Converter Based Medium Voltage Dynamic Voltage Restorer (DVR) for Power Quality Improvement - A Survey

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Abstract - The most noticeable topic for electrical engineering is power quality in recent year. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency. Utility distribution networks, sensitive industrial load and critical commercial operation suffer from various types of outages and service interruption can cost significant financial losses. One of the major problems dealt here is the voltage sag. With the fast development in power electronics technology have made it possible to mitigate power quality problems. This work concentrates on the power quality problem such as voltage sag. Many of the devices such as STATCOM, tap changing transformer, UPFC and DVR are available to mitigate voltage sag problems. Among these, dynamic voltage restorer can provide the most commercial solution to mitigate voltage sag by injecting voltage as well as power in to the system. Dynamic Voltage Restorer is a series connected power electronics based device that can quickly mitigate the voltage sag in the system and restore the load voltage to the pre-fault value.

Keywords- UPFC, DVR, STATCOM, Power Quality Improvement, DFCM.

I. INTRODUCTION

The economy invested in the distribution system is large enough to take into account the concept of equipment protection against various disturbances that affects the reliability of not only the distribution system but the entire power system incorporating generation & transmission too. The wide acceptance of sophisticated electronic devices at the utility end deteriorates the quality of supply & utility is suffering from its bad effects on large scale. The various power quality problems[1] encompass the voltage sags, voltage dips & voltage swells, flickers, harmonics & transients accompanied by unbalanced power, which are results of various faults with three phase fault being the most severe among all, starting of induction motor which is most often used due to its rugged construction, switching off large loads and energizing of capacitor banks.

“Reliability” is a key word for utilities and their customers in general, and it is crucial to companies operating in a highly competitive business environment, because it affects profitability, which definitely is a driving force in the industry. Although electrical transmission and distribution systems have reached a very high level of reliability, disturbances cannot be totally avoided. Any disturbances to voltage waveform can cause problems related with the operation of electrical and electronic devices. Users need constant sine wave shape, constant frequency and symmetrical voltage with a constant rms value to continue the production. This increasing interest to improve efficiency and eliminate variations in the industry has resulted more complex instruments sensitive to voltage disturbances such as voltage sag, voltage swell, interruption, phase shift and harmonic. Voltage sag is considered the most severe since the sensitive loads are very susceptible to temporary changes in the voltage. In some cases, these disturbances can lead to a complete shutdown of an entire production line, in particular at high tech industries like semiconductor plants, with severe economic consequences to the affected enterprise. Figure 1.1 demonstrates the typical application of DVR in Circuitry.

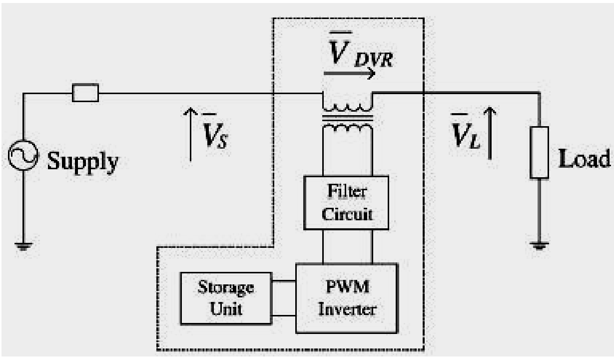

Figure 1.1 Typical Application of DVR.

The DVR is a power quality device, which can protect these industries against the bulk of these disturbances, i.e. voltage sags and swells related to remote system faults. A DVR compensates for these voltage excursions, provided that the supply grid does not get disconnected entirely through breaker trips. Modern pulse-width modulated (PWM) inverters capable of generating accurate high quality voltage waveforms form the power electronic heart of the new Custom Power devices like DVR. Because the performance of the overall control system largely depends on the quality of the applied control strategy, a high performance controller with fast transient response and good steady state characteristics is required. The main considerations for the control system of a DVR include: sag detection, voltage reference generation and transient and steady-state control of the injected voltage.

II. DYNAMIC VOLTAGE RESTORER

Among the power quality problems like sag, swell, harmonic etc, voltage sag is the most severe disturbances in the distribution system. To overcome these problems the concept of custom power devices is introduced lately. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks.

A DVR is a solid state power electronics switching device consisting of either GTO or IGBT, a capacitor bank as an energy storage device and injection transformers. It is linked in series between a distribution system and a load that shown in Figure 2.1. The basic idea of the DVR is to inject a controlled voltage generated by a forced commuted converter in a series to the bus voltage by means of an injecting transformer. A DC to AC inverter regulates this voltage by sinusoidal PWM technique. All through normal operating condition, the DVR injects only a small voltage to compensate for the voltage drop of the injection transformer and device losses. However, when voltage sag occurs in the distribution system, the DVR control system calculates and synthesizes the voltage required to preserve output voltage to the load by injecting a controlled voltage with a certain magnitude and phase angle into the distribution system to the critical load

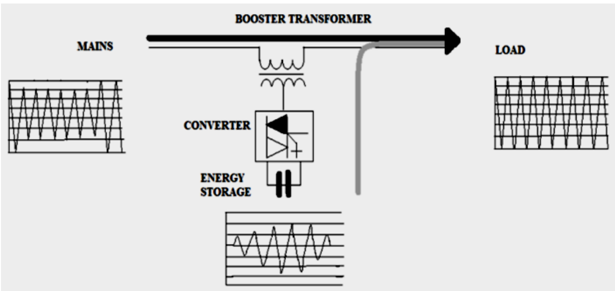

Figure 2.1 System Principle of DVR.

DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is generally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like line voltage harmonics compensation, reduction of transients in voltage and fault current limitations. The DVR capable of generating or absorbing reactive power but the active power injection of the device must be provided by an external energy source or energy storage system. The response time of DVD is very short and is limited by the power electronics devices and the voltage sag detection time. The predictable response time is about 25 milliseconds, and which is much less than some of the traditional methods of voltage correction such as tap changing transformers.

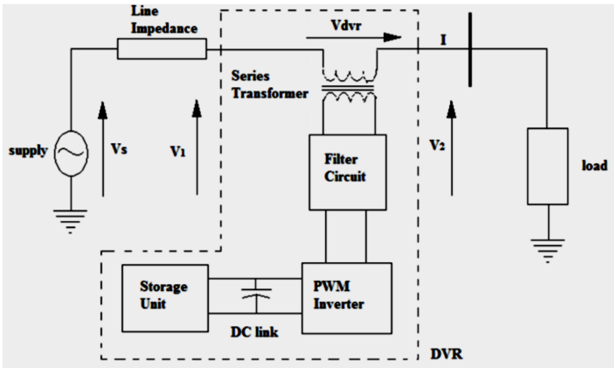

Figure 2.2 Schematic diagram of DVR.

III. PRIOR WORK

V. Dargahi, A. K. Sadigh and K. Corzine,[1] In the present electric power grids, power quality issues are recognized as a crucial concerns and a frequently occurring problem possessing significant costly consequence such as sensitive load tripping and production loss. Consequently, demand for high power quality and voltage stability becomes a pressing issue. Dynamic voltage restorer (DVR), as a custom power device, is one of the most effective solutions for “restoring” the quality of voltage at its load-side terminals when the quality of voltage at its source-side terminals is disturbed. In this exploration, a new DVR topology based on double flying capacitor multicell (DFCM) converter for medium-voltage application has been proposed. The advantage of the proposed DVR is that it does not need any line-frequency step-up isolation transformer, which is bulky and costly, to be connected to medium-voltage power grid. The proposed DVR topology obtains the required active power from the energy storage feeding the dc link of the DFCM converter. The pre-sag compensation method, which is explained in detail, is used to restore amplitude and angle of the sensitive load voltage. Moreover, an approach based on d-q synchronous reference frame to determine DVR reference voltages is utilized. The proposed DVR topology is simulated and results to illustrate its performance under various conditions of voltage sag compensation are provided.

F. Badrkhani Ajaei, S. Farhangi and R. Iravani,[2] This exploration introduces and evaluates an auxiliary control strategy for downstream fault current interruption in a radial distribution line by means of a dynamic voltage restorer (DVR). The proposed controller supplements the voltage-sag compensation control of the DVR. It does not require phase-locked loop and independently controls the magnitude and phase angle of the injected voltage for each phase. Fast least error squares digital filters are used to estimate the magnitude and phase of the measured voltages and effectively reduce the impacts of noise, harmonics, and disturbances on the estimated phasor parameters, and this enables effective fault current interrupting even under arcing fault conditions. The results of the simulation studies performed in the PSCAD/EMTDC software environment indicate that the proposed control scheme: 1) can limit the fault current to less than the nominal load current and restore the point of common coupling voltage within 10 ms; 2) can interrupt the fault current in less than two cycles; 3) limits the dc-link voltage rise and, thus, has no restrictions on the duration of fault current interruption; 4) performs satisfactorily even under arcing fault conditions; and 5) can interrupt the fault current under low dc-link voltage conditions.

P. Kanjiya, B. Singh, A. Chandra and K. Al-Haddad,[3] The protection of the sensitive unbalanced nonlinear loads from sag/swell, distortion, and unbalance in supply voltage is achieved economically using the dynamic voltage restorer (DVR). A simple generalized algorithm based on basic synchronous-reference-frame theory has been developed for the generation of instantaneous reference compensating voltages for controlling a DVR. This novel algorithm makes use of the fundamental positive-sequence phase voltages extracted by sensing only two unbalanced and/or distorted line voltages. The algorithm is general enough to handle linear as well as nonlinear loads. The compensating voltages when injected in series with a distribution feeder by three single-phase H-bridge voltage-source converters with a constant switching frequency hysteresis band voltage controller tightly regulate the voltage at the load terminals against any power quality problems on the source side. A capacitor-supported DVR does not need any active power during steady-state operation because the injected voltage is in quadrature with the feeder current. The proposed control strategy is validated through extensive simulation and real-time experimental studies.

A. Y. Goharrizi, S. H. Hosseini, M. Sabahi and G. B. Gharehpetian,[4] Conventional dynamic voltage restorers (DVRs) are connected to the power grid through power-frequency transformers. These bulky and costly transformers cause voltage drop and power losses. In this exploration, a high-frequency-link dynamic voltage restorer (HFL-DVR) is proposed based on transformer-isolated topologies. This topology facilitates independent operation conditions for each phase in a three-phase system. It enjoys relatively low cost, low losses, and small size. Also, it is free from transformer inrush currents. Small-signal ac equivalent circuit for the power stage including HFL-DVR is derived based on an averaged modeling approach. Transfer functions are obtained to study the effect of inputs such as dc-link voltage, grid voltage, and the load current on the output of HFL-DVR. In order to obtain acceptable properties such as transient overshoot, setting time, and steady-state error, a PID controller is added to the system. This shows that the effect of disturbances on the output of HFL-DVR can be reduced. The experimental results are obtained from a 220V/50Hz HFL-DVR setup. The simulation and experimental results have been compared to verify theoretical aspect of the proposed DVR for both symmetrical and asymmetrical voltage sag conditions.

F. M. Mahdianpoor, R. A. Hooshmand and M. Ataei,[5] he dynamic voltage restorer (DVR) is one of the modern devices used in distribution systems to protect consumers against sudden changes in voltage amplitude. In this exploration, emergency control in distribution systems is discussed by using the proposed multifunctional DVR control strategy. Also, the multiloop controller using the Posicast and P+Resonant controllers is proposed in order to improve the transient response and eliminate the steady-state error in DVR response, respectively. The proposed algorithm is applied to some disturbances in load voltage caused by induction motors starting, and a three-phase short circuit fault. Also, the capability of the proposed DVR has been tested to limit the downstream fault current. The current limitation will restore the point of common coupling (PCC) (the bus to which all feeders under study are connected) voltage and protect the DVR itself. The innovation here is that the DVR acts as a virtual impedance with the main aim of protecting the PCC voltage during downstream fault without any problem in real power injection into the DVR. Simulation results show the capability of the DVR to control the emergency conditions of the distribution systems.

M. Moradlou and H. R. Karshenas,[6] This exploration is concerned with calculating the optimum rating for two dynamic voltage restorers (DVRs) when used in an interline DVR (IDVR) structure. An IDVR consists of two or more DVRs which have a common dc link and, thus, can exchange active power. This can increase the compensation range of an IDVR compared with separate but otherwise similar DVRs. The basic operation of the DVR and IDVR is briefly explained. The limitations of IDVR operation in terms of active power exchange are explained and, based on that, the expressions governing the steady-state operation of IDVR are derived. The compensation range of an IDVR is compared with that of two separate DVRs. This exploration also explores how the limitations in absorbing power from a healthy feeder can narrow the compensation range of an IDVR. After identifying and formulating various limitations in IDVR operation, a design procedure is presented to determine the optimum size (or rating) of the DVRs in an IDVR structure. In the proposed approach, all possible scenarios concerning healthy and faulty feeders are taken into consideration. Examples along with graphs and tables aid in conveying the proposed approach.

Table 3.1 Summary of Literature Review.

SR. NO.	TITLE	AUTHOR	YEAR	APPROACH
1	Medium voltage dynamic voltage restorer (DVR) based on DFCM converter for power quality improvement	V. Dargahi, A. K. Sadigh and K. Corzine,	2016	The pre-sag compensation method, which is explained in detail, is used to restore amplitude and angle of the sensitive load voltage
2	Fault current interruption by the dynamic voltage restorer,	F. Badrkhani Ajaei, S. Farhangi and R. Iravani,	2013	Evaluates an auxiliary control strategy for downstream fault current interruption in a radial distribution line by means of a dynamic voltage restorer (DVR).
3	SRF Theory Revisited” to Control Self-Supported Dynamic Voltage Restorer (DVR) for Unbalanced and Nonlinear Loads,	P. Kanjiya, B. Singh, A. Chandra and K. Al-Haddad,	2013	A simple generalized algorithm based on basic synchronous-reference-frame theory has been developed for the generation of instantaneous reference compensating voltages for controlling a DVR.
4	Three-Phase HFL-DVR With Independently Controlled Phases,"	A. Y. Goharrizi, S. H. Hosseini, M. Sabahi and G. B. Gharehpetian,	2012	a high-frequency-link dynamic voltage restorer (HFL-DVR) is proposed based on transformer-isolated topologies
5	A New Approach to Multifunctional Dynamic Voltage Restorer Implementation for Emergency Control in Distribution Systems,	F. M. Mahdianpoor, R. A. Hooshmand and M. Ataei,	2011	Emergency control in distribution systems is discussed by using the proposed multifunctional DVR control strategy.
6	Design Strategy for Optimum Rating Selection of Interline DVR,	M. Moradlou and H. R. Karshenas,	2011	Calculating the optimum rating for two dynamic voltage restorers (DVRs) when used in an interline DVR (IDVR) structure.

IV. PROBLEM STATEMENT

The users demand higher power quality to use more sensitive loads to automate processes and improve living standards. Some basic criterions for power quality are constant rms value, constant frequency, symmetrical three-phases, pure sinusoidal wave shape and limited THD these values should be kept between limits determined by standards if the power quality level is considered to be high. The key issues of power quality are - Interruption/under voltage/over voltage, Voltage/Current unbalance, Power system harmonics, Power frequency disturbances, Power system transients, Voltage sag, Voltage swell, and Flicker.

V. CONCLUSION

A review of literature has done in this work. The electric power system is considered to be composed of three functional blocks - generation, transmission and distribution. For a reliable power system, the generation unit must produce adequate power to meet customer’s demand, transmission systems must transport bulk power over long distances without overloading or jeopardizing system stability and distribution systems must deliver electric power to each customer's premises from bulk power systems. Distribution system locates the end of power system and is connected to the customer directly, so the power quality mainly depends on distribution system. Power quality is a major issue of concern now a day. This work flash light on some of the major contribution in field of power quality improvement and power mitigation. Initially for the improvement of power quality or reliability of the system FACTS devices like static synchronous compensator (STATCOM), static synchronous series compensator (SSSC), interline power flow controller (IPFC), and unified power flow controller (UPFC) etc are reviewed.

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