"COMPREHENSIVE STUDY OF VARIOUS POWER FACTOR CONTROL TECHNIQUES"

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ABSTRACT: The importance of power-factor correction and the related line-harmonics reduction is increasing as the amount of line-fed electronic equipment grows and the requirements of regulatory agencies tighten. In this paper a comprehensive study of power-factor correction converters, including the definition of power factor and its relation to total harmonic distortion; many passive and active power-factor corrector topologies and control methods.

Keywords: power-factor, factor correction converters, total harmonic distortion, continuous conduction-mode

1. INTRODUCTION

In high-power off-line power supplies, a continuous conduction-mode (CCM) boost rectifier is the preferred topology for implementing the front-end converter with active input-current shaping. However, since the dc-output voltage of the boost converter must be higher than the peak input voltage, the output voltage of the boost input-current shaper is relatively high. Due to the high output voltage, the converter requires the use of a high-voltage, fast-recovery boost rectifier. At high switching frequencies, fast-recovery rectifiers produce significant reverse-recovery-related losses when switched under "hard" switching conditions. These losses can be significantly reduced and, therefore, a high efficiency can be maintained even at high switching frequencies by employing a soft-switching technique. There are various analogue and digital control methods used for converters and some have been adopted by industry including voltage- and current-mode control techniques. Aim of this paper is to have an overview of all the control techniques used to ease the performance of various kinds of converters. We will briefly discuss the basic concept, advantages and disadvantage of each control technique throughout this review.

2. LITERATURE REVIEW

M. Nirmala [1] implements variable duty cycle control for CCM Boost PFC converter. It differs from the conventional power factor correction techniques by eliminating inductor current sensing requirements.CCM mode is chosen which features smaller inductor current ripple resulting in low RMS currents on inductor and switch thus leading to low electromagnetic interference. By this technique supply current is made to follow supply voltage effectively. Thus the input power factor for diode bridge rectifier is improved and harmonic content in the supply current is reduced. It complies with standards for Total Harmonic distortion. In addition it also maintains output voltage regulation. All these together offer a satisfactory performance. Simulation results were presented for this technique which covers load variation also.

Sonima M.P et. al. [2] has presented novel dual mode boost converter for input power factor correction. Working of the boost converter in both light load and heavy load has increased the efficiency of the system. The proposed converter has a natural power factor correction in the circuit and so it exhibit better performance characteristics. A reduction in line current harmonics, increase in system efficiency and increase in capacity is obtained by this natural power factor correction circuit. Because of the simple circuit structure and good control effort, the system has a broad application background. It can be used in integrated chips which require high power and high efficiency in light load condition. In addition, the dual mode control circuit is simple and easy to be built into an integrated circuit without additional cost and space. When used for power factor correction the above scheme can be used in computerized power plants and personal computers to improve the efficiency of the system and to eliminate the effects of input current distortion.

Brian T. Irving et. al [3] three single-phase, high-power-factor rectifier implementations were evaluated on a comparative basis. Specifically, a zero-voltage-switching continuous conduction-mode boost rectifier, a zero-current-zero-voltage switching continuous-conduction-mode boost rectifier, and an interleaved variable-frequency discontinuous-conduction-mode boost rectifier were compared with respect to their efficiencies, compliance with the EN61000-3-2 specifications, complexity, and costs. The comparisons were done for the single-phase input voltage of 90 Vrms – 264 Vrms and for 0 – 1.2 kW output-power range.

Bharat S. Suthar et. al. [5] presents variable duty cycle control for CCM Boost PFC converter. CCM mode of boost converter is chosen which features smaller inductor current ripple resulting in low RMS currents on inductor and switch thus leading to low electromagnetic interference. Using this technique input current is made to follow supply voltage effectively. Thus the input power factor for diode bridge rectifier is improved and harmonic content in the input current is reduced. It also regulates the output DC-bus voltage.

Kotari Sri Harsha Babu et. al. [6] Boost Converter operating in CCM has been successfully implemented to improve the power factor for front-end ACDC conversion. From the waveforms and hardware results, in all operating conditions the PF achieved is greater than 0.9 with an efficiency of more than 90%. The converter topology also minimizes the %THD in input voltage and current. This gives an efficient operation of surrounding appliances and ultimately, resolves the power quality issues. The efficiency of the converter can be improved further by using synchronous rectifier instead of boost diode.

3. POWER FACTOR CONTROL TECHNIQUES

Power Factor Correction is a technique that promotes efficient energy consumption from the power grid. Power Factor correction is employed inside common electrical and electronic equipment that are powered from the AC outlet. Power factor correction enables the equipment to maximize the active power draw and minimize the reactive power draw from the AC outlet. To operate the converter as a power factor corrector, consider continuous conduction mode: as the current stress and current ripple are minimum in this mode. A number of continuous inductor current mode control strategies such as average voltage control, hysteresis current control, and non-linear control techniques are reviewed in this paper.

3.1 Peak current control

In this technique the switch is turned on at constant frequency by a clock signal, and is turned off when the sum of the positive ramp of the inductor current (i.e. the switch current) and an external ramp (compensating ramp) reaches the sinusoidal current reference. This reference is usually obtained by multiplying a scaled replica of the rectified line voltage vg times the output of the voltage error amplifier, which sets the current reference amplitude. In this way, the reference signal is naturally synchronized and always proportional to the line voltage, which is the condition to obtain unity power factor.

3.2 Average Voltage Control

In most of the power electronic converter applications the output variable is the voltage and is involved in the outer loop. The variable within the inner loop is current, this is the reason this technique is called as average current control technique. The average current controlled interleaved boost PFC converter, is designed to operate in CCM, it may transit to DCM when the load becomes light.

3.3 Hysteresis Current Control

Among the various control methods, hysteresis current control [7] is the extensively used technique owing to its noncomplex implementation, enhanced system stability, fast response, less distortion in input current waveform and regulating the output voltage. This technique is believed to exhibit greater stability. According to this control technique, when the inductance current is less than the lower current reference, power switch is turned ON and when the inductance current is more than the upper current reference, power switch is turned OFF. The boost converter is being operated at continuous current mode (CCM).

3.4 Non linear Carrier Control

Nonlinear carrier controllers are proposed for high power factor boost rectifiers with low total harmonic distortion [8]. In this type of controllers, the duty ratio is determined by comparing a signal derived from the main switch current with a periodic nonlinear carrier waveform. As a result, the average input current follows the input line voltage. This technique is suitable for boost converters operating in the continuous conduction mode. The proposed controller obtains the duty ratio in each switching period from the comparison of the negative ramp carrier waveform and the sensed inductor current signal.

3.5 Borderline control

In this control approach the switch on-time is held constant during the line cycle and the switch is turned on when the inductor current falls to zero, so that the converter operates at the boundary between Continuous and Discontinuous Inductor Current Mode. In this way, the freewheeling diode is turned off softly and the switch is turned on at zero current, so the commutation losses are reduced. On the other hand the higher current peaks increase device stresses and conduction losses and may call for heavier input filters.

3.6 Discontinuous current PWM control

With this approach, the internal current loop is completely eliminated, so that the switch is operated at constant on-time and frequency. With the converter working in discontinuous conduction mode (DCM), this control technique allows unity power factor when used with converter topologies like flyback, Cuk and Sepic. Instead, with the boost PFC this technique causes some harmonic distortion in the line current.

4. COMPARATIVE ANALYSIS OF DIFFERENT POWER FACTOR CONTROL TECHNIQUES

SR. NO	POWER FACTOR CONTROL TECHNIQUES	ADVANTAGES	DISADAVANTAGES
1	**Peak current control**	1) Constant switching frequency; only the switch current must be sensed and this can be 2) Accomplished by a current transformer, thus avoiding the losses due to the sensing resistor; 3) No need of current error amplifier and its compensation network; 4) Possibility of a true switch current limiting.	1) Presence of sub harmonic oscillations at duty cycles greater than 50%, so a compensation ramp is needed; 2) Input current distortion which increases at high line voltages and light load and is worsened by the presence of the compensation ramp. 3) Control more sensitive to commutation noises.
2	**Average Voltage Control**	1) Constant switching frequency; 2) No need of compensation ramp; 3) Control is less sensitive to commutation noises, due to current filtering; 4) Better input current waveforms than for the peak current control since, near the zero crossing of the line voltage, the duty cycle is close to one, so reducing the dead angle in the input current	Inductor current must be sensed; a current error amplifier is needed and its compensation network design must take into account the different converter operating points during the line cycle.
3	**Hysteresis Current Control**	1) No need of compensation ramp; 2) Low distorted input current waveforms.	Variable switching frequency; Inductor current must be sensed; 2) Control sensitive to commutation noises.
4	**Non linear Carrier Control**	1) This method offers a completely different approach for dealing with the non linear model and the slowly time varying or uncertain parameter of the system.	1) Sensitivity to parameter variation. 2) Proof of stability is difficult. 3) Need for measuring all state variables or additional measurement. 4) Possible only on stable processes.
5	**Borderline control**	1) No need of a compensation ramp; 2) No need of a current error amplifier. 3) For controllers using switch current sensing, switch current limitation can be introduced;	1) Variable switching frequency; 2) Inductor voltage must be sensed in order to detect the zeroing of the inductor current; 3) For controllers in which the switch current is sensed, control is sensitive to commutation noises.
6	**Discontinuous current PWM control**	1) Constant switching frequency; 2) No need of current sensing; 3) Simple PWM control;	1) Higher devices current stress than for borderline control; 2) Input current distortion with boost topology.

5. CONCLUSIONS

In this paper, several control techniques specifically developed for power factor converter for boost converters are studied. For each control strategy to shows the advantages and drawbacks.

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