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Review on Multilevel Inverter based DVR for Power Quality Improvement

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***Abstract*— Voltage sags and swells, flickers, interruptions, harmonic distortion and many other distortion are the main problems of the power quality and these power quality problem which are arise due to a fault so to solve this, custom power devices are used . One of the example of these devices is Dynamic Voltage Restorer[1]. Dynamic voltage restorer (DVR) is a power electronic converter-based custom power device used to compensate for voltage variations which is considered to be more efficient device.**

Keywords*— *Dynamic Voltage Restorer, Power Quality, Voltage sag

I. INTRODUCTION

Electrical energy is the simple and well regulated form of energy, can be easily changed to other forms. Along with its quality and continuity has to maintain for good economy. Power quality has become main concern for today's power productions and users. Due to the increasing demand of electronic equipments, Power quality problems are arised by increasing demand of equipments[2]. Many disturbances related with electrical power are voltage sag, voltage swell, voltage flicker and harmonic contents. This reduces the efficiency and shortens the life time of end consumer equipment. There is also data and memory loss problems of electronic equipment like computer.

The main power quality problems are voltage sags/swells because of the complex structure of power system network which affects end users and industries and result in high losses. Voltage sag is a small period reduction in rms voltage which can be produced by a short circuit , overload and fault in the system and voltage swell, which is a momentary increase in voltage ,happens when a heavy load turns off in a power system[3]. The continuity of power supply can be maintained by clearing the faults at faster rate. To enhance the power quality the power quality problems i.e. voltage sag/swell , voltage harmonics flickering has to be compensated.

Power electronic devices i.e. Distribution Static Compensator (D-STATCOM) and Dynamic Voltage Restorer (DVR) been recently used for voltage sag/swell compensation. In this project DVR is proposed which can protect the end-consumer load from any unbalance of voltage supply. It is a series compensating device, can maintain the load voltage profile even when the source side voltage is distorted. This series conditioner device is capable of generating or absorbing real and reactive power with the help of its essential components, namely power circuit & control circuit. Various control techniques are available to obtain a controlled output voltage, to be injected into the system. They are known as Linear & Non-linear techniques.

II. POWER QUALITY

Most of international standards describe power quality as the electric supply secured from any changes in voltage, current or frequency under normal situations & do not interrupt the customer's processes. Quality of power supply is mostly described by its two main factors : voltage quality & supply reliability. These main factors cause power quality difficulties when they suffer deviation in their features due to failure of equipments or sudden disturbances in the system[4].

The growing tendency of non linear loads cause harmful effects in the power system network suffered by the customer. Then the era of Custom Power devices introduced and eliminated these harmful effects caused by non linear loads.

III. DYNAMIC VOLTAGE RESTORER

The dynamic voltage restorer is a series connected device, which by voltage injection can control the load voltage. In the case of a voltage dip the DVR injects the missing voltage and it avoids any tripping the load. Fig. 1 illustrates the operation principle of a DVR[5].

The basic function of the DVR is to inject a dynamically controlled voltage V_{DVR} generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage V_L.

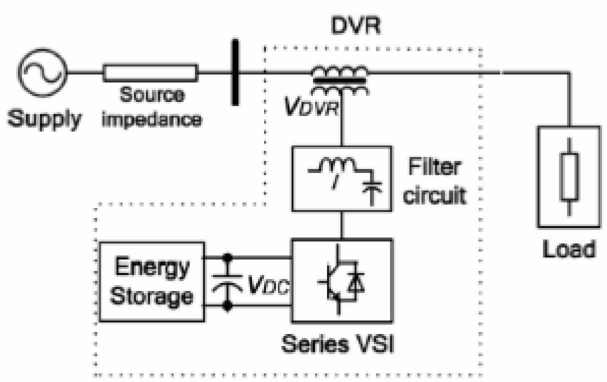

Fig. 1 : Basic circuit of DVR

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This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer.
The main components of the DVR consists of an injection transformer, harmonic filter, series VSI (VSC) , an energy storage and control system.

IV. MULTILEVEL CONVERTERS

Multilevel-converter technology has experienced a fast growing attention in the last decade, and several topologies have been reported. This section is focused mainly on the most established and commercialized multilevel inverters, i.e., the three-level NPC, the four-level FC, and the CHB converter, that will be analyzed for seven levels, although it is also commercially available in 9, 11, and 13 levels.

A. Neutral-Point Clamped

1) Topology Description: In the early 1980s, a new pioneering converter topology was the three-level NPC voltage-source converter (3L NPC-VSC), also known as diode-clamped converter. Since all semiconductors are operated at a commutation voltage of half the dc-link voltage, the topology offered a simple solution to extend voltage and power ranges of the existing 2L-VSC technology, which were severely limited by the blocking voltages of power semiconductors withactive turn-on and turn-off capabilities[6]. Hence, the converter was of particular interest for MV applications (2.3–4.16 kV). The 3L NPC-VSC was soon introduced to the market by leading manufacturers and gained more and more importance. NPC converters can be extended to generate more output-voltage levels However, these topologies have not found industrial acceptance to date and, therefore, will not be further discussed in this paper.
In a 2L VSC, a series connection of two switches per switch position is required to enable an operation at the same dc and converter voltage like a 3L NPC-VSC. The 3L NPC-VSC features two additional diodes per phase leg as compared to a 2L VSC with a direct series connection of two devices per switch position. These so-called NPC diodes link the midpoint of the “indirect series connection” of the main switches to the neutral point of the converter[7]. This allows the connection of the phase output to the converter neutral point N and enables the three-level characteristic of the topology. Table I shows the switch states of one phase leg.
Note that two pairs of switches of one leg receive inverted gate signals S_{ak} and S_{ak} (k = 1, 2) to enable a proper modulation and to avoid forbidden switch states[8]. The overall converter switching state can be defined by $S = (S_a, S_b, S_c)$, where, according to Table I, each phase switching state Sx ($x = a, b, c$) can be represented by a (+1) when generating $V_{dc}/2$, a (−1) when generating $–V_{dc}/2$, or a (0) when connected to the neutral point, hence generating zero-voltage level. Combining the states of all three phases, the 3L NPC-VSC features $n_{ss} = L_3 = 33 = 27$ switch states, where L is the number of voltage levels of v_{xN} ($x = a, b, c$). The different switch states can be represented in the complex $\alpha-\beta$ frame, simply by calculating the space vector ($\mathbf{v}_s$) associated to each switching state[9]

$$\mathbf{v}_s = \frac{2}{3}\left[v_{aN} + a v_{bN} + a^2 v_{cN}\right] = \frac{2}{3}\left[S_a \frac{V_{dc}}{2} + a S_b \frac{V_{dc}}{2} + a^2 S_c \frac{V_{dc}}{2}\right] \quad (1)$$

where $a = e^{j2\pi/3}$.Note that some switching states have redundant space-vector representations.
This redundancies can be used for neutral-point balance purposes.

2) Modulation Methods: There are different modulation schemes to generate the desired converter voltage.

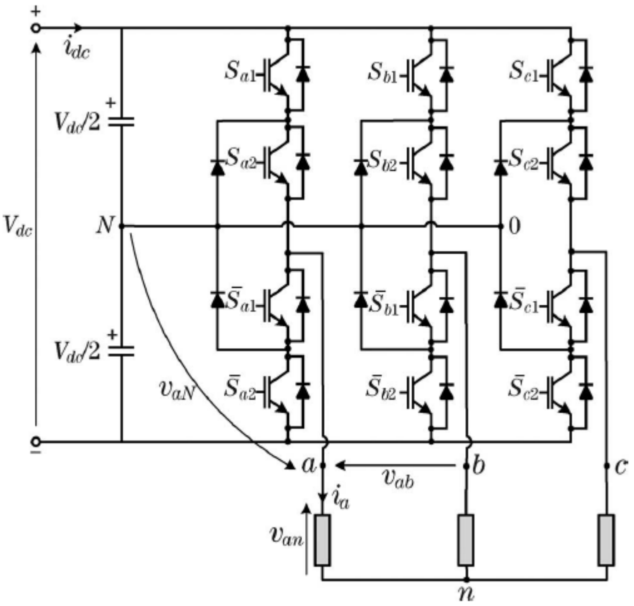

Fig. 2: Circuit configuration of 3L NPC-VSC

Commonly applied modulation methods in industry are the carrier-based sine-triangle modulation based on multiple-carrier arrangements in vertical shifts[10]. In addition, the space-vector modulation has been extended for the multilevel case and has been generalized via 3-D algorithms even for multiphase systems. Other methods have also been adapted for multilevel waveforms

V. TOPOLOGY

Different main circuit structure will have different compensation effectiveness and cost performance. The practical topological structure that can be used in the field of high power is: Three level structure and multilevel structure. Under the circumstances that the same fundamental wave is output, compared with the traditional two level structure, three level structure has the advantage of bearing lower switch frequency, device stress, switching losses, and producing less harmonics. The shortcoming is that, in practical application, the device should still stand large voltage stress, and parameter choice room of the device is relatively small.

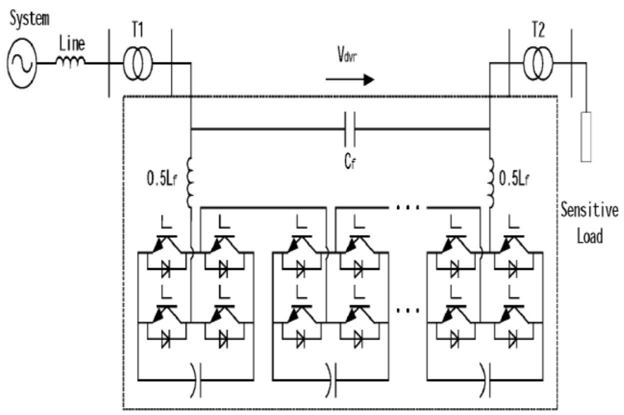

Fig 3 :The main circuit topology of cascaded multilevel Dynamic Voltage Restorer

It makes the control become very complicated to deal with the unbalance of capacity voltage and the elimination of narrow pulse. Meanwhile, the redundant design and the expanding of systematic capacity is difficult. For the cascade multilevel structure, the more levels it has the less harmonics it produces, and less loss it generates.

The topology of the NPC type and cascade multilevel is used widely in field of ASDs, among which the NPC type is suitable for the application of 3-5 levels, the structure and control of this kind of circuit would become very complicated while level number is larger than 5, however, for the cascade structure, it is very easy to expand to 2N +1 levels (N is the number of cascade modules in series connection), without causing the complication of the structure and the control of the circuit. Research shows that DVR on the basis of the topology of multilevel has much comprehensive superiority than other topology in systematic reliability, device type choosing, controlling complexity, and total efficiency. So, cascade multilevel DVR main circuit is put forward as showed in Fig. 3[11].

In the figure, each cascaded H-bridge inverter unit has its own mutually independent DC source. Within one work period, the DVR, formed by several H-bridge inverters that connected in series, outputs voltage waveform of 2N+1 levels. Because of adoption of cascade structure, DVR has novel charge modes and need not add charging circuit, also the series injecting transformer. The topology makes it helpful to save the cost, reduce the space occupation and improve systematic reliability, meanwhile, the cascade modules makes it feasible to improve the equivalent switch frequency of the device greatly, simplify filter design and reduce losses without improving switch frequency of the device.

VI. CONTROL METHOD

The control system for the new configuration is easily adapted from the control system for the DVR proposed earlier in literature. The main aspects of the control system are shown in Fig. 4[12] and include the following blocks: synchronization and voltage measurement at sag detection, injected voltage phase angle calculation, and firing pulse generation. The essential difference from the earlier work is the additional step of switching the shunt inductance and the dc-link control voltage on and off. The control operation, including the two modifications, will be discussed.

A.Sag Detection

The sag is calculated by comparing the long-term steady-state value (in d, q components) of the supply voltage with the instantaneous voltage (d, q components) [13]. This allows for detection of symmetrical and nonsymmetrical sags, as well as the associated phase jump. In order to prevent undue control action, the undervoltage is only considered to be sag if it exceeds a certain threshold.

B. DC-Link Voltage Control

While not in sag-compensation mode, a secondary (slower) dc voltage regulation loop ensures that the capacitors are charged to the rated voltage. This is achieved by marginally phase shifting the carrier waveform of the individual H-bridge inverter so that real power is absorbed (for voltage increase) or delivered (for voltage decrease) [14]. The phase shift was applied to the carrier waveform rather than to the modulating waveform because this simplifies the control as it permits the modulating waveform to be the same for all of the cascaded H-bridges in each phase.

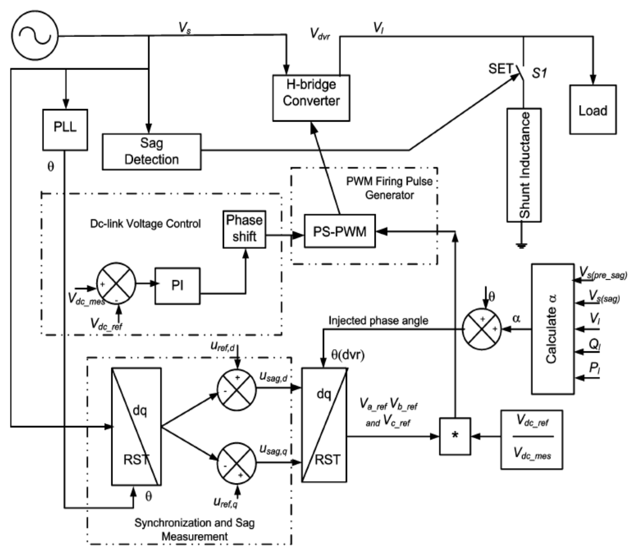

Fig 4: Control structure of DVR with rotating dq reference

VII. PROPOSED SYSTEM WORKING PRINCIPLE

In this paper used in DVR for mitigate sag, swell and harmonics.DVR consists of DC Source,VSC (voltage source converter) and coupling transformer ,so it is connected in series.VSC is multilevel inverter(MLI) [15], it is used for power quality improvement. MLI are 3 types 1)Flying MLI 2)cascaded MLI and 3)Clamped MLI.

In this proposed system we are using MLI type DVR to reducing harmonics at inverter output side in previous paper there are used normal VSC type DVR .Draw backs are 1)The normal VSI(voltage source inverter) output is not pure sine wave i.e quasi square wave ,in this wave forms contains the harmonics.2)now our requirement waveform will be sine wave if you want convert quasi square to sine waveform we can required the fillter that is (LC,LLC) due to the inductance &capacitance of this filter reactive losses will be occurred

due to this reactive losses circuit efficiency will be decreasing.The output of VSC contains the harmonics due to this harmonics our VSC converter output voltage phase sequence will be destroyed and some way harmonic current will be developed in the system due to harmonic currents heat losses will be developed in the system due to this heat losses our system life time be decreasing & power factor(PF) will be decreasing so due to this all reasons over all power systems efficiency will be decreasing at distribution side. To overcome all above draw backs we can go for the our proposed systems, In this proposed system we are using cascaded H bridge MLI to improving the power quality(harmonics,PF,losses and efficiency) [16].
In existing sysyetm that THD is **17.73**.So by using proposed systems (MLI type VSC) we are reduced THD **2.88**. In this paper we are using cascaded type H bridge 9 level MLI so compared to the remaining two MLI (diode clamped and flying MLI)having more advantages like complexity and no. of switching components ,reliability and working principle and working operation simple. In this proposed system we are using SPWM(sine soidal pulse width modulation) are used to MLI, because SPW having more advantages compared to alternative method.

VIII. CONCLUSION

Voltage sag is one of the major and frequently occurring problems in present power grids. Voltage sags are not acceptable for sensitive loads because they cause power loss for sensitive loads, which is a costly problem. Recently due to the increased integration of sensitive loads into power grid, providing high quality power is an important requirement. To suppress the problem of voltage sag, DVRs are suitable devices to compensate these voltage sags, protect sensitive loads and restore their voltage during voltage sag. One of the important topics in DVR is the procedure and method of voltage compensation.

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