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Topological Advancement in DVR; A review

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Abstract – *DVR is a very simplest and widely adopted Power Quality (PQ) improvement controller used in distribution system. Modern power system is structured as deregulated one, hence it is utmost important to PQ under various system conditions. DVR is particularly employed to regulate voltage un der the condition of sag/swell in voltage. DVR is a series connected device designed using power electronics element. With the increase in applications, it has undergone to various topological advancements. This paper presents a brief review on such advancement. Comparative analysis of widely adopted DVR topologies also presented in this paper.*

Key Words: Deregulated Market Structure (DMS), Power Quality (PQ), Dynamic Voltage Restorer (DVR), Voltage Source Inverter (VSI), multi-level inverters (MLI).

1.INTRODUCTION

In Deregulated Market Structure (DMS), there are multiple entities providing power. Hence one who can provide good quality of power has the inherent advantage of large market share. Hence Power Quality (PQ) management is very important in DMS [1]. The frequent type of PQ issues occurring in distribution system is voltage fluctuation due to sag-or-swell, Flickers and transients. Hence it is mostly employed for regulating voltage at consumer end. The condition voltage sag is arises due to power system faults both short circuit or open circuit faults, due to overloading or due to generation-demand mismatch. Swell in voltage is created due to under loading or removal of high rating power transformer, or high power generation from distributed generation at load side. Both the conditions are very harmful for the voltage sensitive devices or loads connected in the system. They can completely damage the sensitive loads or may leads to system maloperation. Hence it is required to mitigate the condition of sag/swell in voltage (SSV) [2].

Dynamic Voltage Restorer (DVR) is the preferred choice for mitigating SSV. It is a series connected device interfaced with the system using power converters [3]. It injects the series voltage into the system to remove the voltage difference also it supplies the required the reactive power to mitigate the PQ issues generated due to fluctuations, transients or flickers in system voltages. It also reduces the harmonics generated in the system due to non-linear loading [4]. Due to its increasing popularity, researchers finds a lot of scope to improvise the DVR technology. Conventionally it was designed using 2-level Voltage Source Inverter (VSI) [5]. With the advancement in power electronic applications, multi-level inverter was preferred to design the DVR architecture, also the control for obtaining reference current for generating gate pulses has the wide research scope [6]. This paper presents the comprehensive reviews on the various DVR topologies available in literature as well as its control architecture.

2. DVR DESIGN AND CONTROL

For load voltage regulation and harmonics mitigation DVR as shown in figure 1 is installed near load end. It is a series connected device connected via coupling transformers. It infuses dynamically controlled voltage of appropriate magnitude and phase [7]. From the figure it can be observed that is comprises of coupling transformer to connect the VSI in series with the power line. The VSI is supplied by a DC source generally any battery storage element. The AC output obtained from VSI is contains high number of harmonics, since VSI is a power converter designed using high frequency switches [8]. Therefore, a filter is connected designed using electrical lumped parameters. The voltage across the transformer is the DVR injected voltage which is added to the system in order to maintain load voltage or output voltage at load side [9]. The way in which compensation is provided by DVR is of three categories;

1) In-phase compensation: in this case it generates the voltage in-phase with the line voltage as shown in figure 2.

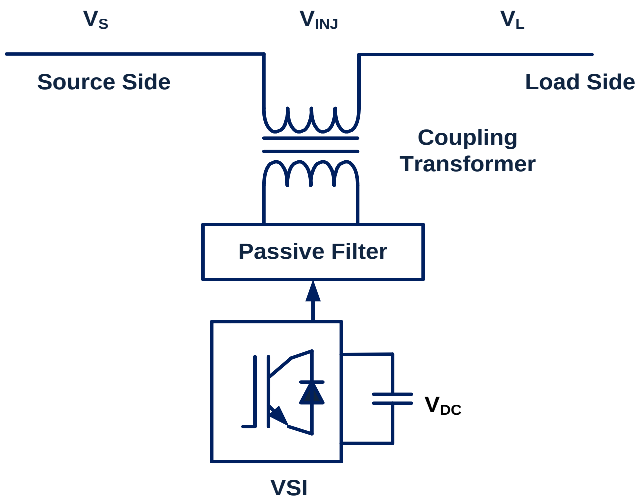

Fig -1: Single-line diagram of DVR

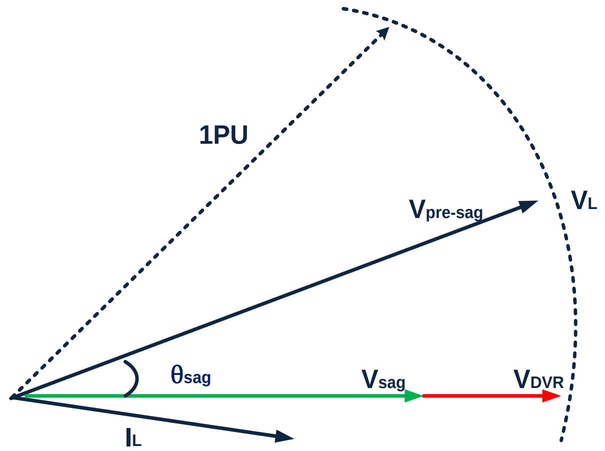

Fig -2: In-phase compensation of DVR

2) Pre-sag compensation: DVR maintains load voltage phasor constant in relation to that before the disturbance as illustrated in figure 3. In this technique value of load current and voltage are immobile so that we can alter only the phase of sag voltage.

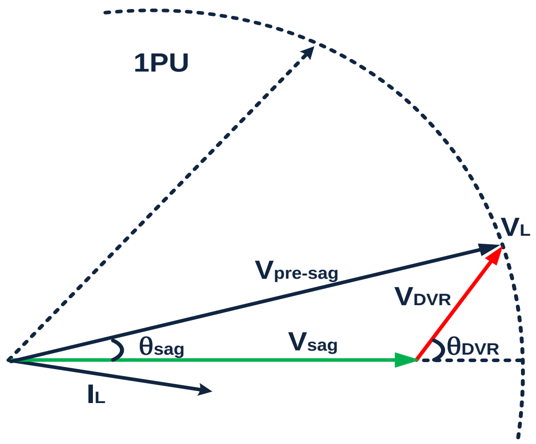

Fig -3: Pre-sag compensation of DVR

3) In-phase advanced compensation: injected voltage advances the voltage, so the injected voltage phasor and line current are perpendicular to each other as displayed in figure 4.

In the figures Θ_{sag} is the voltage angle injected by the DVR in case of sag, Θ_{DVR} is the DVR voltage angle under the condition advanced compensation technique. V_L and I_L is the load voltage and current respectively.

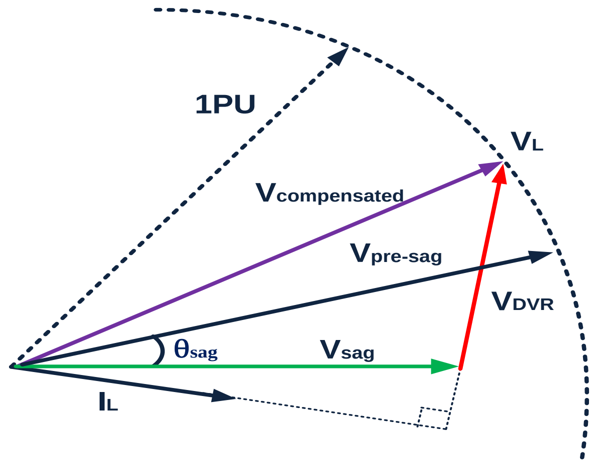

Fig -4 In-phase advanced compensation of DVR

3. Topologies of DVR

Simplicity in design, cost effective and fast action against PQ problems are the merits of DVR which make it widely adoptable [10 11]. The DVR can be installed at medium or low voltage level LV) in the distribution side. The choice is governed by the number or type (either commercial/industrial) of end-user customer. The configuration of the MV-DVR and LV-DVR is presented in figure 5 and figure 6 respectively. The DVR is also designed with and without energy storage element. In case of no-storage device as shown in figure 7, the DVR draws power from the mains. In case of storage device as shown in figure 8, the DVR is supplied via storage device. The conventional AC-DC-AC (DC link) DVR topologies have dc-link and two stage power conversion, which increase its size, cost and associated losses. Besides the conventional topologies, there are some topologies have been introduced for DVR which make use of direct AC-AC (AC link) converters without the need for energy storage elements and intermediate dc link. By using a direct AC-link converter instead of the conventional DC link converters as shown in figure 9.

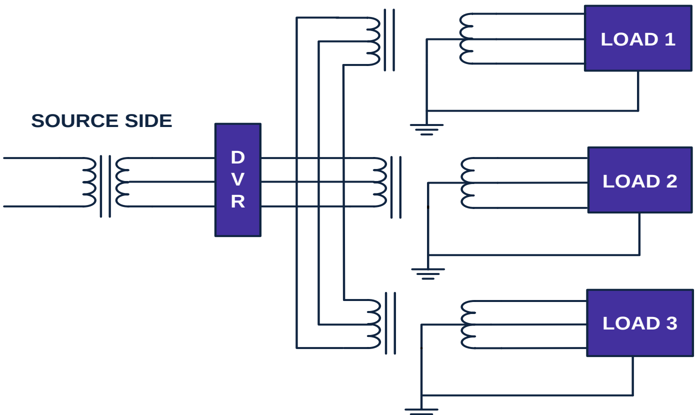

Fig -5: Configuration of MV-DVR

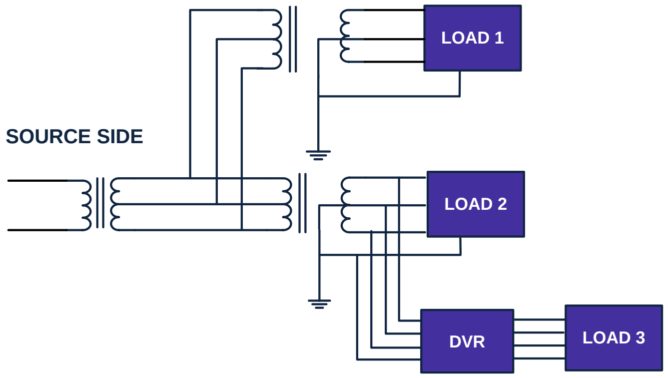

Fig -6: Configuration of LV-DVR

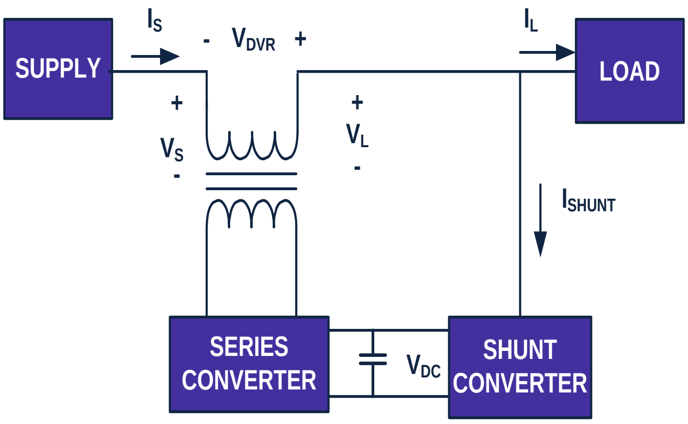

Fig -7: Configuration of without energy storage

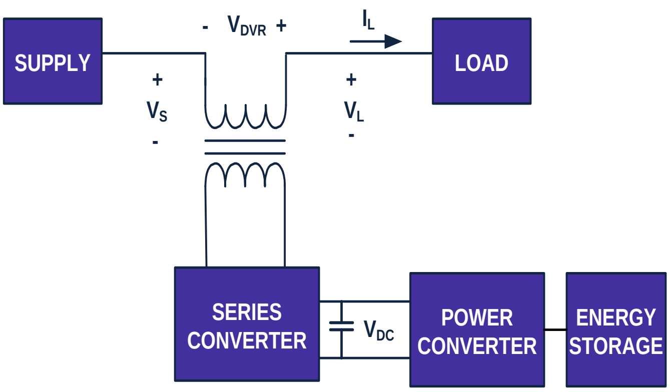

Fig -8: Configuration of with energy storage

One more topology available in literature is interline-DVR. IDVR consists of several DVRs on lines sharing a common DC link, which enables active power exchange between two or more DVR as shown in figure 10. Now a days with the development in multi-level inverters (MLI), an MLI-DVR is also becoming popular. In this DVR topology the conventional VSI in replaced by MLI. The popularly adopted MLIs are neutral-point clamp and cascaded topology.

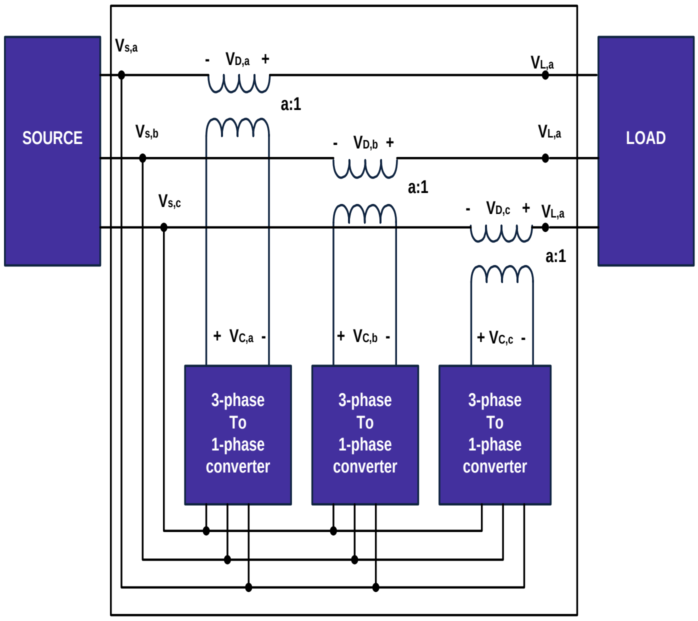

Fig-9: Configuration of AC link-DVR

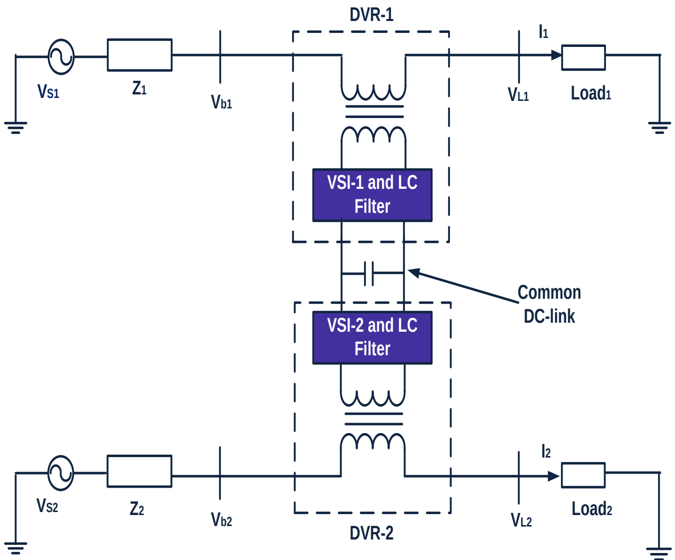

Fig-9: Configuration of IDVR

4. CONCLUSIONS

DVR is a customized power quality improvement device generally installed to regulate the voltage at consumer end and also to mitigate the harmonics in the voltage-current waveforms. This work presents the comprehensive review on the need and utility for installation of DVR. The design aspects and control architecture are also reviewed briefly. The advantages and the conditions in which DVR are installed are also discussed. Various types of DVR topologies available in literature in order to fulfill the system requirement is also presented with circuit configurations.

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