Medium Voltage Dynamic Voltage Restorer (DVR) Based on DFCM Converter for Power Quality: A Survey

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Abstract- Power quality is one of major concerns in the present era, in order to maintain quality supply. Modern generation greatly depends on electrical energy for improving their life style. Modern equipment like computers, electric motors etc. cannot run without electricity. Improved and controlled power quality is one of the essential and fundamental need in any power driven industry for optimum utilization of resources [1]. The power quality is affected by various factors of the electrical network. Power quality problems such as voltage and frequency variation, harmonic contents affect the performance of electrical utility and shorten its life time. Such problem has to be compensated to ensure the quality supply. To solve this problem, custom power devices are used. 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 [1].

Keywords – DVR, Power Quality, DFCM converter, Double Flying Capacitor.

I. INTRODUCTION

Electrical energy is the simple and well regulated form of energy, can be easily transformed to other forms [1]. Along with its quality and continuity has to maintain for good economy. Power quality has become major concern for today's power industries and consumers. Power quality issues are caused by increasingly demand of electronic equipments and non-linear loads [1]. Many disturbances associated with electrical power are voltage sag, voltage swell, voltage flicker and harmonic contents. This degrades the efficiency and shortens the life time of end user equipment. It also causes data and memory loss of electronic equipment like computer.

Due to complexity of power system network voltage sag/swell became the major power quality issue affecting the end consumers and industries. It occurs frequently and result in high losses. Voltage sag is due to sudden disconnection of load, fault in the system and voltage swell is due to single line to ground fault results in voltage rise of unfaulted phases. The continuity of power supply can be maintained by clearing the faults at faster rate. Other power quality issues i.e. voltage flickering, harmonics, transients etc has to be compensated to enhance the power quality.

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice, power systems, especially the distribution systems, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems. Figure 1.1 demonstrated the single line diagram of power distribution system.

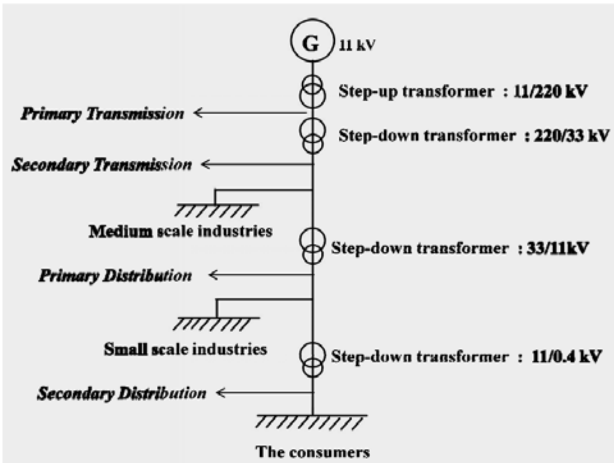

Figure 1.1 Single line diagram of power supply system

Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. The common method for this is to install mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching may be on a schedule, via signals from a supervisory control and data acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage is that, high speed transients cannot be compensated. Some sags are not corrected within the limited time frame of mechanical switching devices. Transformer taps may be used, but tap changing under load is costly.

Another power electronic solution to the voltage regulation is the use of a dynamic voltage restorer (DVR). DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

II. SYSTEM MODEL

Voltage sag/swell are one of considerable problem that our power system network is facing today. Without proper mitigation, such problem can cause severe problem and may result in failure of equipment. Modern development in custom devices can solve such problem. DVR is one of the effective solutions for compensation voltage sag/swell. This chapter gives an overview of DVR, its basic structure and operating principle.

A DVR is a series connected custom device that injects the appropriate/desired voltage to the load bus in order to maintain the voltage profile. However, in standard condition it is in stand-by mode. The compensating voltage is injected by three single phase transformers whose property can be controlled. These voltages are in synchronism with the load voltage. DVR has three mode of operation:

- Protection mode

In order to isolate DVR from the system during overload current caused by short circuit or large inrush current, bypass switches are provided. The current is supplied to the system using other path.

- Standby mode:

In this mode, Low Voltage winding of injection transformer is shorted. No switching operation occurs in this mode.

- Injection mode:

In this mode, DVR injects the compensating voltage through injection transformer.

A. Architecture of DVR

DVR is series connected compensating devices that restore/maintain the voltage profile at the sensitive loads under voltage unbalance. It is usually connected in the distribution network between Common Point of Coupling (PCC) and load. The disturbance in the system is detected by control scheme used which generates the triggering pulses for VSI. Passive filters are used to filter out the harmonic content of injected voltage. DVR injects the filtered output voltage through injection transformer. The basic structure of DVR shown in fig.2.1 consists of following blocks:

1) VSI
2) Injection transformer
3) Passive filter
4) Energy storage unit
5) Control circuit.

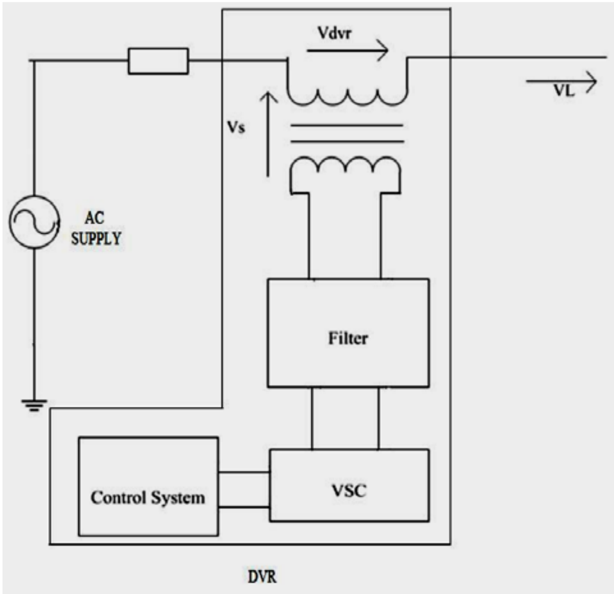

Figure 2.1 Basic Architecture of DVR.

B. DVR Control scheme

The main objective is to maintain voltage profile on the load bus where sensitive load is connected. Here only active power is measured. The switching pulse generated for VSI is based on SVPWM. It is a simple method and better than other PWM techniques. Normally, three phase inverters use SPWM technique. However, problem like large noise peak at carrier frequency are present in such technique. Hence, SVPWM has an advantage over such technique such as better dc utilization and easy implementation with digital signal processor. In this way, SVPWM is used as a control method for 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 research, 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.

A. Tashackori, S. H. Hosseini and M. Sabahi,[2] In this research a three-phase four-wire Dynamic Voltage Restorer (DVR) with bi-directional power electronic transformer structure is proposed to inject required compensating series voltage to the electric power system in such a way that continuous sinusoidal voltage is seen at load side ever at heavy fault occurrences at utility side. The proposed structure is composed of a three-phase four-leg inverter, three single-phase high frequency transformers, three cycloconverters and high frequency harmonic filter that are connected to the utility. Three dimensional space vector modulation (3DSVM) methods are used for pulse generation. Fourth added wire enables the DVR to compensate unbalance voltage disturbance that are custom power quality problems in electrical utility. The performance of the structure and applied switching scheme are verified under both balanced and unbalanced disturbances via simulation study in PSCAD/EMTDC software.

T. C. Archana and P. Reji,[3] In this research a new control algorithm for self-supported Dynamic Voltage Restorer (DVR) is analysed. DVR is used to mitigate the power quality problems in terminal voltage like voltage sag, swell, harmonics etc. Here two PI (Proportional Integrator) controllers are used for regulating the DC bus voltage and the load voltage. The focus of this research is to reduce the active power injected by DVR. Synchronous Rotating Frame (SRF) theory is used to extract the fundamentals of terminal voltage and reference voltage is genereted. The error between sensed load voltage and reference load voltage is used to generate the control signal for the DVR. The compensation of voltage sag, swell, harmonics is evaluated using the Self-supported DVR. The DVR has been modelled using MATLAB software with its Simulink and Sim-power system (SPS) block set tool boxes.

F. Badrkhani Ajaei, S. Farhangi and R. Iravani,[4] This research 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,[5] 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, [6] 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 research, 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.

IV. PROBLEM STATEMENT

Power Quality concerns about the utility ability to provide uninterrupted power supply. The quality of electric power is characterized by parameters such as “continuity of supply, voltage magnitude variation, transients and harmonic contents in electrical signals”. Synchronization of electrical quantities allows electrical systems to function properly and without failure or malfunction of an electric device. Poor PQ problems ultimately results in economic loss of the power system network. PQ mainly concerns to maintain voltage and current profile i.e. any deviation in these parameters can cause severe damage to the electrical utility and end consumers. An overview of many PQ problems along with their causes and consequences are presented.

V. CONCLUSION

Power quality problems are one of the major concerns in present electric power grids. In this brief power quality enhancement with help of DVR has discussed with the help of literature survey. Power the disturbances occur on all electrical systems, electronic devices makes them more susceptible to the quality of power supply. A power voltage spike can damage valuable components. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions DVRs are suitable devices to compensate these voltage disturbances, protect sensitive loads and restore their voltage during voltage sag.

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