

# A Review on Various Mitigation Techniques for Elimination of Voltage Sag

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**Abstract**— The need of advancement of technology has increased now a days and with this advancement various has been created in technology. Various applications in electrical domain requires conversion of energy which increases the power quality problems. The most frequently occurring power quality event is voltage sag which affects the performance of various equipments used in industries. Depending on the level of sag the performance of industry varies and the output of industries is affected. To overcome this problem various mitigation techniques has been proposed recently. This paper presents a review of such various techniques. The paper mainly focus on FACTS devices like DVR, S-STATCOM and Auto transformer which are used for the mitigation of voltage sags.

**Key words:** Power quality; Voltage Sag; DVR; mitigation techniques

## I. INTRODUCTION

Electrical energy is that the most effective and standard variety of energy and also the fashionable society is heavily passionate about the electrical offer. The life can't be fanciful while not the supply of electricity. At a similar time the standard and continuity of the electrical power supplied is additionally vital for the economical functioning of the tip user instrumentation. Most of the business and industrial hundreds demand prime quality uninterrupted power. Thus maintaining the qualitative power is of utmost vital. The quality of the ability is affected if there's any deviation within the voltage and frequency values at that the ability is being equipped. This affects the performance and life time of the tip user instrumentation. Whereas, the continuity of the ability equipped is affected by the faults that occur within the facility. Thus to keep up the continuity of the power being equipped, the faults ought to be cleared at a quicker rate and for this the power system switchgear ought to be designed to control with none hold. The power quality is affected several issues that occur in gear mechanism and distribution system. A number of them square measure like- harmonics, transients, fulminate switch operations, voltage fluctuations, frequency variations etc. These issues also are responsible in deteriorating the patron appliances. So as to reinforce the behavior of the power system, these all issues ought to be eliminated. With the recent advancements in power electronic devices, there square measure several possibilities to scale back these issues within the facility. One in all them is that the use of Flexible AC gear mechanism (FACTS) devices. The association of those devices in the power system helps in up the ability quality and responsibility.

The quality of power transported to the end user is very vital as the performance of the consumer's apparatus is profoundly reliant on it. But the power quality is affected through an assortment of factors like voltage and frequency deviation, occurrence of harmonics, faults in the power

system network etc. Among them the voltage deviation (sag) is one of the most frequently occurring problems. There are many methods to diminish the voltage sag and among them the best way is to attach a FACT device at the point of attention. The renowned devices like DSTATCOM, DVR, and UPQC are used for this intention. The world's earliest DVR 's fitting was done at Duke Power Company's 12.47kV substation in Anderson, South Carolina in 1996. After that immediately then ABB, Siemens and other companies have also focused and worked hard for several years to achieve the design patterns and finally developed their own patterns of the products to ensure the quality of voltage-sensitive load. Therefore, there is lot of research in this field.

The plan of a DVR for voltage sag improvement purpose is obtainable in [1]. It also presents the reaction of the DVR when sag is formed. A survey on the arrangement and control approach of the DVR is obtainable in [2]. It converse how a DVR can be controlled to alleviate voltage sag. It also presents the other advantages of a DVR to the power network. The additional FACT device that is used for voltage sag application is D-STATCOM. The basic structure of D-STATCOM is enlightened in [3]. The authors have conferred the functioning principle of the apparatus. The diverse modes of process of a D-STATCOM are clearly presented in [4]. The control strategy to organize the device is discussed in [5]. It also presents the MATLAB based modeling of the system

A assessment among the DVR and D-STATCOM in mitigating voltage sag is given in [6]. The author utter that the power addition required by D-STATCOM to mitigate a given voltage sag is more compared to that of DVR. But the D-STATCOM is skilled of mitigating superior voltage sags without introduction of active power. Nevertheless, both these devices comprise switching losses. To conquer the problem of these devices, a new method to diminish voltage sag is proposed in [7]. It presents a PWM switched auto transformer to diminish the voltage sag. As this topology uses only one power electronic switch, the switching losses are reduced greatly and the effectiveness of the system is increased. The author has presented various control strategy to organize the IGBT switch such that the auto transformer is responded intact with the voltage unevenness [8]. The planned control strategy was validated with simulation results.

## II. VOLTAGE SAG MITIGATION TECHNIQUES

The voltage sag is a main difficulty that the power system network is facing now-a day. This is a ruthless difficulty and shape the functioning of the apparatus. thus, this problem should be diminished in order to preserve the effectiveness of the power network. The use of custom power devices solves this problem. The basic structure and working principle of

different devices like DVR, D-STATCOM, Auto Transformer used to mitigate the voltage sag is shown.

#### A. Dynamic Voltage Restorer (DVR)

A Dynamic Voltage Restorer is a power electronic converter based device projected to make sure for discriminating load from all supply-side for unsettling influences other than deficiencies [9]. It is linked in collection with the distribution feeder for the majority division at the purpose of normal coupling. The basic structure of DVR is shown in figure 1.

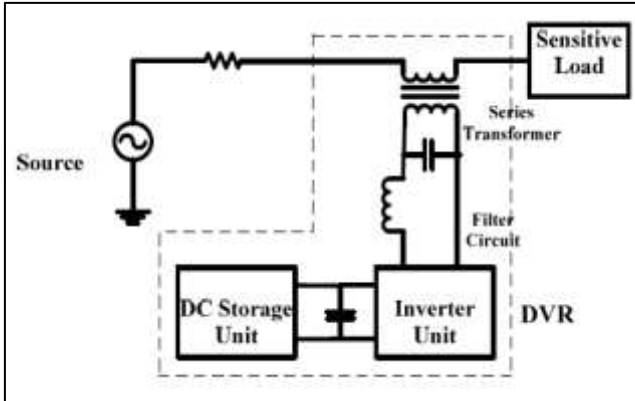


Fig. 1: Basic Structure of DVR

The DVR is a series connected power electronic device used to inject voltage of required magnitude and frequency. The basic structure of a DVR contains the following components- Voltage Source Inverter (VSI), DC storage unit, Filter circuit, Series Transformer

The main function of the DVR is to insert voltage of necessary amount and frequency as most wanted by the power system network. Through the standard operation, the DVR will be in stand-by approach. During the disturbances in the organization, the insignificant or rated voltage is compared with the voltage difference and the DVR injects the difference voltage that is necessary by the load. The equivalent circuit of a DVR coupled to the power network is shown in Fig. 2. Here  $V_s$  is the supply voltage,  $V_{inj}$  is the voltage injected by the DVR and  $V_L$  is the load voltage.

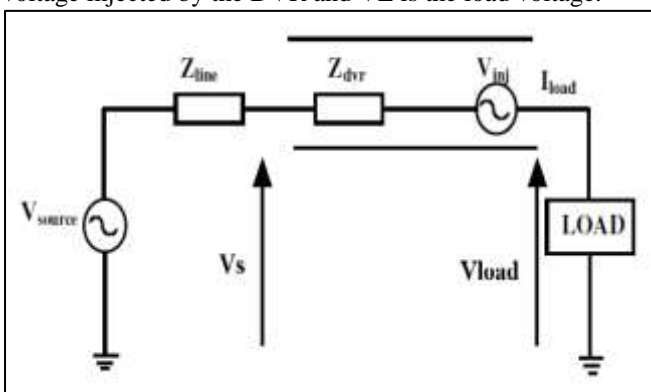


Fig. 2: Equivalent circuit of DVR

The working of DVR and control strategy is shown in figure 3.

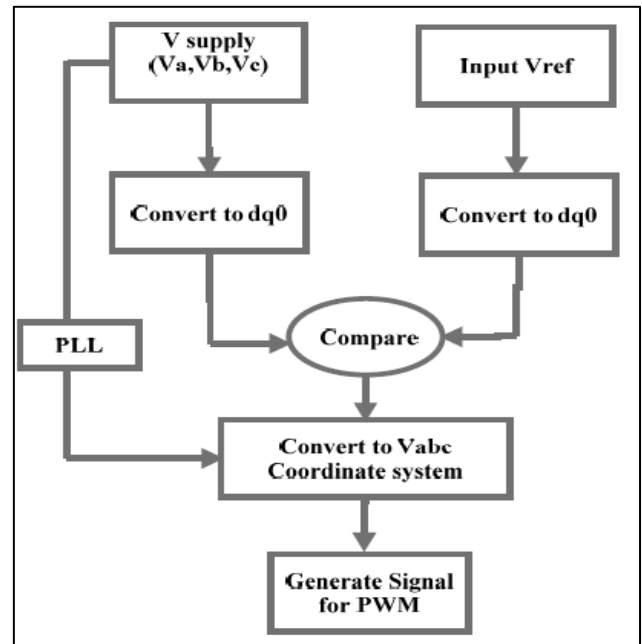


Fig. 3: Working strategy of DVR

#### III. D-STATCOM

A Distribution Static Compensator is in short known as D-STATCOM. It is a power electronic converter based apparatus worn to defend the distribution bus from voltage distortion [10]. It is coupled in shunt to the distribution bus in general at the PCC

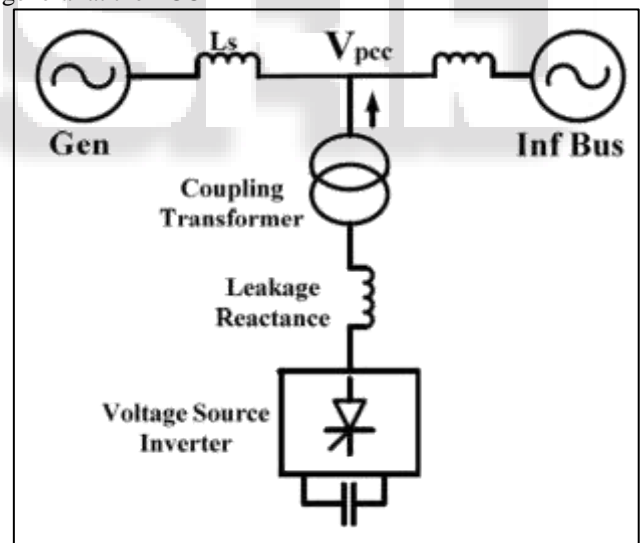


Fig. 4: Basic Structure of D-STATCOM

A D-STATCOM shown in figure 4 is competent of compensating either bus voltage or line current. It can function in two modes based on the constraint which it control. They are-

**Voltage Mode Operation:** In this mode, it can create the bus voltage to which it is connected a sinusoid. This can be achieved irrespective of the unbalance or distortion in the supply voltage.

**Current Mode Operation:** In this mode of operation, the D-STATCOM forces the source current to be a balanced sinusoid irrespective of the load current harmonics.

The basic operating principle of a D-STATCOM in voltage sag mitigation is to regulate the bus voltage by generating or absorbing the reactive power. Therefore, the DSTATCOM operates either as an inductor or as a capacitor based on the magnitude of the bus voltage. The firing pulses to PWM VSI are controlled to control the amount of reactive power exchanged between the STATCOM and the supply bus. The control strategy of D-STATCOM is shown in figure 5

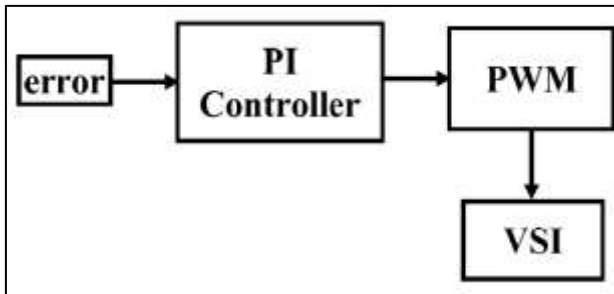


Fig. 5: Working strategy of D-STATCOM

#### IV. AUTO-TRANSFORMER

An auto transformer is a single winding transformer where there is no isolation among the primary and secondary windings. This apparatus need fewer conductor material in its structure and is of less size and weight when weigh against to the normal two winding transformer [11]. This device can be used in mitigating the voltage sag when controlled properly. The basic structure of an auto transformer is shown in Figure 6. Here the secondary voltage is more than primary and thus the transformer acts as step-up transformer which is used to mitigate the sag

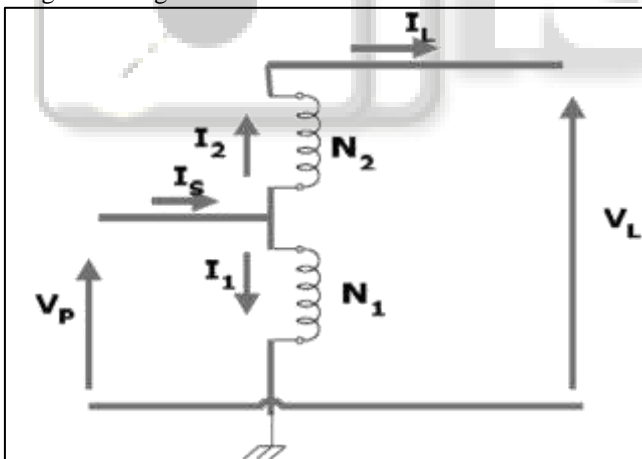


Fig. 6: Structure of Auto Transformer

The auto transformer is controlled by a PWM operated power electronic switch. The single-phase diagram of a power system network with a PWM switched auto transformer used for voltage sag mitigation is shown in figure 7

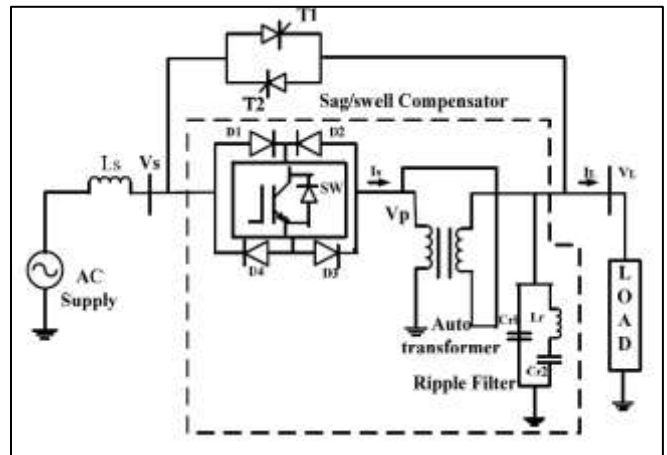


Fig. 7: Voltage Sag Mitigation Scheme Using Auto Transformer

The single-phase circuit diagram during voltage sag condition is shown in Figure 8 Here the bypass switch is off and the auto-transformer works based on the IGBT switch operation to generate required voltage on the load side

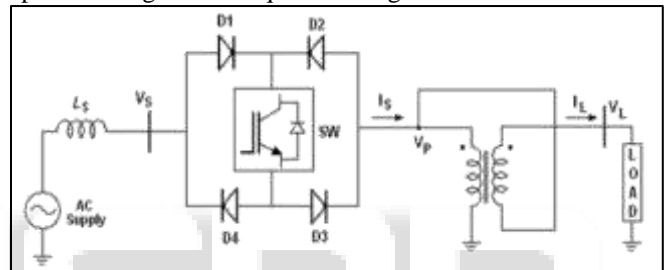


Fig. 8: Single-phase Circuit Diagram during Voltage Sag

The control strategy of auto transformer is to control the pulses generated to the IGBT switch such that the auto-transformer generates desired voltage to mitigate the voltage sag. The flowchart of working of auto transformer is shown in figure 9

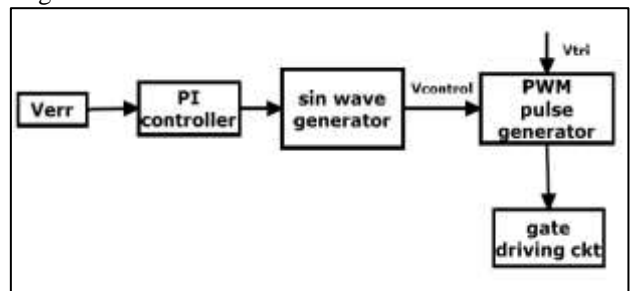


Fig. 9: Block Diagram of Control Circuit of Auto-transformer

There are various techniques to diminish the voltage sag. Amongst them the most excellent method is to use a device at the point of attention to standardize the voltage. The devices used for this purpose are already indicated in this paper. A comparative study is discussed between three above mentioned devices for mitigating voltage sag. From this study it is clear that the Auto-Transformer is more efficient in mitigating the voltage sag

#### V. CONCLUSION

Among the different power quality problems, voltage sag is one of the major one affecting the performance of the end user appliances. In this project the methods to mitigate the voltage

sag are presented. From this project, the following conclusions are made-

- Among the different methods to mitigate the voltage sag, the use of FACT devices is the best method
- The FACT devices like DVR, D-STATCOM are helpful in overcoming the voltage unbalance problems in power system
- DVR is a series connected device and injects voltage to compensate the voltage imbalance
- D-STATCOM is a shunt connected device and injects current into the system
- These devices are connected to the power network at the point of interest to protect the critical loads
- These devices also have other advantages like harmonic reduction, power factor correction
- The research can further be extended to;
- Implementation of digital controllers to control the power electronic switches present in the device
- To study the operation of the devices in mitigating other voltage problems that occurs in power system

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