Improvement In Performance Of Power Factor Correction Converters For Distributed Power System

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Abstract

In present situation, the power control of a DC load can be achieved via an AC-DC converter consisting of a rectifier bridge and a switching element (operating by sPWM technique). The use of such a converter causes a lot of high harmonics at the AC side, which reduce the power factor and distort the grid voltage. Using passive filter in the converter input to avoid the high harmonics consequences the power factor decrease. The increase in the utilization of computers, laptops, uninterruptable power supplies, telecom and bio-medical equipments has become uncontrollable as its growth is rising exponentially. Hence, increase in functionality of such equipments leads to the higher power consumption and low power density which provided a large market to distributed power systems (DPS). The development of these DPS posed challenges to power engineers for an efficient power delivery with stringent regulating standards; this is the motivation and driving force of this thesis. The objective is to minimize the switching losses of front-end converters employed in DPS, with the primary aim of achieving nearly unity power factor operation of converters.

Keywords: *PWM, PFC, DPS, DC-DC converter, MOSFET, Active PFC Converter, Passive PFC Converter.*

INTRODUCTION

In present situation, the increase in the utilization of computers, laptops, telecom, biomedical equipments, and uninterruptable power supplies is uncontrollable as its growth is rising exponentially. Hence, increase in functionality of such equipments leads to the higher power consumption and low power density. On the other hand, today's industry/market demands the miniaturization of power sources with higher power density at reasonable price.

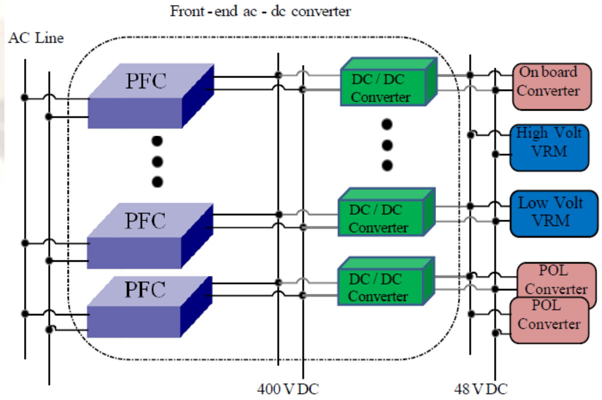
Therefore, the power supplies for the telecom and computer applications are required to provide more power with less cost and small size.

To achieve these requirements, distributed power system (DPS) is widely adopted.

Hence, DPS has evolved from a conventional approach (such as centralized system) by employing isolated DC-DC converters to intermediate bus architecture using non-isolated converters.

The requirements aimed by DPSs continue to expand beyond its initial goal of dealing with power distribution problems associated with computer and telecom applications. While centralized power system continues to be a cost effective solution for some applications, additional important factors such as the easier thermal management, higher reliability, need of tight regulation during load current transients, reduced current ripple and the increased quantity of voltages required on a board, have spawned a multitude of distributed power solutions. The basic configuration of a typical DPS is shown in Fig. In this system, the front end converters used in DPS applications adopt a two stage approach. In the first stage, the front-end converters connected in parallel provide the power factor correction (PFC) and the second stage provides isolation and highest regulation of the required output DC voltage.

As a result, the overall performance of the entire system strongly depends on the choice and design of individual stages. Because of this modular approach, DPS system has many advantages over centralized power system. It is widely adopted for telecom and computer server applications because of its inherent advantages such as higher reliability, modularity, high power density, easier thermal management and easy maintainability. Because of these benefits of DPS over the centralized power system, installations of DPSs are rising up especially for power sources to telecom and computer applications.

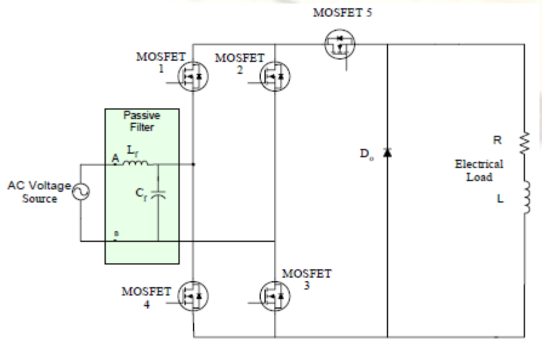


Structure of basic distributed power system

Power Control of a DC Load:

It is well known that the power control of a DC load feeding by the grid is achieved by the use of an AC-DC converter structure operating through a sPWM technique. In figure 1 one can see such a converter structure consisting of a MOSFET single phase rectifier bridge in series connected with a switching MOSFET5. In the case of an ohmic – inductive load a parallel freewheeling diode is necessary. The rectification becomes by the parasitic bridge MOSFET diodes, while the MOSFETs 1-4 enable the power inversion, if an active load is considered.

The sPWM operation can be succeeded by comparison of a sinusoidal voltage waveform (Uc)in phase to the grid voltage (Ug) with a high frequency triangular waveform in order to obtain a switching pulse waveform. The pulse duration inside of a half sinusoidal period is not constant and the pulse of the maximum duration is located exact at the middle of the half period, while the pulse of the minimum duration appears at the beginning of that, as it appears in figure 2a. Figure 3 shows the waveforms of the grid voltage (50Hz) and the corresponding current pulse waveforms (switching frequency 5 kHz). In case of an ohmic DC load the basic harmonic of the grid current pulse waveform (fig.3a) is in phase with the grid sinusoidal voltage waveform. If the DC load is ohmic inductive one, then the basic current harmonic is shifted in relation to the voltage waveform U g (fig.3b). In the case that a sinusoidal waveform Uc is leading upon the grid voltage Ug by an angle 'a' via comparison to the triangular waveform (fig.2b), a grid current pulse waveform is obtained of which the basic harmonic is shifted to the grid voltage. In this way the grid current basic harmonic can becomes in phase with the grid sinusoidal voltage, if we have an ohmic-inductive DC load. It means that the power factor can be corrected. In this paper an extensive investigation of the influence of the leading or lagging angle 'a' to the power factor via simulation as well as experimentally has been carried out.



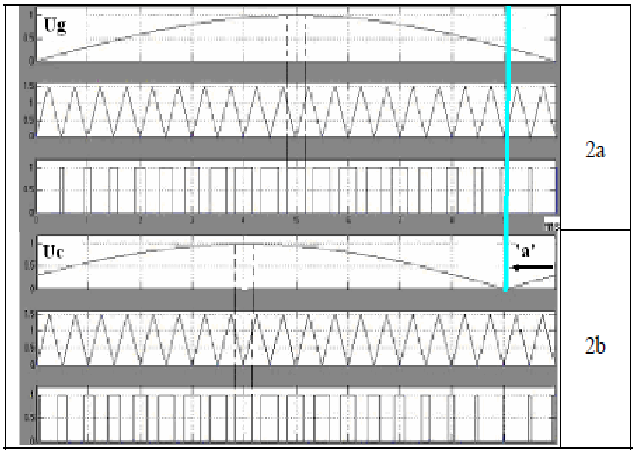


Figure 2. Pulse waveforms obtained by sPWM when 'a'=0° (2a) and 'a'≠0° (2b).

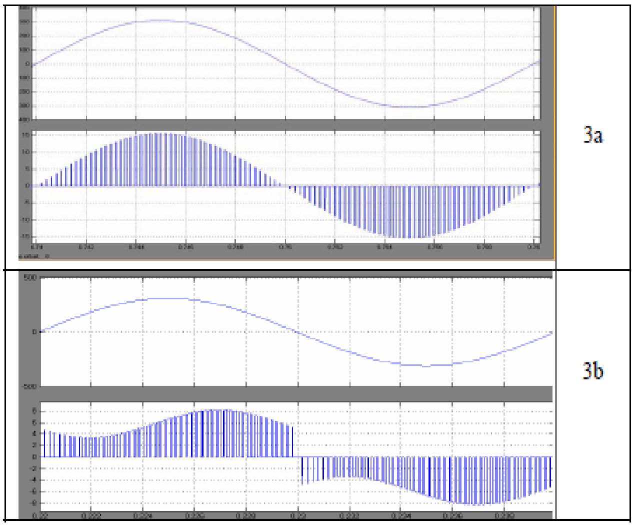


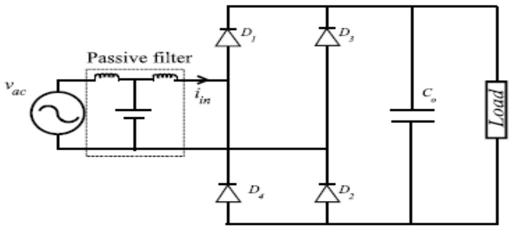
Figure 3. Grid voltage and current in the case of ohmic load (3a) and ohmic-inductive load (3b).

Power factor correction techniques:

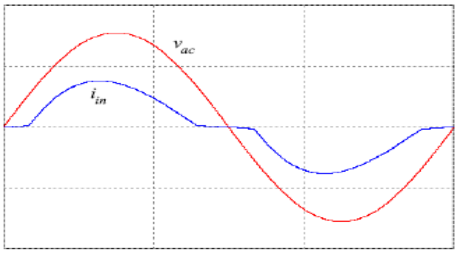
As mentioned earlier, due to the proliferation of non-linear loads in the distribution systems, current and voltage harmonics are generated in the power grid. Therefore, there is a need to compensate these undesired distortions in order to minimize their effects on the distribution system and hence to improve its efficiency. Broadly, two methods have been come across to eliminate the harmonic related problems and to enhance the overall performance of the grid or distribution systems, namely passive method, and active method. These two harmonic filtering methods are presented and briefly discussed in the following sections.

In passive PFC approach, an L-C filter is inserted between the AC line and the input port of the diode rectifier of AC-DC converter as shown in Fig. This technique is simple and rugged but has bulky size and heavy weight components. One filter is to be connected to eliminate one particular harmonic and hence system becomes bulky and expensive in order to eliminate significant amount of harmonics. Moreover, the power factor cannot be very high in this technique.

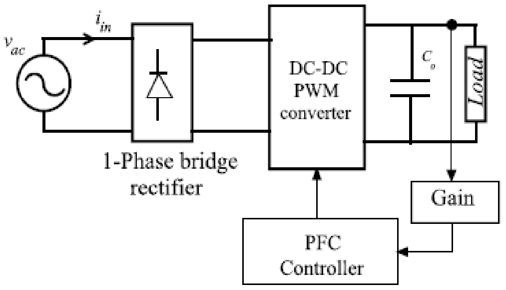
In active PFC converter techniques, power electronics DC-DC converter is employed and operated at high frequency to shape the input line current as sinusoidal as possible. The simplified basic block diagram of active PFC technique is shown in Fig. The commonly used topologies as DC-DC converter in active PFC converter are boost, buck, buck-boost, flyback, cuk, or sepic topologies. In active PFC technique, the input power factor can reach nearly unity and the AC-DC interface of power converter emulates a pure resistor. The boost converter is widely used as a DC-DC converter for PFC applications and is most suitable topology for PFC pre-regulator in telecom applications because of its inherent properties. Hence the DC-DC converter of boost topology is the basic interest of our research and our significance of novel techniques are applied to boost converter in PFC pre-regulator system. The active PFC methods have many advantages over the passive PFC techniques high power factor, reduced harmonics, smaller size and weight. Hence this thesis is focused in the area of active PFC converter to achieve near unity input power factor and hence to increase quality of power in the grid.



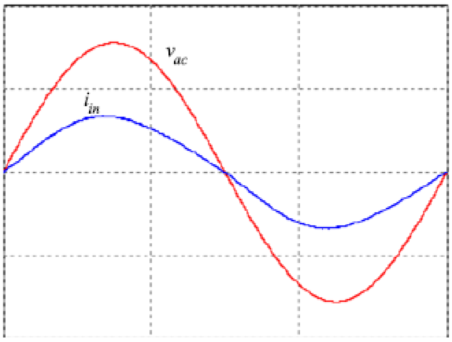
Passive power factor correction technique



Input voltage and input current response of passive PFC technique



Active power factor correction technique



Input voltage and input current response of active PFC technique

RESULT AND COMPRATIVE STUDY

Because of high performance, easy maintainability, and high reliability, DPS systems are widely employed for telecom and computer server applications. In present situation, the exponential increase in the functionality of these applications demands the power management, which provides a large market to DPS systems. Hence, the emergence of frontend AC-DC converters (PFC + DC/DC converter) in these DPS poses many challenges and attracts large efforts to investigate different solutions such as: high efficiency, fast dynamic response, and high power density. Improved performance of these front-end ACDC converters in DPS systems must meet these requirements.

CONCLUSIONS

The simulation and experimental results show that there is a leading angle ‘a’ by which the power factor becomes maximum. The value of this angle depends on the nature of the load, the output power, the input filter and the switching frequency. A sinusoidal signal (voltage Uc) created by microprocessor and leading upon the sinusoidal grid voltage determines the sPWM converter operation and so the appropriate value ‘a’ can be achieved. The target is to shift the grid current waveform relatively to the grid voltage in order to be the basic current harmonic in phase with the grid voltage.

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