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POWER QUALITY ANALYSIS OF PHASE CONTROLLED BIDIRECTIONAL AND UNIDIRECTIONAL AC VOLTAGE CONTROLLERS AND THEIR IMPACTS ON INPUT POWER SYSTEM

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ABSTRACT:

Power factor correction (PFC) is a mandatory functionality of electronic products in the industrial and commercial market in order to mitigate grid harmonics to improve power quality. Since the load characteristics of most PFC applications such as home appliances, battery chargers, switched mode power supplies and other digital products support unidirectional power flow, the general ac-dc boost converter is considered a popular topology. It is one of the low cost, simple methodologies and their performance is well proven. Maintaining dc-link voltage constantly inside the system in order to feed loads at different power ratings is the main task. Active power filters (APF) is another approach capable of improving grid power quality to control input current with a pure sinusoidal waveform in phase with input voltage. Unlike PFC circuits, the APF is a system in itself which provides compensation of harmonics and reactive power in order to reduce undesirable effects from non-linear loads and uncontrolled passive loads in power systems. The paper introduces a versatile method for mitigating grid power quality using unidirectional ac – dc boost converter. The additional focus of this paper is to measure the quantity of input current distortions by the unidirectional ac – dc boost converter used for supplying active power to the load and reactive power. By using this method, the amount of reactive power injected due to input current distortion from an individual converter to the grid should be restricted.

Keywords: ***PFC, Active power, current distortion, AC –DC boost converter.***

1. INTRODUCTION

In AC voltage controllers, voltage sag may occur due to the change in loads which may affect domestic, industrial and commercial customers [6]. Now days, certain devices are developed which are having built-in power controllers to improve the efficiency and to provide uninterruptable supply to the systems [7]. The ac voltage controllers can be configured as single phase controllers for low power domestic applications or three phase controllers for industrial loads. In AC voltage regulator, switching operations generate harmonics and nonlinearities which are harmful for electrical networks and degrade the performance of the system. Harmonics are frequencies present in the

system other than fundamental frequencies. The most common effects of harmonics include distortion in supply voltage, supply side power factor, heating of conductors, overloading of transformers and errors in energy meters [8]. The study of these harmonics is essential because it degrades the performance of machines [9]. To examine the effects of harmonics on power quality factor, researchers are working on converter topologies to improve the efficiency of converters [10]. In this work, the behaviour of distortions at the single phase input power supply using unidirectional and bidirectional controllers is investigated under resistive and inductive loads. Since most of the loads are RL type, hence during analysis and design of ac voltage regulators, RL load is considered.

2. LITERATURE SURVEY

Reactive power compensation is important not only for power system stability but also efficient use of the power transmitted through the electric grid. Although many power electronics based technologies such as flexible alternating current transmission systems and active power filters have emerged to overcome the shortcomings of traditional passive shunt compensation methods, they may not be the best solution for improvement of power quality of an entire power system due to high capital and operating costs, as well as additional inherent power losses. In this paper, reactive power capabilities of existing aggregated unidirectional converters is investigated and a cost effective solution for reactive power compensation through control and integration strategies for unidirectional in residential distributed power systems is proposed. Usually, unidirectional power factor correction converters are utilized in many commercial applications such as laundry machines, air conditioners, and battery chargers as front end circuitry in order to minimize the effects of harmonic distortion and poor power factor caused by their respective nonlinear loads. Since these converters are found everywhere, they have great potential as reactive power resources in distribution level power systems if they possess reactive power compensation functionality. Ultimately, residential power systems will possess the ability to act as large reactive power compensators, resulting in more efficient and stable electric power distribution system. Traditional reactive power compensation methods include rotating synchronous condensers and fixed or mechanically switched capacitors or inductors. However, there are limitations in both dynamic and steady state performance, because these methods use mechanical devices with little or no high-speed controllability. In addition, these mechanical devices cannot be switched frequently due to their low durability. To overcome the demerits of traditional technologies, several power electronics based technologies have been developed to enhance the controllability and power transfer capability in transmission and distribution systems.

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3. RELATED STUDY

Loads such as induction motors, heating furnaces, pumps, blowers and driller machines need variable ac supply. The conversion of fixed AC supply to variable AC can be done by autotransformers but they have more power losses, heating, reduced system efficiency, high cost and also occupy more space. AC voltage controller converts fixed AC to variable AC by varying the supply of gate currents without changing the frequency. This conversion with the advent of power electronic devices such as MOSFETs, IGCTs, MCTs, SCRs, GTOs, etc. is made efficient and accurate. There are various techniques to control the output AC supply like phase angle control, integral cycle control. Phase controlled AC voltage controllers are having various applications like speed control of motors, transformer tap changing, industrial and domestic heating, induction heating and AC magnet controls. To find better economical solutions, the demands of power quality mitigation have continuously encouraged power electronics engineers to include HCC and RPC capabilities in power converters typically used for renewable energy conversion systems such as wind turbines, photovoltaic (PV) and fuel cell systems. These may have HCC and RPC functionalities as ancillary services, usually typical of converters capable of bidirectional power flow. As power converters for renewable energy sources become more popular in ac power systems, the potential for HCC and RPC will greatly increase, as these control schemes can be employed in existing topologies without hardware changes, while simultaneously sending generated energy back to the grid [6]. Despite the increased utility and cost savings, the number of renewable power converters capable of fulfilling these functions is still limited.

4. PROPOSED SYSTEM

In high-power applications, ac–dc converters based on the concept of multipulse, namely, 12, 18, 24, 30, 36, 48 pulses are used to reduce the harmonics in ac supply currents. These are named as multipulse converters. They use either a diode bridge or thyristor bridge and a special arrangement of magnetics through transformers and tapped inductors. Therefore, the last category is multipulse converters with unidirectional and bidirectional power flow. One of the important reasons for such an extensive development in ac–dc converters is due to self-commutating devices. At low power rating, MOSFETs are used with unsurpassed performance because of their high switching rate with negligible losses. At medium power rating, an IGBT is considered an ideal device for such converters with PWM technology. At a higher power rating, a GTO is normally used with self-commutating and reverse voltage-blocking capabilities at only a few kilohertz switching frequency. A number of manufacturers are developing an intelligent power module (IPM) with several devices to give a cost effectiveness and compact size to the IPQCs. Another breakthrough in IPQCs has been because of fast response Hall-effect voltage and current

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sensors, and isolation amplifiers normally required for the feedback used in the control of these ac–dc converters result in a high level of dynamic and steady-state performance. Many manufacturers, such as ABB, LEM, HEME, Analog Devices, and others are offering the sensors at competitively low prices.

SIMULATION RESULTS:

The simulation model of bidirectional AC voltage controller. It should be noted that the fundamental frequency is of 50 Hz while the load resistance of 182 Ω is taken. Resistive-Inductive load is also simulated having inductance of 280 µH. Smaller value of inductance is chosen, as the thyristor may fail to commutate for having very large inductance, which in turn will be a full sine wave at the load.

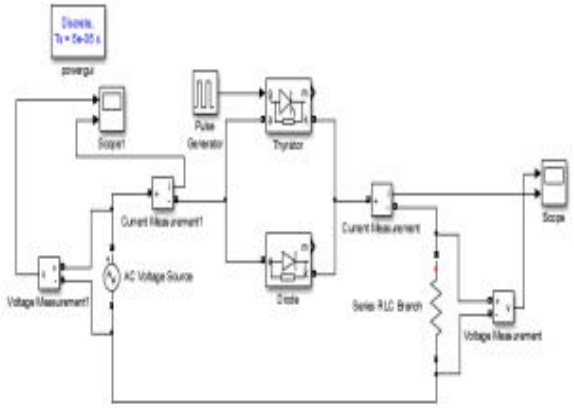

Fig.4.1. Simulation model of Unidirectional AC Voltage Controller with R load.

The harmonic distortions injected by power electronic switching devices in converters cause line losses, damage the equipment, increase power costs and waste energy. Hence the analyzation of these harmonics is of great concern to the researchers, as they produce undesirable effects in the power system.

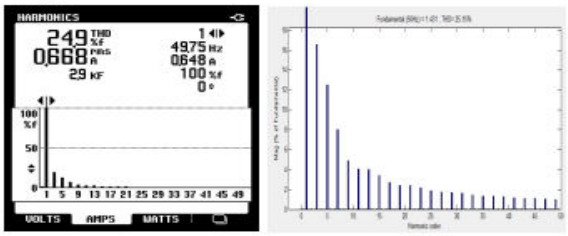

Fig.4.2. Experimental and simulated output current %THD of bidirectional AC voltage controller with R load

By fft analysis of output voltage and current waveforms of bidirectional AC voltage controller, it was found that these waveforms have half-wave symmetry and no dc component. Due to this, these full wave AC voltage controllers are preferred for motor applications. The given depicts the change in the percentage of total harmonic distortions at different firing angles. It is clearly shown that as we increase the firing angle, the THD is also increased. In order to have better system quality, smaller firing angle is preferable.

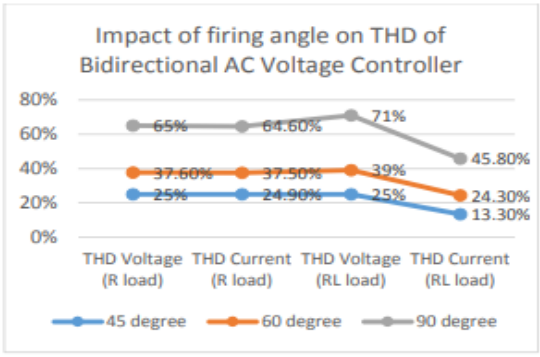

Fig.4.3. Comparative THD of bidirectional and unidirectional AC voltage controllers at different firing angles.

IPQC technology has developed to a mature level and is employed in widespread applications in fraction of kilowatt to megawatt converter systems such as UPSs, ac–dc–ac links, BESSs, ASDs, etc. However, there are new developments in IPQCs for further improvements in their performance. The new trends are improved control algorithms and soft-switching techniques to reduce switching losses in IPQCs even at high switching frequency, to enhance the dynamic response, and to reduce the size of energy storage elements (filters at input and output, high-frequency transformers). The new developments toward single-stage conversion have resulted in increased efficiency, reduced size, high reliability, and compactness of IPQCs. Sensor reduction has also revolutionized the IPQC technology to reduce their cost and enhance their reliability. Novel configurations in autotransformers for multipulse converters have resulted in their reduced size, cost, rating, weight, and losses. The new approaches in multilevel converters are offering high efficiency, reduced stress on devices, and a low level of high-frequency noise. The further improvement in solid-state device technology in terms of low conduction losses, higher permissible switching frequency, ease in gating process, and new devices, especially low voltage drop and reduced switching losses, will give a real boost for IPQCs in low-voltage dc power applications. The multiple device integration into a single power module as a cell for direct use as a configuration of IPQCs will result in size reduction, increased efficiency, and low-cost option. The sensors, control, gating, and protection integration in the IPM will provide a new direction in the development of IPQCs. Dedicated processors and ASICs development for IPQCs are also expected in the near future to reduce their cost, provide ease in control, and result in compact and efficient ac–dc conversion.

5. CONCLUSION

It can be concluded that as we increase the firing angle, the total harmonic distortions are increased. Hence, the smaller the firing angle, the less would be THD and the better would be performance of power system. It was observed that the nonlinearities and distortions, generated by converter, directly affect the input system and disturb the performance of input network. This is the reason, many industries give separate supply to such converters in order to isolate other loads from being disturbed. Moreover, in bidirectional AC voltage controller, half wave symmetry was followed i.e. only odd harmonics were present in the configurations. While in case of unidirectional, half wave symmetry was not found and we noticed both even and odd harmonics in the results. Even harmonics are not suitable for motor applications as they may cause disturbances. That's why bidirectional AC voltage controller is being preferred for electrical drives, AC motors and power systems. On other hand, unidirectional AC voltage controller is being preferred for welding, heating and melting applications.

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