

Review paper on Mitigating Voltage Sags/Swells using Converter based Dynamic Voltage Restorer

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Abstract—Power quality has become a major concern of the modern industries in the present era. Voltage sags/swells are considered as the most significant power quality problems because of increasing complexity in the power system. To overcome these problems, Custom Power Devices (CPD) is connected closer to the load end. One of those devices is Dynamic Voltage Restorer (DVR) which is a series connected most efficient and effective modern CPD used in power distribution network. The main function of the DVR is to monitor the load voltage constantly and if any sag or swell occurs, it can quickly mitigate by injecting the balance (or excess) voltage to the load voltage. The primary advantage of the DVR is keeping the users always on-line with high quality constant voltage to maintain the continuity of production.

Keywords: -Dynamic Voltage Restorer, Custom Power Device, Voltage Sag, Swell, Distribution Transform.

I. INTRODUCTION

The voltage sag or swell which is usually encountered in distribution systems can be compensated by three-phase DVRs. In general, when the sag or swell in any phase is sought to be compensated by using the power from the other phases, extensive signal processing is required. This is mainly because of the phase shift and of the non-linear magnitude of the voltage available for compensation. In this work new control procedure is presented without involving intensive computations, which is mostly analog and which would take care of the phase shift and of the non-linear magnitude of the voltage available for compensation when the power is utilized from the other two phases [1]. In this paper, an application is discussed in which the sag is controlled by using the power from the same phase while the swell is brought down by using the power from the other two phases. However, the potential of the basic control procedure is not limited to the above strategy, but can be applied to a variety of other sag and swell mitigation schemes also. The emphasis is not to establish the superiority or otherwise of any of the arrangements of diverting power from any one phase to other phases for mitigating the sag or swell [2]. The core of the work deals with the simplicity of the new control procedure employed for such diversion of power. The feedforward nature of the control leads to stable operation. Its effectiveness has been demonstrated by simulations. The modern manufacturing and process

equipment which operates at high efficiency require high quality power for the successful operation of their machines [3].

The failure of required quality power can cause complete shutdown of the industries which will make a major financial loss to the industry concerned. In practice, power systems, especially the distribution system has numerous nonlinear loads which produce power quality problems such as voltage sag and swell, flicker, harmonics, distortion, impulse transient and interruptions [4]. Among these, two power quality problems such as voltage sag and swell have been identified a major concern to the customers. The voltage sag and swell have major impact on the performance of the microprocessor based loads as well as the sensitive loads [5]. Though there are many different methods to mitigate voltage sag and swell, but the use of a custom Power device is considered to be the most efficient method. The term custom power pertains to the use of power electronics controllers in a distribution system specially to deal with various power quality problems. Dynamic Voltage Restorer (DVR) is one of the most efficient and effective modern custom power device used in power distribution networks. DVR is series connected solid state device that injects voltage into the system in order to regulate the load side voltage [6]. It is normally installed in the distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sag and swell compensation, DVR can also have other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

II. LITERATURE REVIEW

Taeyong Kang et al. [1], this paper displays an arrangement voltage controller for a dispersion transformer which tends to control quality issues in the electrical power circulation framework. The proposed framework is involved a line recurrence transformer associated with a power electronic converter which is auto-associated on the auxiliary side. This auto-association is encouraged by utilization of a high-recurrence or then again medium recurrence transformer.

A rearranged system to make up for voltage lists and swells on the matrix side, by giving ceaseless air conditioning voltage guideline, is talked about. Whenever a voltage lists or swells happen, the power electronic converter produces a remunerating voltage, which is vector-added to the lattice voltage so as to control the yield voltage provided to the load. The proposed framework fulfills needs of brilliant dissemination networks regarding improved accessibility, hardware assurance, and flexibility. Nitty gritty investigation is given test results so as to approve the adequacy of the proposed framework.

A. Rauf et al. [2], this paper manages improving the voltage nature of delicate burdens from voltage droops utilizing a dynamic voltage restorer (DVR). The higher dynamic power necessity related with voltage stage bounce pay has caused a generous ascent in size and cost of the dc connects vitality stockpiling arrangement of DVR. The current control procedures either moderate the stage bounce or improve the usage of dc interface vitality by the accompanying: 1) lessening the sufficiency of the infused voltage or 2) advancing the dc transport vitality support. In this paper, an upgraded droop pay methodology is proposed, which mitigates the stage bounce in the heap voltage while improving the general hang remuneration time. An explanatory investigation demonstrates that the proposed technique altogether expands the DVR hang bolster time (over half) contrasted and the current stage bounce remuneration strategies. This improvement can likewise be viewed as an impressive decrease in dc interface capacitor estimate for new establishment. The exhibition of the proposed strategy is assessed utilizing reenactment study lastly confirmed tentatively on a scaled research center model.

S. Jothibasu et al. [3], dynamic voltage restorer (DVR) is an authoritative arrangement toward remuneration of voltage hang with stage bounce. Ordinary DVR topologies, in any case, have dc connections and two-organize control changes. This expands its size, cost, and related misfortunes. Subsequently, topologies without the dc interface, moderating hang by using direct air conditioning air conditioning converters, are ideal over the traditional ones. As no capacity gadget is utilized, remuneration by these topologies is restricted distinctly by the voltages at the purpose of basic coupling that is sustaining the converters. In this paper, an immediate air conditioning air conditioning converter-based topology encouraged with line voltages is proposed. The plan gives expanded scope of pay as far as extent and stage edge revision. Point by point recreations have been completed in MATLAB to think about the capacity of the proposed topology with other comparable topologies. Test results are displayed to approve the capacity of the topology to repay different lists.

J. Kaniewski, et al. [4], the parameters of electrical vitality, for example, supply voltage sufficiency, are significant, particularly from the perspective of the last purchaser concerning delicate burdens associated with the network. Dynamic states in the power framework voltage hangs and swells-may make blames and imperfections create in delicate burdens. To relieve undesirable impacts, numerous topologies of air conditioning/air conditioning converters are actualized as voltage compensators. This article displays an audit of half and half air conditioning/air conditioning converters intended to repay voltage hangs and swells with the point of ensuring delicate burdens against unexpected and extreme changes in supply voltage plentifulness. In this article, just arrangements without galvanic detachment among source and burden are depicted. To survey the properties and to think about various topologies of voltage compensators, some basic parameters, for example, scope of voltage list and swell pay, unwavering quality, amount of switches and transformers, and required power evaluations of intensity electronic units in connection to intensity of burden, are presented. Moreover, we examine potential outcomes for remuneration of voltage intrusion, time of pay, the proficiency, and the impact on the supply system of the portrayed circuits. The aftereffects of the examination have been gathered and thought about in forbidden structure and spoke to in graphical structure. Moreover, we show potential territories of utilization for specific arrangements of air conditioning voltage compensators.

Radi et al. [5], the future substation relies upon figuring out how to relieve the impacts of the downsides of the ordinary inheritance by utilizing the proficiency of the strong state switches [1]. This paper talks about the contemplations of planning a circulation transformer that gives extra capacities in directing the voltage and controlling the receptive power that is infused in the dissemination organize, utilizing a fragmentary appraised converter appended mostly with the windings of the transformer. This methodology points mostly to upgrade the unit with greater adaptability in controlling the voltage at the last mile of the system, so as to diminish the misfortunes and meet the future desires for low voltage systems alterations, and that by utilizing an influence electronic (PE) approach has not so much misfortunes but rather more usefulness (contingent upon the dependability of transformer and knowledge of PE). The plan of a half and half circulation transformer is point by point and its usefulness in controlling the voltage is examined as a mix between the highlights of a standout amongst the most dependable system gadgets, the transformer, and the impact of PE presence with less misfortunes in both exchanging and conduction misfortunes. Decreased evaluations PE are utilized in this methodology, whereby

the strong state switches are controlled by the prompt requirement for voltage control in low voltage (LV) systems.

J. Kaniewski et al. [6], this paper presents a combined phase-shift and frequency modulation scheme of a dual-active-bridge (DAB) ac-dc converter with power factor correction (PFC) to achieve zero voltage switching (ZVS) over the full range of the ac mains voltage. The DAB consists of a half bridge with bidirectional switches on the ac side and a full bridge on the dc side of the isolation transformer to accomplish single-stage power conversion. The modulation scheme is described by means of analytical formulas, which are used in an optimization procedure to determine the optimal control variables for minimum switch commutation currents. Furthermore, an ac current controller suitable for the proposed modulation scheme is described. A loss model and measurements on a 3.3-kW electric vehicle battery charger to connect to the 230 V_{rms} / 50-Hz mains considering a battery voltage range of 280-420 V validate the theoretical analysis.

Sastry, J. et al. [7], a single-stage bridgeless ac-dc PFC converter using a lossless passive snubber and valley switching is proposed. The proposed converter is based on a two-stage bridgeless boost-flyback converter. In the proposed converter, the conduction losses are reduced by removing an input full-bridge diode rectifier. The boost inductor is designed to be operated in the discontinuous-conduction mode for achieving high power factor. In the flyback module, the couple inductor that provides input-output electrical isolation for safety is designed to be operated in the critical-conduction mode for low RMS current and low turn-on switching loss by using valley-switching operation. Because of the lossless snubber circuit, the voltage spike of switch is clamped, and the leakage inductor energy is recycled. The snubber capacitor is used as a dc-bus capacitor, which is divided into two capacitors. In addition, some input power is directly conducted to the output, and the remaining power is stored in dc-bus capacitor. So, low-voltage rating capacitors can be used as the dc-bus capacitor and power transfer efficiency is improved. The presented theoretical analysis is verified on an output 48-V and 60-W experimental prototype.

III. POWER QUALITY

Over the last thirty years or so, the amount of equipment containing electronics has increased dramatically. Such equipment can both cause and be affected by electromagnetic disturbances. A disturbance that affects a process control computer in a large industrial complex could easily result in shutdown of the process. The lost production and product loss/recycling during start-up represent a large cost to the business. Similarly, a protection relay affected by a disturbance through

conduction or radiation from nearby conductors could trip a feeder or substation, causing loss of supply to a large number of consumers. At the other end of the scale, a domestic user of a PC has to re-boot the PC due to a transient voltage dip, causing annoyance to that and other similarly affected users. Therefore, transporters and users of electrical energy have become much more interested in the nature and frequency of disturbances in the power supply. The topic has become known by the title of Power Quality. The main reasons for concern with power quality (PQ) are as following [7]:

- End user devices become more sensitive to PQ due to many Microprocessorbased controls.
- Complexity of industrial processes: the re-startup is very costly.
- Large computer systems in many businesses facilities
- Power electronics equipment used for enhancing system Stability, operation and efficiency. They are major source of bad PQ and are vulnerable to bad PQ as well.
- Deregulation of the power industry
- Complex interconnection of systems, which results in more
- Severe consequences if any one component fails.
- Continuous development of high performance equipment: Such equipment is more susceptible to power disturbances.

IV. POWER QUALITY DISTURBANCES

Power quality disturbances can be summarized as follows

Voltage sag

Voltage sag is defined as the reduction of R.M.S voltage to a value between 10-90% and lasting for duration of half a cycle to one minute. Voltage sags are mostly caused by system faults and starting of induction motor of large rating.

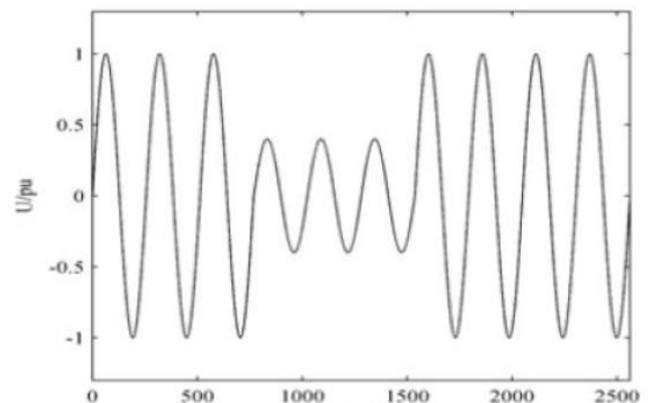


Figure 1: Voltage sag waveform

It may be also caused by switching operations associated with a temporary disconnection of supply, the flow of heavy current associated with the starting of a large electric motors or the flow of fault currents or the transfer of load from one power source to another. These events may emanate from customers' systems or from the public supply network. The main cause of momentary voltage dips is probably the lightning strike. Each of these cases may cause sag with a special characteristics (magnitude and duration). Figure 1 shows a waveform depicting voltage sags.

Voltage swell

Voltage Swell is defined as an increase in R.M.S voltage between 110 % to 180% at the power frequency for durations from 0.5 cycles to 1 min. They appear on the switching off of a large load; energizing a capacitor bank; or voltage increase of the unfaulted phases during a single line-to ground fault. Figure 2 shows a waveform of voltage swell.

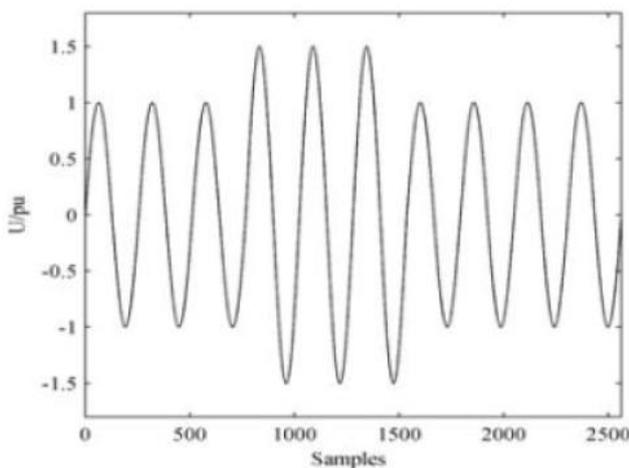


Figure 2: Voltage swell waveform

V. STRUCTURE OF DVR

DVR is a series connected device located between sensitive load and grid insystem. It detects both voltage sag/swell problems and injects controlled voltage to system. Additionally, it can be used for harmonics compensation and transient reduction in voltage and fault current limitations in available literature. To perform these processes, DVR injects a controlled voltage in series with the supply voltage in phase via injection transformer to restore the power quality.

It can be divided into four categories: inverter, DC-link capacitor, filter andinjection transformer. An inverter system is used to convert dc storage into ac form.Passive filter is responsible for eliminating the unwanted harmonic components generated in inverter.

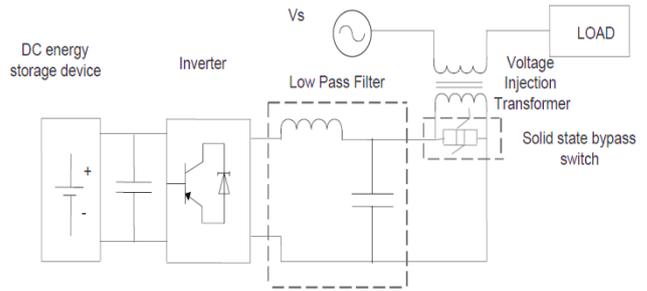


Figure 3: Basic structure of a conventional DVR

In this way, it converts inverter PWM output to sinusoidal waveform. Another component, energy storage unit such as batteries, super capacitors, SMES etc. is used to provide energy requirement in DC form. Lastly, transformer injects controlled voltage and provides isolation between load and the system.

The basic function of DVR is to compensate the voltage sag/swell bytransfer the voltage from DC side of the inverter to the injected transformer after the filter.The compensation capacity of a particular DVR depends on the maximum voltage injection capability and the active power that can be supplied by the DVR.When DVR's voltage disturbances occurs active power or energy should be injected from DVR to the distribution system. A DC system which is connected to the inverter input contains a large capacitor for storage.It provides reactive power to the load during faulty conditions.Therefore, there is a minimum voltage required below which the inverter of the DVR cannot generate the require voltage thus, size and rating of capacitor is very important DVR power circuit. The DC capacitor value for a three phase system can be derived. The most important advantage of these capacitors is the capability to supply high current pulses repeatedly for hundreds of thousands of cycles.

COMPONENTS OF DVR

The main components of DVR are energy storage unit, converter circuit, filter unit and series injection transformer. The components are described with more details on the following.

Inverters

The common inverter connection methods for three phase DVRs are 3 phase Graetz bridge inverter, Neutral Point Clamp inverter.

Voltage Source Inverter

Generally Pulse-Width Modulated Voltage Source Inverter (PWM VSI) is used. The most common inverter topologies are the two- or three-level three-phase converter where the dc-side capacitor(s) is connected alternately to all ac phases.

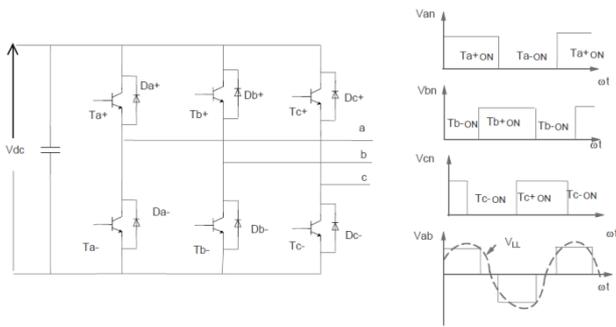


Figure 4: Three phase Inverter and its switching arrangement

The inverter configuration, switching and output waveforms for the fundamental switching are shown in Figure 4.

This is referred to as two-level since the phase output voltage waveform consists of two output levels; $+V_d$ and 0 Volts. The basic function of the VSI is to convert the DC voltage supplied by the energy storage device into an AC voltage. In the DVR power circuit step up voltage injection transformer is used. Thus a VSI with a low voltage rating is sufficient. In three phase inverter each leg is switched according to the PWM technique used. In the case of fundamental switching is used then the switches are ON for a period of 180° with a duty ratio of 50%. The purpose of the capacitor is to absorb harmonic ripple and hence, it has a relatively small energy storage requirement, particularly when operating in balanced conditions. The size of this capacitor has to be increased, if needed, to provide voltage support in unbalanced conditions. Also, since the capacitor is shared between the three phases, sag on only one phase may cause a distortion in the injected current waveforms on the other phases.

H Bridge Inverter

Another popular converter topology is the H-bridge cascade inverter. A single phase of this converter and its switching arrangement is shown in Figure 5. For fundamental switching each switch is ON for a duty cycle of 50%. Converters with this topology are suitable in power systems applications due to their ability to synthesize waveforms with reduced lower order harmonics and to attain higher voltages with a limited maximum device rating. The principle of operation for this topology is that each capacitor can be connected by means of the insulated-gate bipolar transistor (IGBT) switches so that its voltage contributes positively or negatively or not at all to the output waveform. In the H bridge inverter, four switches are used. When it used for multilevel arrangement especially for high voltage application, it is commonly called as chain circuits.

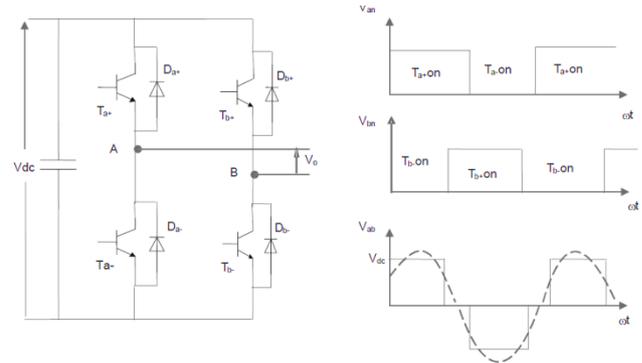


Figure 5: H-bridge inverter configuration and its switching arrangement

VI. CONCLUSION

Dynamic voltage restorers (DVR) are used to protect sensitive loads from the effects of voltage sags and voltage swells on the distribution feeder. The DVR is a cost – effective device which is placed in series with a sensitive load, must be able to respond quickly if end users of sensitive equipment are to experience voltage sags/swells. It is appropriate before choosing the rating of DVR components to determine a proper compensation strategy. The control algorithm based on in-phase injection method has been employed in the thesis. This method has ensured the minimum injected voltage magnitude and reduced active power injection especially for high power factor loads.

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