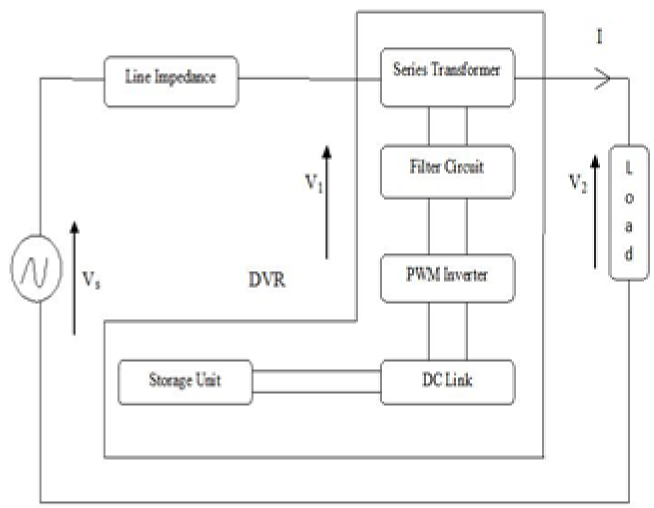

Figure.1 Block diagram of DVR

A. Rectifier

The process of converting AC supply into DC supply is known as rectification. A device which is used for rectification is known as rectifier. The AC voltage cannot be stored directly in a storage device. Hence, the rectifier circuit is used in the DVR.

B. Energy Storage Device

Energy storage device stores the converted DC voltage from the rectifier. It is very important device in the DVR. The energy storage device is DC capacity, batteries, super-capacitor, super conducting magnetic energy storage and flywheels.

C. PWM inverter

The DC supply from the storage device is passed to the PWM inverter. The PWM inverter generates the voltage with required magnitude and frequency. It converts the DC voltage into AC voltage. The PWM inverter is connected between the energy storage device and filter circuit.

D. Filter

Filter circuit is used to remove the unwanted noise signals or harmonics in the generated voltage from the PWM inverter. The LC filter is used in the DVR to improve the quality of power.

E. Injection Transformer

The injection transformer is connected with the transmission line in series. When the voltage level is decreased in the transmission line then the transformer inject the voltage with required magnitude and frequency. The supply to the transformer is given from the filter circuit.

IV. INJECTION METHODS

Voltage injection or compensation methods by means of a DVR depend upon the limiting factors such as; DVR power ratings, various conditions of load, and different types of voltage sags. Some loads are sensitive towards phase angel jump and some are sensitive towards change in magnitude and others are tolerant to these. Therefore the control strategies depend upon the type of load characteristics. There are four different methods of DVR voltage injection which are

A. Pre-sag compensation method
B. In-phase compensation method
C. In-phase advanced compensation method
D. Voltage tolerance method with minimum energy injection.

VDVR=VL + (Zth * IL)-Vth…..(1)

IL= (PL+jQL) / V……(2)

θ = (θL/ PL)…..(3)

SDVR=VDVR*IL……(4)

A. Pre-Sag/Dip Compensation

The pre-sag method tracks the supply voltage continuously and if it detects any disturbances in supply voltage it will inject the difference voltage between the sag or voltage at PCC and pre-fault condition, so that the load voltage can be restored back to the pre-fault condition. Compensation of voltage sags in the both phase angle and amplitude sensitive loads would be achieved by pre-sag compensation method as shown in Figure.2. In this method the injected active power cannot be controlled and it is determined by external conditions such as the type of faults and load conditions [10].

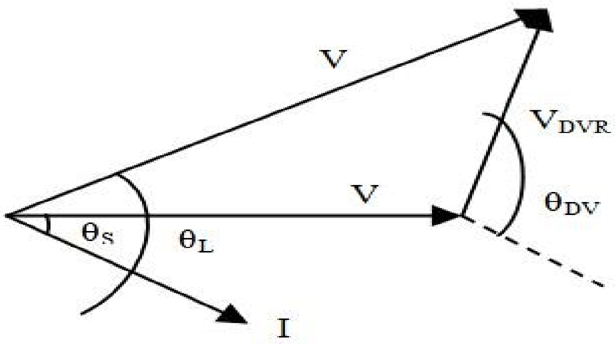

Figure .2 Pre-Sag Compensation

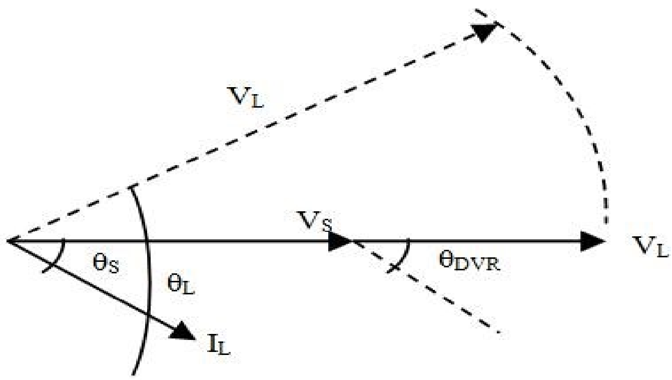

Figure.3 In-phase compensation method

B. In phase Compensation Method

This is the most straight forward method. In this method the injected voltage is in phase with the supply side voltage.

Irrespective of the load current and pre-fault voltage as shown in Figure. 3. The phase angles of the pre-sag and load voltage are different but the most important criteria for power quality that is the constant magnitude of load voltage are satisfied. One of the advantages of this method is that the amplitude of DVR injection voltage is minimum for certain voltage sag in comparison with other strategies [10].

C. In Phase Advanced Compensation

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. The active power supply is limited stored energy in the DC links and this part is one of the most expensive parts of DVR. 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. 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 as shown in Figure. 4. 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 [10].

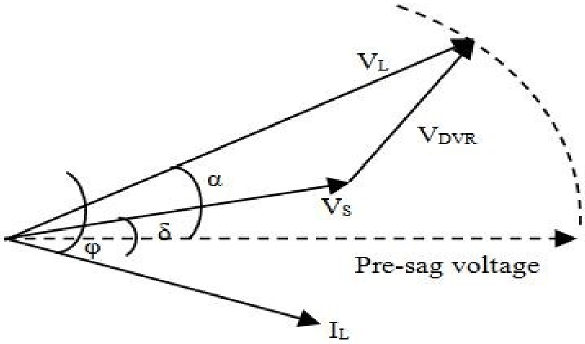

Figure. 4 In-phase advance compensation method

D. Voltage Tolerance Method with Minimum Energy Injection

A small drop in voltage and small jump in phase angle can be tolerated by the load itself. If the voltage magnitude lies between 90%-110% of nominal voltage and 5%-10% of nominal state that will not disturb the operation characteristics of loads [10]. Both magnitude and phase are the control parameter for this method which can be achieved by small energy injection as shown in Figure. 5.

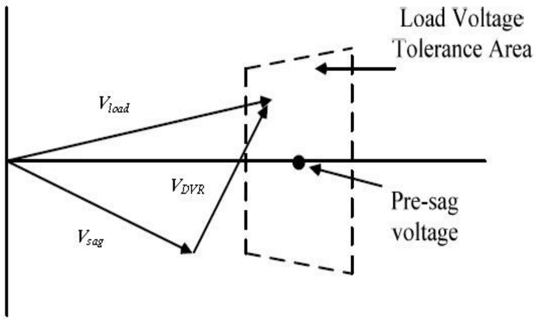

Figure.5 Voltage tolerance method with minimum energy injection

V. RESULTS AND ANALYSIS OF THE DVR TEST MODELS

In this section the various results obtained after simulation are analyzed and discussed. The test system comprises of 580V distribution network and the system has been examined under different fault conditions such as three phase fault, single line to ground fault and line to line fault.

A. Test Results

Simulation model of proposed system without fault is shown in Figure. 6. The simulation time for the model is taken as 0.5 sec. The first simulation was done without creating any fault at the network where supply is 580V with frequency 50 Hz. Figure. 6 shows the waveforms of input voltage without fault. Y- Axis shows the magnitude of voltage and X-axis shows the simulation time. Figs. 7 and 8 show the waveform of input and load voltage without fault. Hence from the input voltage 580V it is found that the magnitude of both the input and the load voltage is almost same.

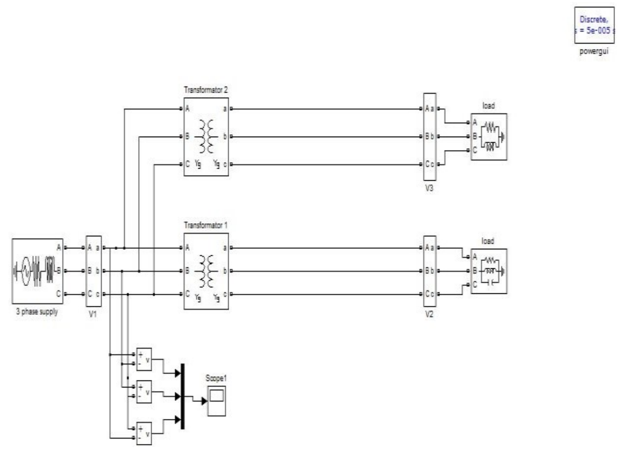

Figure. 6 Simulation model without fault

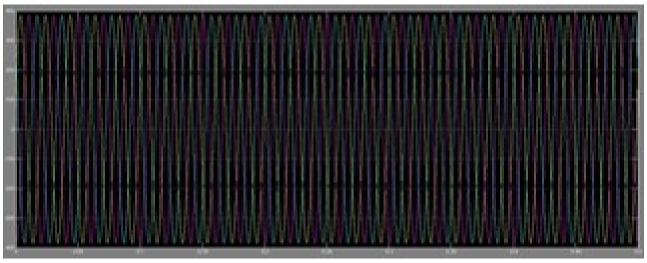

Figure. 7 Input voltage without fault

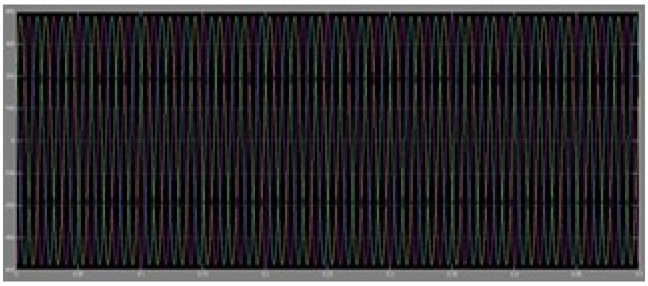

Figure.8 Load voltage without fault

The second simulation is done by applying three-phase to ground fault with fault resistance of 4.6L for a time durationof 100 ms i.e. from 0.2s to 0.3s and the ground resistance is 0.1L. Supply is 580V, with frequency 50 Hz. Simulation model of proposed system with fault is shown in Figure. 9.

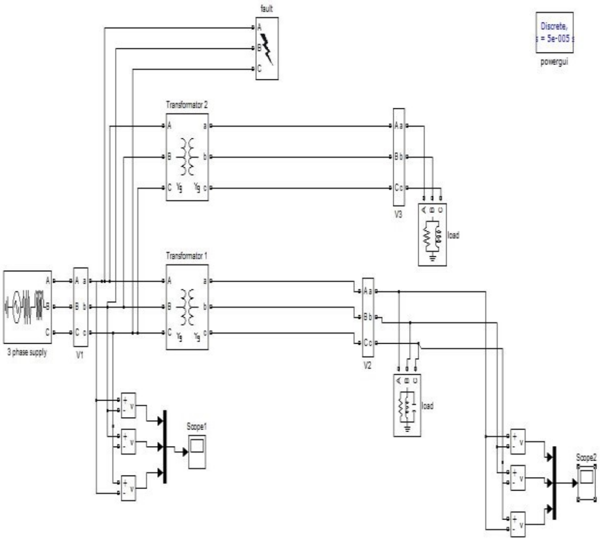

Figure. 9 Simulation model with fault

Waveforms for the load voltages (without compensation) are given below. Figure. 10 shows the waveform of the input voltage with L-G fault and without DVR. Figure. 11 shows the waveform of the input voltage with L-L fault and without DVR. Figure. 12 shows the waveform of the input voltage with three phase fault and without DVR. Even after the fault is created the input voltage remains almost same as before while load voltage experiences a huge change. With the application of the fault to the circuit the magnitude of the load voltage decreases at the fault period from 580V to 250V. This voltage dip is needed to be compensated to get the desired voltage at the load.

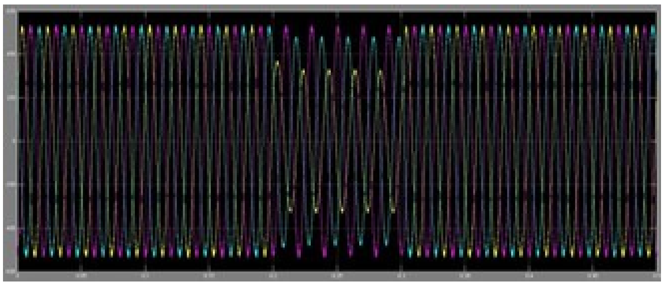

Figure. 10 Input voltage with L-G fault

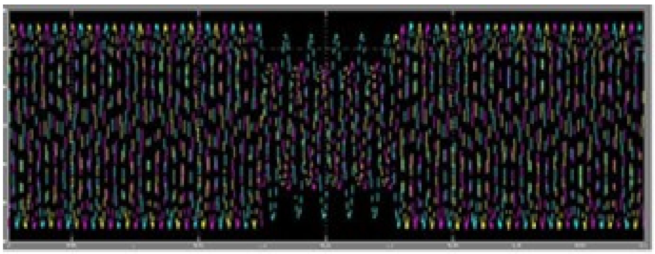

Figure. 11 Input voltage with L-L fault

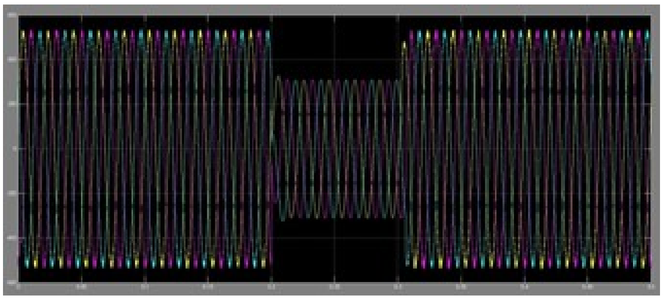

Figure. 12 Input voltage with three phase fault.

Figure. 13 shows the Matlab/Simulink of power system grid under the fault condition connected to the Dynamic Voltage Restorer. The third simulation is carried out at the same scenario as above but the DVR is now introduced at the load side to compensate the voltage sag occurred due to the three phase fault applied. Figure. 14 shows the injected voltage generated by the dynamic voltage restorer to compensate the voltage sag. The waveform obtained from the test model is shown in Figure. 15. It is clearly observed that the voltage waveform that is obtained after connection of DVR in series is almost similar to the supply voltage i.e. the DVR we installed is working efficiently.

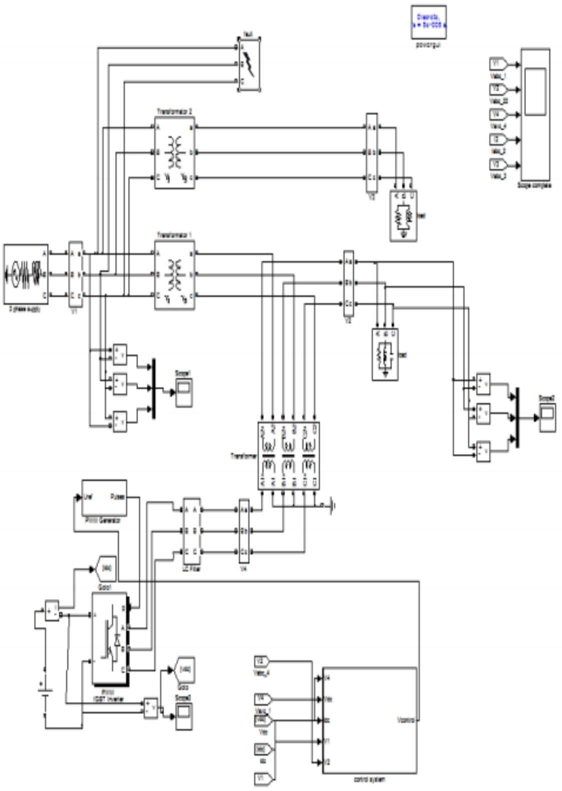

Figure.13 Matlab model of the DVR connected system

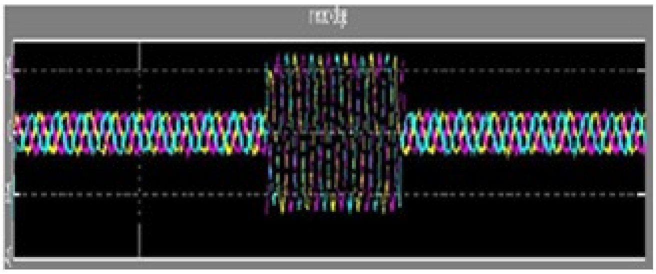

Figure. 14 Injected voltage

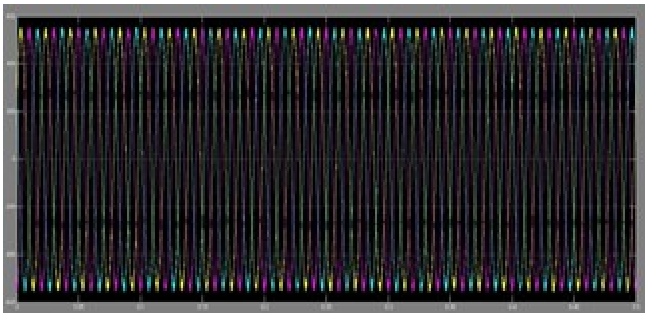

Figure. 15 Compensated voltage by DVR

VI. CONCLUSION

Inthiswork,afastandcosteffectiveDynamicVoltageRestorer(DVR)isproposedfor mitigatingtheproblemofvoltagesagordipandotherfaultconditionsinindustrialdistribution systems,speciallyconsistingoftheinductionmotorload.A controllerwhichisbasedonfeed forewordtechniqueisusedwhichutilizestheerrorsignalwhichisthedifferencebetweenthe referencevoltageandactualmeasuredloadvoltagetotriggertheswitchesofaninverterusinga PulseWidthModulation(PWM)scheme.Here,investigationswerecarriedoutforvariouscases ofloadat11kvfeeder.Itisclearfromtheresultsthatthepower qualityofthesystemwith inductionmotorasloadisincreasedinthesensethattheTHD andtheamountofunbalancein loadvoltagearedecreasedwiththeapplicationofDVR.The effectivenessofDVRusingPI controller is established both for linearstatic load and induction motor load.

VII. FUTURE SCOPE

The following points are recommended for future extension of work,

1. Other types of controller like FUZZY controller and adaptive PI FUZZY controller can be employed in the DVR compensation technique.
2. Investigation of the effectiveness of multi-level DVR can be investigated.

The effectiveness of the DVR can be established for active load like PV source and Wind Turbine.

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