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REVIEW OF A NOVEL SOLAR PHOTOVOLTAIC FED TRANSZSI-DVR FOR POWER QUALITY IMPROVEMENT OF GRID-CONNECTED PV SYSTEMS

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Abstract - *In this article, a new solar PV fed Dynamic Voltage Restorer (DVR) based on Trans-Z-source Inverter (Trans ZSI) is proposed to improve the power quality of on-grid Photovoltaic (PV) systems. DVR is a power electronic compensator using for injecting the desired voltage to the Point of Common Coupling (PCC) as per the voltage disturbance. In the proposed DVR, in place of traditional VSI, Trans ZSI with outstanding merits of buck/boost, a broader range of voltage boost gain, fewer passive components, and lower voltage stress, is put forth. For efficient detection, accurate voltage disturbances mitigation, and also lessening the injected voltage harmonics, a hybrid Unit Vector Template with Maximum Constant Boost Control (UVT-MCBC) method is proposed for Trans ZSI-DVR. The performance of the proposed Trans ZSI-DVR with UVT-MCBC has been analyzed under severe sag, slight sag with harmonics, swell, and interruption. The comparative studies and simulation results have shown the effectiveness of the proposed Trans ZSI-DVR, as opposed to traditional ZSI-DVR and VSI-DVR. The Trans ZSI-DVR in the PV system has mitigated voltage sag/swell/interruption. It has also improved the power quality of both the injected voltage to the PCC and PV system's output voltage.*

Index Terms: *PV, DVR, Trans ZSI, voltage sag, voltage transient, THD*

I. Introduction

Future power systems will have a significant penetration of solar PV and wind power systems due to environmental concerns and the growth towards a sustainable society. The pattern is in favour of phasing out coal and fossil fuels and increasing renewable energy. Since sunlight is one of the most plentiful and accessible energy supplies on Earth, photovoltaic systems have seen a notable bias among renewable energy sources [1]. However, a number of variables, including temperature, soiling, clouds, solar radiation, and so on, can affect how well PV systems work. As a result, voltage sag—one of the most frequent yet serious power quality problems—occurs when the PV output voltage is reduced. Power quality problems including sags, swells, and interruptions have gotten worse in the modern power system due to an increase in sensitive and important loads. Significant losses arise from these power quality problems, including diminished producer competitiveness, decreased efficiency, higher production and maintenance costs, lower product quality, shorter equipment lifespans, production disruptions, and energy losses. Possessing superior power Thus, thus manufacturing company can benefit economically and save a significant amount of money by obtaining high-quality power.

An ideal power supply with no noise, a sinusoidal waveform, and constant availability, and voltage and frequency tolerances is produced by high power quality. The most significant power quality problems are defined as short-duration voltage changes, which include voltage sags, swells, and interruptions.

Voltage sag is defined by IEEE standard 1159 as a decline in the Root Mean Square (RMS) voltage (0.1~0.9pu of normal voltage) lasting 0.5 cycles-1min. Large loads, such as motors, are frequently started improperly and generate sags. Voltage sags in grid-connected photovoltaic systems are mostly caused by partial shadowing conditions. A voltage swell is also defined as an increase in the RMS voltage (1.1–1.8pu of nominal value) that occurs simultaneously with a voltage sag.

The main sources of swells are shutting off huge loads and starting and stopping large capacitors. There are numerous ways to protect sensitive and important loads from the effects of such voltage changes. Using specialised power devices, often known as devices built on power converters, is the most sensible and efficient option. Out of all of them, the Dynamic Voltage Restorer (DVR) is the most effective tool for reducing voltage dips, surges, and interruptions. The DVR is in standby mode while the PCC is in good condition and is connected in series between the load and source sides. The DVR controller senses the supply voltage's duration and magnitude once it deviates from its nominal value. It then injects the appropriate voltage into the PCC in accordance with the findings. Three single phase injection/coupling transformers, an LC filter, a voltage source inverter (VSI), and a DC storage unit make up a DVR.

In the DVR configuration, the VSI has historically been used. In, simulation for voltage sag and voltage swell scenarios is carried out, and the DVR system's performance based on the VSI is examined. The load requires a balanced and consistent voltage, which the DVR system can readily handle and maintain. Despite being frequently utilised in DVR configuration, the VSI has certain drawbacks.

It requires a DC/DC boost converter because it is a buck converter. Additionally, the semiconductors in each leg must not be turned on simultaneously to prevent shoot-through (ST), which could harm the inverter bridge. It should be noted that the ST is caused by short-circuiting the supply by simultaneously turning on both switches in the 1', 2', or all 3' legs. Similar to VSI, CSI requires a buck converter and at least one of the upper or lower semiconductors to be turned on.

II. Literature Survey

In the last few years renewable energies have experienced one of the largest growth areas in percentage of over 30 % per year, compared with the growth of coal and lignite energy. The goal of the European Community (the EU) is to reach 20 % in 2020, but the EU-27 energy is only 17 % of world energy. The US, with 22 % of energy share, has adopted similar goals under the pressure of public opinion concerned by environmental problems and in order to overcome the economic crisis. However, the policies of Asia and Pacific countries, with 35 % of energy share, will probably be more important in the future energy scenario. In fact, countries like China and India require continuously more energy (China energy share has increased 1 point every year from 2000). The need for more energy of the emerging countries and the environmental concerns of the US and the EU increases the importance of renewable energy sources in the future energy scenario [1].

The global concern with power quality is increasing due to the penetration of renewable energy (RE) sources to cater the energy demands and meet de-carbonization targets. Power quality (PQ) disturbances are found to be more predominant with RE penetration due to the variable outputs and interfacing converters. There is a need to recognize and mitigate PQ disturbances to supply clean power to the consumer. This paper presents a critical review of techniques used for detection and classification PQ disturbances in the utility grid with renewable energy penetration. The broad perspective of this review paper is to provide various concepts utilized for extraction of the features to detect and classify the PQ disturbances even in the noisy environment [2].

Rapid industrialization and its automation on the globe demands increased generation of electrical energy with more reliability and quality. Renewable energy (RE) sources are considered as a green form of energy and extensively used as an alternative source of energy for conventional energy sources to meet the increased demand for electrical power. However, these sources, when integrated to the utility grid, pose challenges in maintaining the power quality (PQ) and stability of the power system network. This is due to the unpredictable and variable nature of generation by these sources. The distributed flexible AC transmission system (DFACTS) devices such as distributed static compensator (DSTATCOM) and dynamic voltage restorer (DVR) play an active role in mitigating PQ issues associated with RE penetration. The performance of DFACTS devices is mostly dependent on the type of control algorithms employed for switching of these devices [3].

Power quality is a pressing concern and of the utmost importance for advanced and high-tech equipment in particular, whose performance relies heavily on the supply’s quality. Power quality issues like voltage sags/swells, harmonics, interruptions, etc. are defined as any deviations in current, voltage, or frequency that result in end-use equipment damage or failure. Sensitive loads like medical equipment in hospitals and health clinics, schools, prisons, etc. malfunction for the outages and interruptions, thereby causing substantial economic losses. For enhancing power quality, custom power devices (CPDs) are recommended, among which the Dynamic Voltage Restorer (DVR) is considered as the best and cost-effective solution [4].

Super capacitor as the energy storage device for the DVR to compensate voltage sag, voltage swell and harmonics due to addition of nonlinear load in the distribution line. Based on this topology, DVR consist of super capacitor, z source inverter and injection transformer. Super capacitor produces the necessary dc voltage which is given as the input voltage to the z-source inverter; provide the necessary injecting voltage, which has to be restored. In addition, it also consists of PI controller which provides the necessary control signals for the z source inverter [5].

The grid-connected PV system in partial shading conditions through the three-level SVM inverter and compensation of inverter output voltage sag caused by the partial shading using the dynamic voltage restorer (DVR). A function per time and the amount of radiation has been used to create the partial shading condition in the photovoltaic system. The advantages of three-level SVM inverter include the complete region detection method even in the boundary points between two regions through boundary lines equations and complete online solution of those equations. Also the reduction of total harmonic distortion (THD) through the switching table is appropriate. The results show that in the partial shading conditions the three-level SVM inverter decreased THD in the presence or absence of DVR [6].

This research activity is aimed at introducing a comprehensive review of these different modulation schemes employed for the three-phase impedance source inverters, which is enhanced with a comparative assessment. In this paper, different modulation schemes are classified and reviewed, introducing an important benchmark in order to identify the basic differences between these modulation schemes. In other words, from this paper, the concept of classifying the different modulation schemes and the mandatory equations to implement each scheme can easily be drawn [7].

The dynamic voltage restorer has been gaining acceptance as an effective device for voltage sag compensation. The compensation capability of a dynamic voltage restore (DVR) depends primarily on the maximum voltage injection ability and the amount of stored energy available within the restorer. A new topology based on Z-source inverter for the DVR is proposed in order to enhance the voltage restoration property of the device. Z-source impedance network along with shoot through capability of the proposed inverter would ensure a constant dc-voltage across the dc-link despite dwindling voltage in the storage devices connected in the dc-link during the process of voltage compensation. Even when the dc-link energy is supplied through a shunt connected auxiliary supply, the voltage rating of the shunt converter, shunt transformer and the dc-link capacitor can be kept smaller with the proposed topology [8].

The dynamic voltage restorer, with its excellent dynamic capabilities, when installed between the supply and a critical load feeder, can compensate for voltage sag/swells, restoring line voltage to its nominal value within few milliseconds and hence avoiding any power disruption to the load. A new topology based on Z-source inverter is presented in order to enhance the voltage restoration property of dynamic voltage restorer. Z-source inverter would ensure a constant DC voltage across the DC-link during the process of voltage compensation [9].

The power quality requirement is one of the major issues for power companies and their customers. The analysis of power disturbance characteristics and finding solution to the power quality problems have resulted in an increased interest for power quality. The most concerning disturbances affecting the quality of the power in the distribution system are voltage sag/swell. The DVR is used to mitigate the voltage sag/swell on sensitive load. In this paper Z-source inverter (ZSI) based DVR is proposed to enhance the voltage restoration property of the system. The ZSI uses an LC impedance grid to couple power source to inverter circuit and prepares the possibility of voltage buck and boost by short circuiting the inverter legs. Additionally a fuzzy logic control scheme for Z-source inverter based DVR is proposed to obtain desired injecting voltage [10].

The Dynamic Voltage Restorer (DVR) using Z-Source Inverter. Voltage sag is a crucial power quality problem faced by the utility industry which has resulted in increased attention. The DVR is a series power quality conditioning device used to eliminate the voltage disturbance. The DVR compensates the voltage disturbances by injecting the voltage of suitable magnitude and phase in series with the line. The compensation capability of a dynamic voltage restorer primarily depends on the maximum voltage injection ability and the amount of stored energy available within the restorer. The topology is proposed in this paper in order to enhance the voltage restoration property of the device. A constant dc-link is ensured during sag compensation by having an X-shaped impedance network with inherent shoot-through capability [11].

III. Conclusion

A new PV fed Trans ZSI-DVR has been presented to enhance the power quality of PV systems. Compared to traditional VSI-DVR and ZSI configurations, the proposed Trans-ZSIDVR brings significant benefits like being a buck and boost converter simultaneously, fewer passive components, broader voltage gain, and lower voltage stress on switches. For accurate detection and adequate compensation for voltage disturbances, the UVT-MCBC method has been implemented for Trans ZSI-DVR. Four different voltage disturbances such as severe sag (75%), slight sag with harmonics (50%), swell (20%), and interruption (100%) have been considered for performance evaluation of the proposed Trans ZSI-DVR with UVT-MCBC. Such voltage disturbances have been tested in three different DVR scenarios. The performance of the proposed Trans ZSI-DVR in terms of sufficient compensation for sag/swell/interruption, a considerable reduction in voltage THD harmonics, power quality enhancement of injected voltage to the PCC and PV system's output voltage as well.

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