A Literature Review on Dynamic Voltage Restorer for Voltage Sags Mitigation in Medium Voltage Networks with Secondary Distribution Configuration

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Abstract - In recent years, utilities have been facing rising number of complaints regarding quality of power due to sags and swells. The paper is focused on the analysis of research works on mitigation of voltage sag problems in medium voltage with secondary distribution networks configuration and have been reviewed with aspect to DVR technology .The DVR (Dynamic Voltage Restorer) is a power custom device used to restore the load voltage to pre-sag voltage conditions during sag event. The DVR normally installed between the sources. Voltage and critical or sensitive load .DVR has to automatically detect and inject required voltage into the system whenever power quality problems occur. The Dynamic Voltage Restore (DVR) has become widely accepted as a cost effective key for the protection of sensitive loads from disturbances.

Keywords: - Dynamic voltage restorer (DVR), Voltage sag, Power quality, PI controller, Synchronous Reference Frame Theory (SRF theory).

1. INTRODUCTION

In the 19th century, with the introduction of electrical energy, after undergoing considerable technological advancements the present day electric power systems have been built. These electric power systems have been developed in complications and these days they are the outcome of a huge network of distribution system. In the last century the quality of life has increased significantly due to these technological progress and many other technical accomplishments. However, there has been a start of straining the power generation systems because of the ever growing population, the industry development, the increased generation sources at the load and the network's intrinsic volatility. This results in voltage fluctuations (dips and interruptions) in electricity supply. Electronic component which are used in modern power systems are sensitive to perturbations of voltage waveform, even a slight non-conformity of power quality delivered by the electricity companies, can cause consumers suffer huge financial losses and the end of comfort. Voltage dips and interruptions in electrical distribution system is one of the key factors for arising such problems. Equipment based on power electronic components can be used in power distribution systems with assistance for providing solution for a wide range of problem in electricity. These types of power electronic equipments, known as Custom Power Devices, are capable to improve the quality of power. Dynamic Voltage Restorer (DVR) is one such custom power device capable to provide the necessary voltage control at common union point with the electricity distribution network for voltage quality improvement. This research discusses the performance of the DVR for improving the voltage quality in medium voltage distribution networks with secondary distribution configuration.

1.1 MEDIUM VOLTAGE DISTRIBUTION NETWORK WITH SECONDARY DISTRIBUTION STRUCTURE

In urban areas, the MV distribution networks are compiled of large radial arrangements which can be attained using primary distribution or secondary distribution configurations.

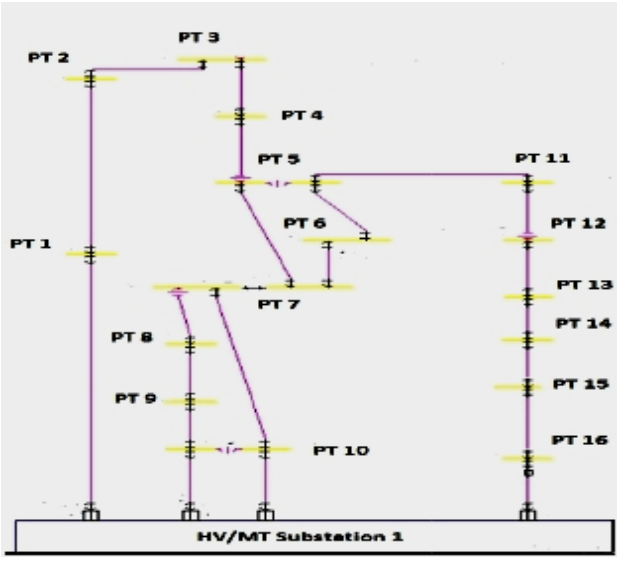

Fig.1.1 Primary distribution network configuration

A large number of transformer rooms are installed in input output configuration, along a loop that is powered directly from the medium voltage bus bar of the power substation, In the case of primary distribution configuration, presented in figure 1.1.If the power station is supplied with at least two HV/MV transformers with same medium voltage level, the end of the loop is preferred to be connected to either of the medium voltage bus bar in other HV/MV power station with same medium voltage level or another bus bar section from the first HV/MV power stations.

On the other hand, a secondary distribution configuration means a further medium voltage connection substation as is shown in figure 1.2. This connection substation has two power supply, one main and another backup supply.

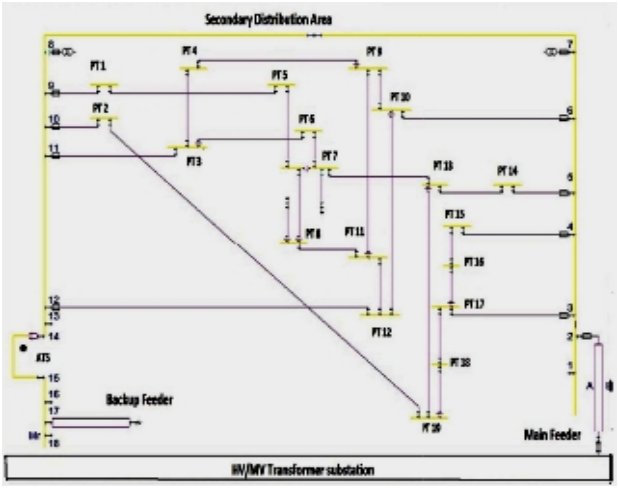

Fig1.2 Secondary distribution network configuration.

Main power supply is provided though a double-circuit underground cable connected to a medium voltage bus bar of the power stations. The backup power supply is the one provided through another double circuit underground cable connected to a dissimilar power station bus bar from an additional section of the bus bar of the initial HV/MV power stations with same medium voltage level, if this power station is provided with at least two HV/MV transformers with same medium voltage level.

In this medium voltage connection substation, the backup power line is connected to a backup bus bar, which can supplies another power line that provides power backup for a second medium voltage connection substation.

With two power supply, this connection substation can be provided with an automatic transfer switch between the main supply and backup supply and automatically the power supply will be restored if a permanently fault occurs on the main power supply. The main bus bar of the connection substation feeds up to eight distribution branches. This connection types allows a better flexibility in the choice of opening stage for the network.

1.2. Dynamic Voltage Restorer

DVR is one of the excellent ‘‘custom power” devices in distribution network which is connected in series with transmission line. Load voltage gets balance by injecting three phase controlled voltages during disturbance in the power system. DVR is based on injection of requisite voltage when ever voltage sag occurs to compensate it. Functionally, DVR can be categorized as two types : Standby mode and Injection mode. In the standby mode a low voltage is injected into the network to compensate voltage sag caused by transformer reactance. In injection mode, DVR injects appropriate voltage to sensitive load to compensate voltage sag. DVR circuit consists of 5 main components. They are shown in Fig.1.3

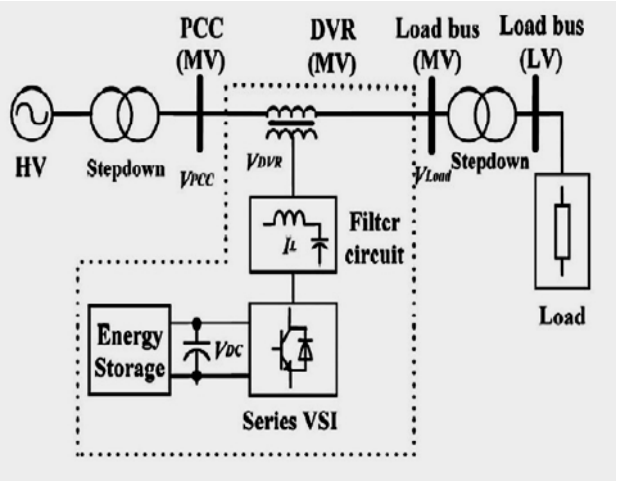

Fig.1.3 B**asic** Structure of DVR

(1) Series transformer: Its primary winding is linked to the inverter and its secondary winding is linked to the and sensitive load and distribution network.

(2) Voltage inverter: The inverter is attached to the injection transformer. In this inverter, energy storage equipment has been well thought-out. This inverter includes IGBT switches self commutating by shunt diodes and PWM control technique is used.

(3) Energy storage equipment: Power storage resources like capacitor banks, batteries, flywheels and SMES which have been used for supplying adequate voltage, active power and compensating sag.

(4) Passive filter: It is linked to the high voltage side of inverter to get rid of harmonics produced by switching.

(5) Control system: Voltage sag detection is the basic logical fundamental of control system providing appropriate switching strategies for the inverter.

The DVR Voltage Control system uses the abc-dq transformation to calculate Vd and Vq. In balance condition, the voltages Vd is equal to unity and Vq is equal to zero. But in fault condition, these voltages change. We can control the changes of these signals by compare these voltages signal with their references and giving their error signals to a PI controller.

2. SYSTEM MODEL

The Block diagram of the DVR system is shown in Fig. 1.4, where is the voltage of the ac system injected in the control strategy which also is connected by three phase DVR The DVR is connected in series with the ac system.

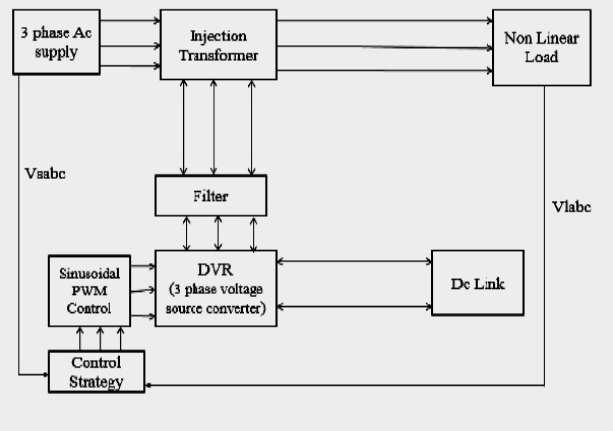

Fig. 1.4 Basic configuration of a DVR.

PWM control is achieved by comparing the Sine Wave (Reference Signal) and Triangular Wave (Carrier Signal) with the help of comparator and to give positive gate pulses to the upper switches of the inverter and the negative gate pulses are given to the lower switch of the inverter.

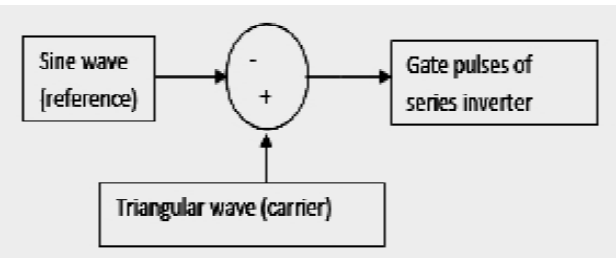

Fig.1.5 Basic representation sinusoidal pulse width modulation

A power electronic converter consists of a dc link storage and Thyristor based switching devices, which can produce a sinusoidal voltage for our require. In DVR application, VSC is used to for a moment change the utility voltage or to generate the required part of the utility voltage which is missing.

There are four main kinds of switching devices they are GTO -Gate Turn-Off Thruster, MOSFET –Metal Oxide Semiconductor Field Effect Transistor, IGBT-Insulated Gate Bipolar Transistor and. Each type has its own limitations and advantages. The IGCT is a modern compact device with better performance and reliability that allows constructing VSC with very large power ratings. Because of the highly developed converter design with IGCTs, the DVR can compensate distortions which are beyond the capability of the earlier DVRs using usual devices. The purpose of storage devices is to give the essential energy to the VSC through the dc line for the generation of injected voltage.

3. PREVIOUS WORK

Gheorghe-Ioan Nicolaescu, Horia Andrei, Stefan Radulescu [1] [2]This research discusses the performance of a dynamic voltage restorer (DVR) used for improving the voltage quality in medium voltage distribution networks with secondary distribution configuration. The DVR compensator is analyzed as a rectifier & inverter based voltage controller. Matlab/Simulink modeling of DVR and his control strategy are presented. The DVR performances are compared for different grid connection of the DVR rectifier. The obtained results demonstrate the performances and the benefits of dynamic voltage restorer use in power network with secondary distribution structure

Yanpeng Li, Tianzheng Wang,Yongxiang Li,Dongdong Yang,Lu Bai [3]The voltage sag is one of the most serious power quality problems, especially for the sensitive power user. At present, dynamic voltage restorer (DVR) is the effective solution to suppress the voltage sag. And the control strategy of DVR determines its dynamic performance. In this research, a new control strategy, closed-loop control integrated with feed forward adjustment based on interference voltage, is proposed to resolve current defects of DVR control system. The new control strategy not only improve steady margin but also speed up system dynamic response.

Md.Shahedul Alam, S. M. Shahnewaz Siddique [4] FACTS devices such as Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), and Unified Power Flow Controller (UPFC) etc are designed for improving power quality in the transmission system. But these devices are now modified to be used in the distribution system rated from 1 to 38kV

for the improvement of power quality and known as Custom Power Devices (CPD). The main custom power devices are Distribution Static Synchronous Compensator (DST A TCOM), Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC). Among these devices DVR can work as a harmonic isolator to prevent the harmonics in the source voltage reaching the load in addition to balancing the voltages and providing voltage regulation that facilitates to use it against power quality problem like voltage sag. This research presents implementation and control of a low voltage Dynamic Voltage Restorer (DVR) using Park's Transformation for minimizing voltage sag problem in distribution system.

Kohila, J., Kannan, S., & Kumar, V. S[5] This research presents a Synchronous Reference Frame Theory (SRF theory) based control strategy for Dynamic Voltage Restorer (DVR) using MATLAAB/ SIMULINK. The DVR is a normal three phase inverter which converts DC to AC and vice-versa using the dc link capacitor. Whenever utility is distorted by voltage related faults, DVR is active and it protects the load from utility distortions. The control strategy for the DVR plays an important role to make the DVR in heart of the DVR. The research also deals with how the DVR is performing with three phase voltage distortion condition.

Table 1: Summary of Literature Review

SR. NO.	TITLE	AUTHORS	YEAR	METHODOLOGY
1	Modeling and Simulation of Dynamic Voltage Restorer for Voltage Sags Mitigation in Medium Voltage Networks with Secondary Distribution Configuration	Gheorghe-Ioan Nicolaescu	May 2014	The performance of a dynamic voltage restorer (DVR) used for improving the voltage quality in medium voltage distribution networks with secondary distribution configuration.
2	PI controller and park's transformation based control of dynamic voltage restorer for voltage sag minimization	Mohammad Faisal.	Oct. 2014	This research present Control technique based on Park's Transformation provides better sag improvement than PI Control
3	Fast response DVR control strategy design to compensate unbalanced voltage sags and swells in distribution systems.	Tavighi	July 2013	A new multilevel voltage-source inverter with separate DC sources is proposed for high-voltage
4	Power Quality Improvement in Low Voltage Distribution System Using Dynamic Voltage Restorer	Rosli Omar	March 2010	The new configuration of DVR has been proposed using improved d-q-o controller technique. The proposal is then implemented using 5KVA DVR experimental setup.
5	Design of a Capacitor-Supported Dynamic Voltage Restorer (DVR) for Unbalanced and Distorted Loads	Arindam Ghosh	Jan. 2004	The research discusses the operating principles and control characteristics of a dynamic voltage restorer (DVR) that protects sensitive but unbalanced and/or distorted loads.

Mohammad Faisal,Md. Shahedul Alam [6] Modern electronics based on power electronic devices such as Programmable Logic Controllers (PLC), Distributed Control System (DCS) are used frequently in industrials plants to improve efficient production. These systems are extremely sensitive to power quality problem like voltage sag. Voltage sag is considered to be one of the most severe problems that cause failure, overheating and finally a total shutdown of industrial plants. It has been observed that, Dynamic Voltage Restorer (DVR) is the most efficient and effective modern custom power device exercised in power distribution networks to minimize voltage sags. The efficiency of the DVR depends on the performance of the control technique, which involved in switching the inverters. This research presents modeling, analysis and simulation of a Dynamic Voltage Restorer (DVR) test systems using MATLAB Simulink for minimizing voltage sag by two promising controlling strategies: control using PI controller and control based on Park's Transformation. Simulation results of DVR controlling found by MATLAB Simulink here which demonstrates the well-organized plant applications. Moreover, this work shows that, control based on Park's Transformation provides better sag improvement than PI Control.

Arash Tavighi, Hamed Abdollahzadeh, José Martí [7] The

Synchronous Reference Frame (SRF) has been known as one of the most common methods of voltage sag compensation. Despite suitable performance in 3-phase voltage sags mitigation, the application of the SRF does not work that well in unbalanced situations. This research addresses this problem, through the use of a novel control strategy based on the pre-fault compensation theory. In this strategy, not only the control system is capable of restoring the amplitude of the voltage to its pre-fault value, but it also can remove phase angle jumps. Furthermore, the compensator's response has been remarkably improved with the application of a Least Squares (LS) algorithm in the estimation part of the control module. The response and accuracy of the proposed LS estimation algorithm is compared with other conventional methods such as SRF, Adaptive Linear Combiner (ADALINE), and Fast Fourier Transform (FFT). Finally, the proposed and SRF control algorithms are simulated in, and their performance is assessed in voltage sag/swell mitigation of a distribution system during asymmetrical faults.

Rosli Omar N.A Rahim [10] This research discusses the mitigation of power quality disturbance in low voltage distribution system due to voltage swells using one of the powerful power custom devices namely Dynamic Voltage Restorer (DVR). The DVR normally installed between the source voltage and critical or sensitive load. The new configuration of DVR has been proposed using improved d-q-o controller technique. The proposal is then implemented using 5KVA DVR experimental setup. The simulation and experimental results demonstrate the effective dynamic performance of the proposed configuration.

Amrita RAI and A. K. Nadir [12] The aim of this research is to summaries the fundamental aspects of voltage sag, production and their effects on power quality as well as enhancing this power quality in distribution network, using FACTS (Flexible AC Transmission System) Devices i.e. Dynamic Voltage Restorer (DVR). DVR is a powerful custom power device for short duration voltage compensation, which hence it possesses some advantages. (In this research detailed is connected in series with the load modeling and simulation and analysis of the DVR device is presented).

Arindam Ghosh [15] The research discusses the operating principles and control characteristics of a dynamic voltage restorer (DVR) that protects sensitive but unbalanced and/or distorted loads. The main aim of the DVR is to regulate the voltage at the load terminal irrespective of sag/swell, distortion, or unbalance in the supply voltage. In this research, the DVR is operated in such a fashion that it does not supply or absorb any active power during the steady-state operation. Hence, a dc capacitor rather than a dc source can supply the voltage source inverter realizing the DVR. The proposed DVR operation is verified through extensive digital computer simulation studies.

4. PROBLEM IDENTIFICATION

The fundamentals of DVR based on multilevel inverter with series configuration. The Dynamic Voltage Restorer with 3 level inverter is used in previous research work. Now 5 levels & 7 level inverter based DVR using pulse width modulation technique are being used which will improve the inverter output as compared to the already used 3 level inverter in previous research work, and the viability is verified by the experimental results. The experimental results may further improve and will confirm the feasibility and effectiveness in improving power quality, stability and reliability in medium voltage network with secondary distribution configuration.

5 .CONCLUSION

This paper proposes analyzing the dynamic model of DVR which is efficient custom power device for mitigating voltage transients, flickers, sags and swells. The effect of voltage flicker, sag, swell and transient on sensitive equipments is severe. With the rising industrialization and developing society, there has been a huge surge in demand of electric power supply and the overall stability of the electrical distribution network has become a major concern. In order to protect sensitive loads from severe faults in Medium Voltage Distribution Network the use of DVR is more reliable providing stability which improves power quality .DVR based multilevel, inverter has been broadly accepted as a most efficient solution owing to its low cost and small size with fast dynamic response. DVR provides reliability and cost effective solution to compensate voltage magnitude as compared to other custom power electronic devices. To get the compensating signal for Sinusoidal Pulse Width Modulation Technique, PI controller is used. The results show the efficiency of DVR under fault condition of voltage sag and voltage swell.

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