Voltage Quality Improvement Using Dynamic Voltage Restorer (DVR)

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***Abstract:* -** Voltage sags and swells are well-known problems with serious consequences for sensitive loads. Custom power devices are utilized to solve this problem. One of them is the Dynamic Voltage Restorer (DVR) is one of these devices. One of the most efficient and effective bespoke power systems available today. In electricity distribution networks, these are the equipment that are employed. This is a paper about DVR fundamentals and voltage correction methods are discussed for voltage sags and swells in a balanced and/or unbalanced system of distribution The results of the simulation were presented to Analyze and comprehend DVR's performance under circumstances of voltage sags/swells The outcomes of the research The efficiency of the method was proved by simulation using MATLAB. This gadget is particularly effective in compensating voltage sags and swells (relative to voltage sag/swell duration) Quick reaction.

Key Words: — *Dynamic Voltage Restorer (DVR), Voltage sags, Voltage swells, Custom power, Power Quality*.

I. Introduction

Faults at either the transmission or distribution level may cause voltage sag or swell in the entire system or a large part of it. Also, under heavy load conditions, a significant voltage drop may occur in the system. 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 [1]**.** Voltage swells are not as important as voltage sags because they are less common in distribution systems. Voltage sag and swell can cause sensitive equipment (such as found in semiconductor or chemical plants) to fail, or shutdown, as well as create a large current unbalance that could blow fuses or trip breakers. Customers can pay a high price for these consequences, which can range from small quality deviations to production downtime and equipment damage [3].

There are a variety of ways to reduce voltage sags and swells, but using a bespoke Power device is thought to be the most efficient.

Manuscript revised December 30, 2021; accepted December 31, 2021. Date of publication January 02, 2022.

This paper available online at www.ijprse.com

ISSN (Online): 2582-7898; SJIF: 5.494

N.G. Hingorani first proposed the concept of custom Power in 1995.

Custom power, like Flexible AC Transmission Systems (FACTS) for transmission systems, refers to the employment of power electronics controllers in a distribution system to address various power quality issues. Each Custom Power gadget has its own set of advantages and disadvantages. One of the most effective types of these devices is the Dynamic Voltage Restorer (DVR). The DVR is favoured above the others for a variety of reasons. The following are a few of these causes. Although the SVC predates the DVR, the DVR is still favoured since the SVC lacks active power flow control [5]. Another factor is that the DVR is less expensive than the UPS [6, 7]. Other advantages of the DVR over the SMES device include better energy capacity and cheaper prices [5]. In addition, the DVR is smaller and less expensive than the DSTATCOM [5]. It's no wonder, then, that the DVR is commonly regarded as an excellent bespoke power device for minimizing voltage sags [8].

This paper explains what a Dynamic Voltage Restorer (DVR) is and how it works. Then there were analyses of the voltage correcting methods. Finally, the simulation results were shown and discussed using MATLAB.

II. DYNAMIC VOLTAGE RESTORER (DVR)

A Dynamic Voltage Restorer (DVR) is a solid-state device with a series connection that injects voltage into the system to adjust the load side voltage. The DVR was implemented for the first time in 1996 [8]. It's usually situated between the supply and the essential load feeder in a distribution system [9]. Its principal role is to quickly enhance the load-side voltage in the case of a disturbance, preventing any power interruption to that load [7, 10]. A DVR can be implemented using a variety of circuit topologies and control approaches. DVR can include other characteristics such as line voltage harmonics correction, voltage transient reduction, and fault current restrictions in addition to voltage sags and swells compensation.

As illustrated in Figure 1, the DVR's general configuration includes an Injection/Booster transformer, a Harmonic filter, a Voltage Source Converter (VSC), and a Control and Protection system.

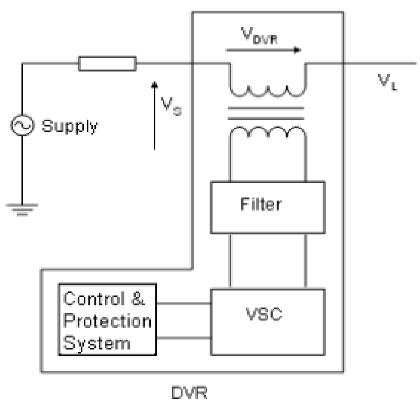

Fig.1. DVR Series Connected Topology

2.1 Injection/Booster Transformer

The Injection / Booster transformer is a particularly constructed transformer that aims to reduce noise and transient energy coupling from the primary to the secondary side [11]. Its primary responsibilities include connecting the DVR to the distribution network via HV-windings, as well as transforming and coupling the injected compensatory voltages generated by the voltage source converters to the incoming supply voltage. Furthermore, the Injection / Booster transformer is used to isolate the load from the system (VSC and control mechanism).

2.2 Harmonic Filter

The fundamental purpose of a harmonic filter is to keep the harmonic voltage content created by voltage source converters under control (i.e. to eliminate high frequency switching harmonics). It only has a tiny rating of about 2% of the load MVA [12].

2.3 Voltage Source Converter (VSC)

A VSC is a power electronic system made up of a storage device and switching devices that may generate a sinusoidal voltage at any frequency, amplitude, or phase angle. The VSC is utilized in the DVR application to temporarily replace the supply voltage or to create the missing portion of the supply voltage [13].

The VSC can be configured in a variety of circuit topologies [14-15]. The two-level or multilevel three-phase converter, which shares a dc capacitor between all phases, is a widely used technique. Because the major purpose of this capacitor is to absorb harmonic ripple, it has a low energy storage demand, especially while running in balanced conditions. Safe energy sources can be found all around us, and we can use them in a variety of ways, as detailed below.

2.3.1 Switching Devices:

Metal Oxide Semiconductor Field Effect Transistors (MOSFET), Gate Turn-Off Thyristors (GTO), Insulated Gate Bipolar Transistors (IGBT), and Integrated Gate Commutated Thyristors (IGCT) are the four primary types of switching devices (IGCT). Each type \shas its own pros and cons. The IGCT is a new small device with improved performance and reliability that permits VSC with extremely high-power ratings to be built. The DVR can compensate for dips that are beyond the capability of previous DVRs utilizing conventional devices thanks to the very complex converter architecture with IGCTs.

2.3.2 Storage Devices:

The goal is to provide the necessary energy to the VSC via a dc link so that injected voltages can be generated. The most prevalent forms of energy storage devices are batteries and ultracapacitors. The duration of the sag is directly determined by the capacity of the stored energy, which can be mitigated by the DVR. Batteries are the most typical option, and if a high voltage battery setup is employed, they can be extremely effective. Certain ultracapacitors (unsymmetrical electrochemical) can store charge for long periods of time, allowing them to function as a battery. These ultracapacitors, unlike batteries, have a short charge time and a significantly longer lifespan.

2.4 Control & Protection System

Digital Signal Processing (DSP) boards are commonly used as the overall configuration's control mechanism. Controls like detection and correction are provided by software on the DSP board. For these purposes, filters are widely utilized. The Fourier Transform (FT) and the Wavelet Transform (WT) are the two most prevalent forms of filter algorithms (WT). Despite this, the Fourier Transform is still the most popular [22, 23].

III. Operating Principle OF DVR

The DVR's primary function is to inject, via a booster transformer, a dynamically controlled voltage VDVR generated by a forced commutated converter in series with the bus voltage. The three injected phase voltages' momentary amplitudes are managed to eliminate any negative consequences of a bus fault on the load voltage VL. This means that any differential voltages induced by ac feeder disruptions will be compensated by a converter-generated equivalent voltage injected on the medium voltage level through the booster transformer.

The DVR functions regardless of the sort of fault or event that occurs in the system, as long as the entire system is linked to the supply grid, i.e. the line breaker does not trip. In most practical cases, a more cost-effective design can be achieved by only compensating the positive and negative sequence components of the voltage disturbance seen at the DVR's input (because the zero-sequence part of a disturbance will not pass through the step-down transformer, which has infinite impedance for this component in a typical distribution bus configuration).

There are two modes of operation for the DVR: standby and boost. The low voltage winding of the booster transformer is shorted through the converter in standby mode (V_{DVR}=0). In this mode of operation, no semiconductors are switched because the individual converter legs are activated to create a short-circuit channel for the transformer connection. As a result, only the semiconductors' relatively low conduction losses in this current loop contribute to the losses. The DVR will be in this mode for the majority of the time. When the DVR detects a supply voltage disruption in boost mode (V_{DVR}>0), it injects a compensation voltage through the booster transformer.

IV. Simulation

A small distribution network is simulated using MATLAB to demonstrate the DVR's performance in mitigating voltage sags and swells (fig.1). Temporary connections of varied impedances at the supply side bus are used to simulate voltage sags and swells. A series transformer connects the DVR to the system, allowing it to insert a maximum voltage of 50% of the phase to ground system voltage. In addition, a series filter is utilized to remove any high-frequency power components. The In-Phase Compensation (IPC) approach is employed in this simulation. The load used in the study is a 5.5 MVA lagging load with a power factor of 0.92.

V. Voltage Sags

The results of a simulation of three-phase voltage sag are displayed in Fig.2.

In this scenario, we'll assume that there's a 30% three-phase voltage drop with a +30° phase leap in phase-a in supply voltage that starts at 0.1s and lasts until 1.8s. The outcome of voltage sag compensation is shown in Fig.10. The serial injected voltage components are shown in Fig.10 (b) and Fig.11 (b). In addition, Fig.10 (c) and Fig.11 illustrate the corrected load voltage (c). As the findings show, the DVR is capable of promptly producing the appropriate voltage components for different phases and assisting in the maintenance of a balanced and stable load voltage at the nominal value (400 V).

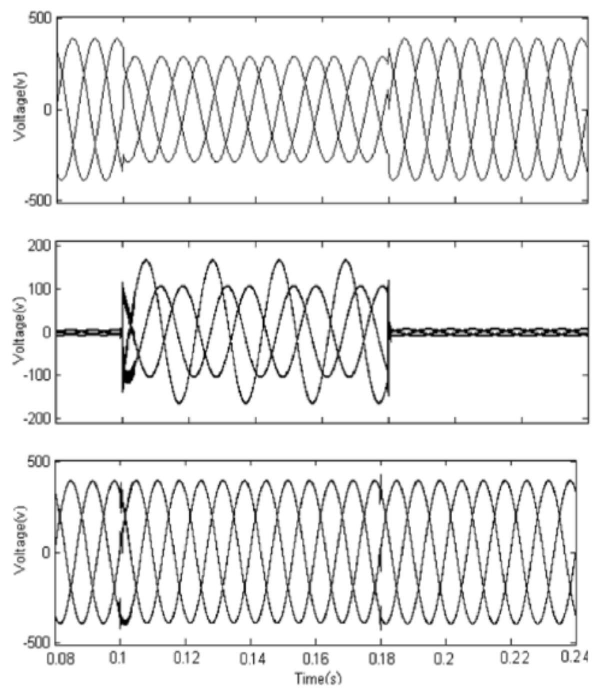

Fig.2. Three-phase voltages sag: (a)-Source voltage, (b)-Injected voltage, (c)-Load voltage

The performance of DVR in the presence of a voltage swell is explored. As indicated in Figure 3, the supply voltage swell is formed (a). The performance of DVR in a voltage swell condition is investigated in the second case. An imbalance voltage swell is considered here, with a 30% three-phase voltage swell and a +30° phase jump in phase-a that starts at 0.1s and finishes at 1.8s. Figures 12 (b) and 13 demonstrate the injected voltage created by DVR to rectify the load voltage (b). DVR can fix the voltage swell by injecting negative three phase voltage components, as shown in Fig.12 and Fig.13

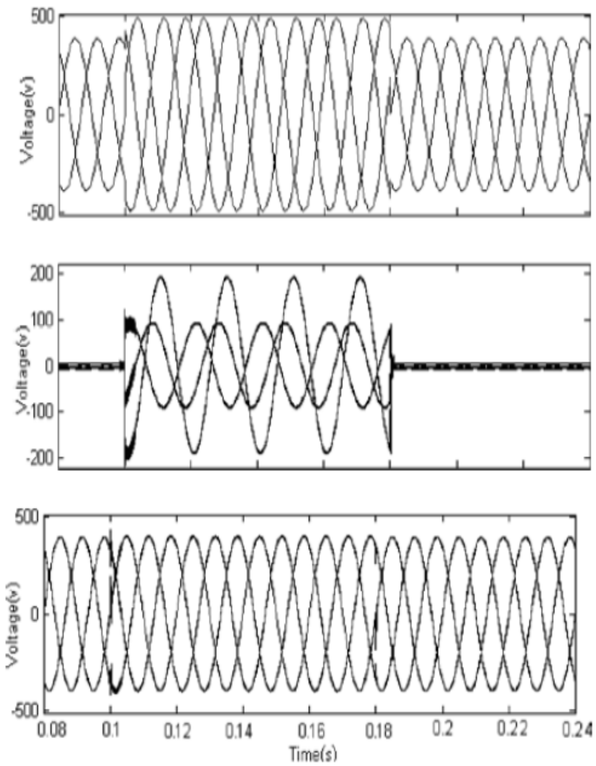

Fig.3. Three-phase voltages swell: (a)-Source voltage, (b)-Injected voltage, (c)-Load voltage

VI. Conclusion

The purpose of this study is to provide an overview of DVR. DVR is a useful bespoke power gadget for reducing voltage sags and swells. Voltage sags have a significant influence on sensitive equipment. As a result, DVR is regarded as a cost-effective solution due to its small size and inexpensive cost, as well as its quick dynamic reaction.

The simulation findings clearly demonstrate a DVR's ability to mitigate voltage sags and swells. The DVR easily manages both balanced and unbalanced circumstances, injecting the necessary voltage component to quickly rectify any abnormality in the supply voltage, ensuring that the load voltage remains balanced and steady at the nominal value.

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