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"Three Phase Boost Rectifier for Power Factor in Continuous Conduction Mode"

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Abstract

The present project work proposes a power factor (PF) corrected single stage, single switch three phase boost converter for a power application. This three phase boost converter uses single switch and single clamping diode on which results in reduced switch stress. The proposed converter is designed to operate in a continuous inductor current mode (CCM) to achieve inherent PF correction at the utility. The closed loop control of the system is achieved using PI Controller. The

CCM operation substantially reduces the complexity of the control and effectively regulates the output dc voltage. The proposed converter offers several features, such as inherent overload current limit and fast parametrical response, to the load and source voltage conditions. This inturn, results in an improved performance in terms of power quality indices and an enhanced power quality. The performance of the system was investigated in terms of its input PF, displacement PF, total harmonic distortion of ac mains current, voltage regulation, and robustness to prove its efficacy in overall performance. The closed loop control of the proposed system is achieved by using PI controller and is implemented in MatLab Simulink simulation.

1.INTRODUCTION

In this work unidirectional three-phase rectifiers are evaluated which are able to meet the enhanced requirements of aircraft application. Starting with a brief survey on the power supply structure and the demanding requirements to be met such as the power factor or input current quality, a survey on three-phase rectifier topologies suited for aircraft applications is given. There, also passive and hybrid (active/passive) systems are considered. Based on this evaluation, the two-level three-phase Δ-switch rectifier is found to be an ideal solution for a mains voltage of 115 V and the three-phase three-level Vienna Rectifier topology optimally fits the requirements for a 230 V mains. Initially, the specific characteristics and control approaches of the well known Vienna Rectifier topology are summarized. The MEA concept calls for a minimization of volume and weight and hence a single-objective optimization of the three-phase Vienna Rectifier topology regarding maximum possible power density is performed which finally results in a 10 kW rectifier system with a power density of 14.1 kW/dm3 .

Several limitations of the power density optimizations are addressed. A magnetically coupled damping layer is proposed for reducing the switching transients oscillations caused by the high-speed switching. It is shown how the turn-off delay of power MOSFETs degrades the input current quality and how the switching losses can be minimized. These effects can clearly be illustrated with a η-THDI-Pareto Curve. Furthermore, a purely digital implementation of a high-speed controller using an FPGA is developed which achieves a total control cycle time of 490 ns. Also substantial improvements of the current controller, mainly for operation at the high mains frequencies of 360 Hz to 800 Hz, are shown which finally results in a THDI of the input current below 2 %.

A considerably improved noise model of the Vienna Rectifier system is derived considering parasitic capacitances concept for eliminating the CM voltage of the output is proposed and analyzed in detail. Measurements taken from the implemented prototype finally confirm the proper operation of the rectifier circuit and the effectiveness of the discussed improvements. Next to the Vienna Rectifier topology, a two-level Δ-switch rectifier system is analyzed. Basic operation of the topology is discussed, detailed loss models are derived and a digital PWM current controller/modulation concept is developed where all three phases are controlled simultaneously.

The proposed, phase related controller concept is able to handle a single phase loss without any changes in the controller structure. A detailed study on reactive power used to compensate capacitive currents drawn by the EMI filter capacitors.

II. THREE PHASE BOOST RECTIFIER.

This project presents a new unidirectional hybrid three-phase rectifier composed by the parallel association of a single switch three-phase boost rectifier with a PWM three phase unidirectional rectifier. The objective to be reached is to reduce the harmonic content of input currents by processing a fraction of output active power with the PWM rectifier. The proposed structure allows to obtain a THD varying between 0 and 32%, just depending on the power processed by PWM three phase unidirectional rectifier. So, if the PWM rectifier is settled to process 45% of the total output power, the THD obtained is 0. Decreasing the PWM power to about 33% of the load power is possible to achieve the standards requirements. The rectifier topology conception, the principle of operation, control scheme and simulation results are also presented in this project.

Three-phase PWM rectifiers are widely employed in low and medium power drive applications where Recent trends in high-power rectifiers introduces new class of three-phase rectifiers; the Hybrid Rectifiers.Three-phase PWM rectifiers are widely employed in low and medium power drive applications where the requirements of the international standards should be satisfied. These structures are the most promising rectifier technology from a power quality viewpoint. A very low harmonic distortion and a unity power factor can be achieved. However, this structures are current not available for high power applications, specially due to unavailability of suitable cost-effective power electronics devices. The term “Hybrid Rectifier” denotes the series and/or parallel connection of a line-commuted rectifier and a self-commuted converter.

Moreover, the line-commuted rectifier operates with low frequency and it handles the higher output power rating. Therefore, the active rectifier is designed to operate with small power ratings and with high frequency. In this work unidirectional three-phase rectifiers are evaluated which are able to meet the enhanced requirements of aircraft application. Starting with a brief survey on the power supply structure and the demanding requirements to be met such as the power factor or input current quality, a survey on three-phase rectifier topologies suited for aircraft applications is given. There, also passive and hybrid (active/passive) systems are considered. Based on this evaluation, the two-level three-phase Δ-switch rectifier is found to be an ideal solution for a mains voltage of 115 V and the three-phase three-level Vienna Rectifier topology optimally fits the requirements for a 230 V mains.

This procedure is important to a future easier visualization of the circuit. A traditional single-phase boost PFC is settled to generate the active current presented in At first, a single phase boost is added to phase 1, resulting in the circuit presented. The new hybrid rectifier depicted can be obtained repeating this same procedure to phases 2 and 3.The neutral point can be disconnected without changes in the converter behaviour.

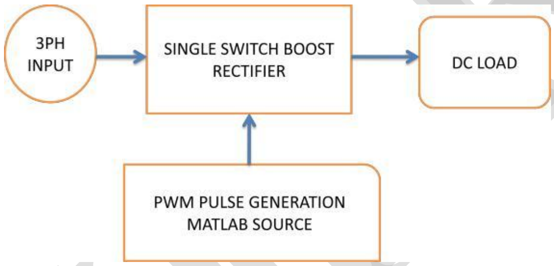

Fig 1.1 Block Diagram Of Three Phase Boost Rectifier

Initially, the specific characteristics and control approaches of the well known Vienna Rectifier topology are summarized. The MEA concept calls for a minimization of volume and weight and hence a single-objective optimization of the three-phase Vienna Rectifier topology regarding maximum possible power density is performed which finally results in a 10 kW rectifier system with a power density of 14.1 kW/dm3 . Several limitations of the power density optimizations are addressed. A magnetically coupled damping layer is proposed for reducing the switching transients oscillations caused by the high-speed switching. It is shown how the turn-off delay of power MOSFETs degrades the input current quality and how the switching losses can be minimized.

III- CIRCUIT DIAGRAM OF THREE PHASE BOOST RECTIFIER.

The single switch three-phase boost rectifier, presented is the basis of the proposed hybrid converter. This structure is settled due to present robustness, high efficiency and low complexity. A rectangular shape is imposed to the input current waveforms, as can be observed for that reason, the power factor obtained is about 0.95. The control loop can impose only the amplitude of these currents, maintaining the output voltage constant under load variations.To obtain a sinusoidal waveform , an appropriated current wave shape, generated by an active PWM rectifier, should be added to each phase to compose the respective input current.

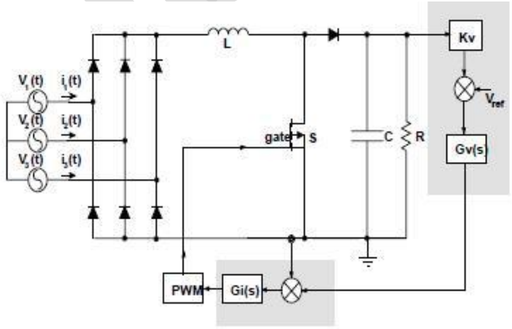

Fig 1.2 Circuit Diagram of Three phase Boost Rectifier.

However, depending on the application area and the required operational behavior some switches can not be applied. The latest advances in highpower semiconductor devices have introduced newer solutions for high power conversion systems, however, the degree of acceptance of each technology vary in accordance with various industries and applications.

Traditionally, three-phase AC-to-DC conversions are performed by diode or phase-controlled rectifiers. Due to the commutation of these structures to be done by the zero current crossing, they are also called "line-commutated" rectifiers.

These rectifiers are extremely robust and present low cost, but draw non-sinusoidal currents or reactive power from the source, deteriorating the electrical power system quality. To compensate the harmonic distortion generated by the standard diode rectifiers, passive linear filters or power factor correction structures can be employed.

THE CONTROL STRATEGY:

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A three-phase boost PFC consists of three coupled AC-DC boost converters with the same output VDC. According to the output and input voltages of the converter are VDC and VAN, respectively

From volt-second balance, the generalized relationship between the DC link voltage and any input phase voltage (phase ‘k’) could be established from the principle of boost converter according from volt-second balance, the generalized relationship between the DC link voltage and any input phase voltage (phase ‘*k*’) could be established from the principle of boost converter according to Eq. (1):

$$V_{kN} = (1 - d_{kL})V_{DC} = d_{kH}V_{DC} \qquad (1)$$

Applying summation operator in Eq. (1) to both sides by varying phase ‘*k*’ from *A* to *C*, the subsequent relationships are formed for a balanced 3-phase AC system i.e. *VAn+VBn+VCn=0.*

$$\sum_{k=A}^{C} V_{kN} = V_{DC}\sum_{k=A}^{C} d_{kH} \qquad (2)$$

The voltage difference between neutral point and DC link negative terminal, which is the common coupling term among the three input voltages of the AC-DC converter. The voltage between the leg-midpoint

$$V_{nN} = \frac{V_{DC}\sum_{k=A}^{C} d_{kH}}{3} \qquad (3)$$

and the negative DC link terminal is 0 or VDC, depending on whether the corresponding lower leg switch is ON or OFF, respectively.

Therefore, the switching average of the voltage across the leg-midpoint of ‘*k*’th phase to the negative terminal of DC link i.e. *Vk1N* would be *dkHVDC*. Hence, for any decoupled AC/DC converter, the following relationship could be written.

=

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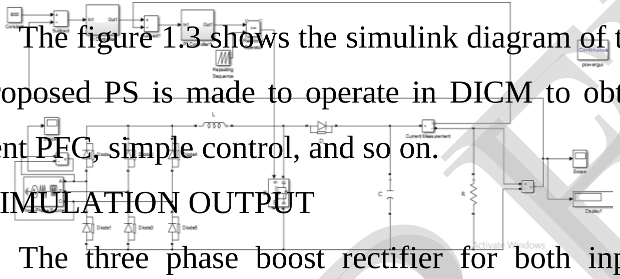
In a conventional linear feedback-only control with Sine- PWM technique, the instantaneous sum of all the duty modulation signals, generated from three outputs of inner loop current compensators have 120^{o} phase difference

IV STIMULATION OF THREE PHASE BOOST RECTIFIER.

Three outputs of inner loop current compensators have 120o phase difference and hence, add up to 0. This implies the presence of non-zero third and higher order harmonics in the inductor voltages and input currents

Fig 1.3 Stimulation Diagram Of Three Phase Boost Rectifier.

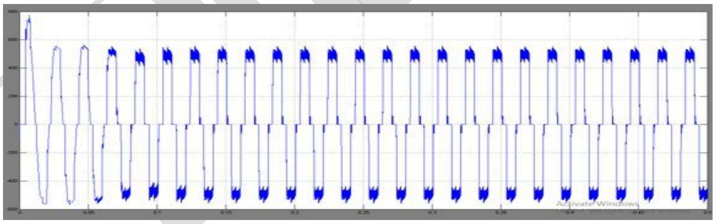


The figure 1.3 shows the simulink diagram of three phase boost rectifier and the proposed PS is made to operate in DICM to obtain various benefits, such as inherent PFC, simple control, and so on.

V. STIMULATION OUTPUT

The three phase boost rectifier for both input and Output DC Voltage Waveform for the proposed to operate in continuous conduction mode[CCM]. Power application and with power factor correction circuit of closed loop is simulated in Matlab/Simulink environment. The simulation model is presented in figure 5.1 with resistive load connected

A. INPUT AC CURRENT WAVEFORM



VI. CONCULSION

A Three Phase Boost Rectifier is still unexplored for the development of computer SMPSs that are capable of drawing a purely sinusoidal current with unity PF, offering low rippled output which is the prime requirement of PCs. Proposed Future Scope is to build a multioutput Boost for PC and Power Monitoring System for UAVwith3phaseInput.

A 2.2-kW three-phase boost PFC converter prototype is built and tested under different line and load conditions to illustrate the effectiveness of the proposed control technique. A conversion efficiency of 98.3%, THD as low as 4.3%, output voltage ripple less than ±2% (peak-peak) and an input power factor more than 0.999 are achieved according to the test results at 120V RMS AC line input and a regulated DC link voltage of 400V.

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