# Dynamic Voltage Restorer and Its application at LV & MV Level

Ankit Pandey, Rajlakshmi

**Abstract:** Dynamic Voltage Restorer is a power electronic device that can protect sensitive loads from various disturbances in the power supply. This paper presents the study & analysis of DVR and power quality problems, voltage sag & swells with its application at Low Voltage and Medium Voltage level. DVR is always connected in series with the distribution feeder. The basic principle of a DVR is simple, by supplying a voltage of desired magnitude and frequency, the DVR restores the load voltage to a desired pre-sag voltage quantity even when source voltage is not balanced. Implementation of DVR has been proposed at both low voltage level as well as medium voltage level thus giving an opportunity to protect high power sensitive loads from voltage deflections[1].

**Keywords:** Dynamic Voltage Restorer (DVR), Low voltage level, Medium voltage level, Power quality, Power system, Voltage sag, Voltage swell.

## I. INTRODUCTION

An Electrical power system mainly comprises of Generation, Transmission and Distribution. Earlier the power quality improvement mainly depended upon generation and transmission only. But in present days, distribution system is also a major focus for power quality improvement. Initially for power quality and reliability improvement, FACTS devices like STATCOM: Static Synchronous Compensator, SSSC: Static Synchronous Series Compensator, IPFC: Interline Power Flow Controller and UPFC: Unified Power Flow Controller were used. But these FACTS devices were only for transmission system. Presently these devices are modified for the use in distribution system so that power quality can be further improved. These modified devices are called Custom Power Devices. The basic Custom power devices which are used for power quality improvement in distribution system are DSTATCOM: Distribution Static Synchronous Compensator, DVR: Dynamic Voltage Restorer, UPQC: Unified Power Quality conditioner etc. Among these devices, DVR is the most effective and efficient custom power device.


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The reason behind this is its lower cost, smaller size and its fast response towards the disturbances. The main function of DVR is to inject the desired voltage quantity in series with the supply with the help of an injection transformer whenever a voltage sag is detected. The basic elements of a DVR consists of a series connected Injection transformer, an Inverter, a low pass filter and an Energy storage device connected to DC link as shown in Fig. 1.

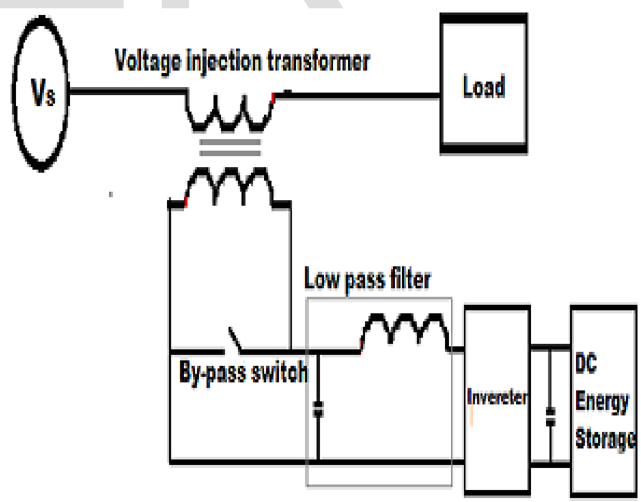


Fig.1 Application of DVR

Energy storage unit is for supplying real power requirement for the compensation of required voltage during sag conditions. Lead acid batteries and super capacitors are mostly used as energy storage unit in such devices. The maximum compensation a DVR can provide for voltage sag depends upon the active power supplied by these energy storage devices. The function of inverter is to convert the DC voltage that is supplied by the energy storage unit into AC voltage. Mostly pulse-width modulated voltage source inverter is used in case of DVR. The PWM inverted pulse waveforms are converted into sinusoidal waveforms using low pass filters. The function of such filters is to remove the higher order harmonics present in the AC after being inverted from DC. A DVR is always connected in series, so if any fault occurs in the circuit, the inverter circuit may get affected. Thus, to protect the inverter from this fault current, a by-pass switch is used to by-pass the inverter. An injection transformer is used to inject the voltage into the load line. The high voltage side of the injection transformer is connected in series to the distribution line, while the low voltage side is towards the DVR circuit. The injection transformer is a step-up transformer which increases the voltage to be injected in the distribution circuit to a desired level simultaneously isolating the DVR circuit from the distribution line.

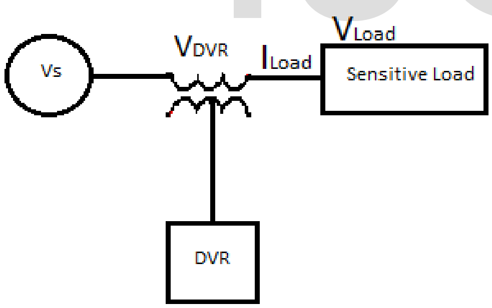


Fig. 2 DVR model.

When the distribution system is running in normal mode with no voltage sag, the supply voltage $V_s$ is equal to pre-sag voltage $V_{pre\text{-}sag}$. The DVR is not injecting any voltage to the system. The load voltage $V_L$ is equal to supply voltage $V_s$. During voltage sag, the supply voltage is changed and is denoted by $V_{sag}$. The DVR starts operating and injects voltage equal to $V_{DVR}$. If the voltage sag is fully compensated by the DVR, the load voltage during voltage sag will be $V_{pre\text{-}sag}$.

A DVR can be used at both Low level voltage as well as Medium level voltage. On this basis, a DVR can be of two types. The first DVR is a Low voltage DVR (LV-DVR) rated for 10 kVA for insertion in 400 volt low voltage grid and the second DVR is a Medium voltage DVR (MV-DVR) rated for 200 kVA for insertion in 10 kV medium voltage distribution system.

## II Calculation for voltage sag

Let there be two loads A & B. In normal condition, when there is No-Fault, The current through the loads A & B is equal i.e. Load is balanced[2].

Let for Feeder 1, Reactance = $X_1$, Current = $I_1$. for Feeder 2, Reactance = $X_2$, Current = $I_2$.

Load A = $Z_{A(load)}$. Load B = $Z_{B(load)}$.

Source Reactance = $X_s$. Supply Current: I

If any fault occurs in feeder 1, a high current will flow through feeder 1, short circuit will occur in feeder 1. According to Kirchhoff's current law, current flow to feeder 2 will be reduced. As a result, voltage will drop in feeder 2; this drop of voltage in feeder 2 is called voltage sag.

Using KCL, $I = I_1 + I_2$

During Normal Condition,

$$I = V_R/(X_1+Z_{A(load)}) + V_R/(X_2+Z_{B(load)}). \quad (1)$$

During Voltage Sag, Feeder-2 voltage decreases as the voltage drop increases through source reactance $X_s$.

$$I = V_R/X_1 + V_R/(X_2+Z_{B(load)}) \quad (2)$$

Where; $V_R = V_s - I.X_s$

$I.X_s$ is the Voltage drop

## III. Location of DVR

A simplified model of a DVR is shown in Fig.3. In this simplified model, DVR is considered as an ideal voltage source ($P_{VS}$) along with a reactance ($X_{DVR}$) and resistance ($R_{DVR}$). This reactance $X_{DVR}$ represents the reactive element of the injection transformer and filters, and the inserted resistance $R_{DVR}$ represents the various losses of the DVR[3].

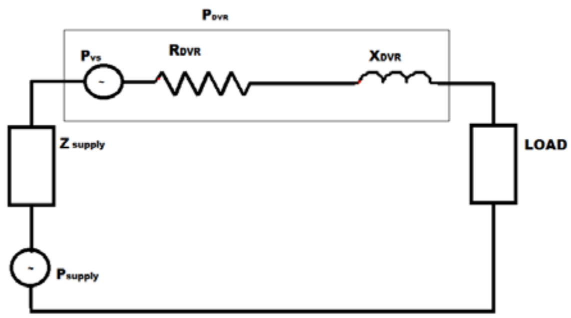


Fig.3 simplified model of DVR

Let $P_{DVR}$ be the DVR voltage rating and $S_{DVR}$ be the DVR power rating. The inserted impedance can be calculated using the following relation.

$X_{DVR}=(P^2_{DVR}/S_{DVR}).\mu_{DVR,}X$ (3)

$R_{DVR}= (P^2_{DVR}/S_{DVR}).\mu_{DVR}, R.$ (4)

$Z_{DVR}= (P^2_{DVR}/S_{DVR}).\mu_{DVR}, Z.$ (5)

Where $\mu_{DVR,}\ Z = \mu_{DVR}, R + j\ \mu_{DVR}, X.$

A DVR with high voltage rating ($P_{DVR}$) and low power rating $S_{DVR}$ has large equivalent $Z_{DVR}$. Increasing from LV-level DVR to MV-level DVR, the pu value of the reactance $\mu_{DVR,\ X}$ increases and the pu value of resistance $\mu_{DVR}$, R decreases.

## A. DVR at MV-Level

A large group of consumers can be protected using DVR at MV-Level. If we assume an infinite bus bar of 50kV, the impedance for LV load will be the summation of impedances of 50/10kV transformers, the cables, the 10kV overhead lines, 10/4kV distribution transformers and the LV cables. The impedance and resultant impedance is as follows.

$Z_{without\ DVR} = Z_{50/10} + Z_{line,10} + Z_{10/0.4} + Z_{line,0.4}.$ (6)

$Z_{with\ DVR} = Z_{DVR} + Z_{without\ DVR}$ (7)

$Z_{increase} = (Z_{DVR}/Z_{without\ DVR}).100$ (8)

Fig.4 shows application of DVR at MV-level.

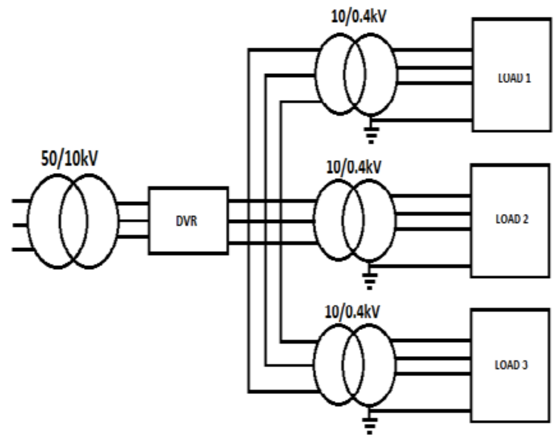


Fig. 4 DVR at MV-Level

## B. DVR at LV-Level.

A DVR when used at LV-Level works more specifically for voltage dips in case of sensitive loads. DVR works only for the desired load and not for the whole system like in case of MV-Level. The percentage change in impedance, $Z_{increase,\%}$ (3) for DVR at LV level can be increased up to several hundred percent.

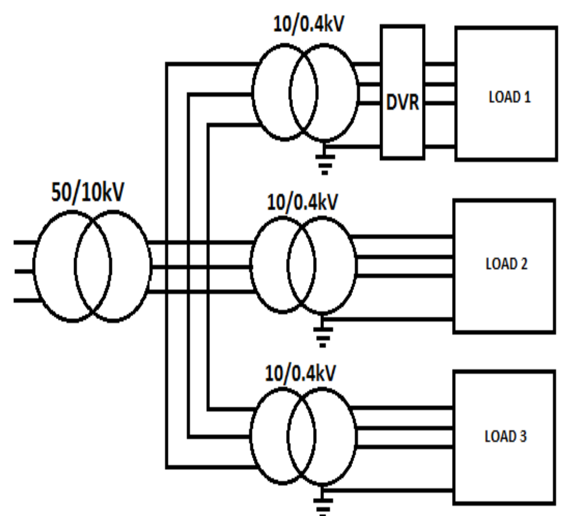


Fig. 5 DVR at LV-Level

# IV. PERFORMANCE OF DVR

### A. Advantages

- DVR is mostly preferred because it is less expensive. If compared to DSTATCOM and UPS, DVR is a lot cheaper.
- UPS requires a lot of maintenance which may be due to problems of battery leakage and replacement.
- DVR is small in size and is a better power effective device as compared to others link UPS, SMES and DSTATCOM.
- SVC cannot control active power flow that creates a reason of preference for DVR in spite of the fact that SVC is better than DVR.

### B. Limitations

- DVR has a limited current conduction and voltage injection capability which is due to such design of DVR to keep its cost low as well as to reduce the voltage drop across it in standby mode.
- In order to reduce the cost of DVR, the energy storage size of DVR is kept low. Due to voltage dips, the stored energy can deplete fast and therefore to avoid load tripping due to insufficient stored energy, an adequate control is required.

### C. Features

- There is a limitation for the fault current.
- DVR reduces transients from voltages.
- One of most efficient way to compensate voltage sags and voltage swells.
- DVR also compensates line voltage harmonics[5].

## V. CONCLUSION

This paper presents the study of a DVR and its application for the compensation of voltage sag for sensitive loads. The paper explains the types of DVR, LV-Level rated for 10kVA and MV-Level rated for 200kVA and their comparative application at both these two levels has been done. The calculation for voltage sag with consideration of fault and No-fault conditions are done with reference to application of DVR. DVR has a tremendous application for voltage sag compensation for sensitive loads. The paper also explains the various advantages, limitations related to the DVR along with its features. A general study of how a DVR can be such useful for the sensitive loads has been done in this paper.

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