Study and Simulation of Single-Phase to Three-Phase UPF System for Agricultural Applications

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Abstract - **This paper describes simulation and design of single-phase to three-phase UPF system for agricultural/ household applications. The average current mode control (ACMC) technique is used for Unity Power Factor (UPF) correction of single phase AC-DC boost converter. A comprehensive study and analysis of single-phase to three-phase converter with UPF operation is presented. Closed loop control of single phase AC-DC UPF boost converter is designed. The three phase voltage source inverter with Sinusoidal Pulse Width Modulation (SPWM) technique has been used for dc to 3-phase ac conversion. The voltage mode control of three-phase voltage source SPWM inverter have been designed and simulated. The complete system with the integration of single-phase and three-phase converter has been simulated. The simulation results with their performance such as power factor (pf), Total Harmonic Distortion (THD) and efficiency have been analysed. The simulation results on resistive load is presented in this paper.**

Keywords – **Average current mode control, Sinusoidal pulse width modulation, Total harmonic distortion, Unity power factor correction.**

I. INTRODUCTION

Most of the rural areas are supplied by single-phase electrical systems. Single-phase electrical distribution systems are less expensive to install than three phase distribution systems. But it can only be used for low power applications such as lighting, home appliances etc. The electrical equipment whose motor size is about 5 Hp, single-phase supply is usually adequate. Beyond that, appliances are usually designed to run on three phase power. The rural/agricultural applications such as motors to operate irrigation pumps, grain handling systems, large air compressors, refrigeration units etc. are designed to run on three phase supply but in general single phase supply is available in the rural areas.

Generally, electrical and electronics equipment are supplied by 50Hz utility power supply. The power systems of these equipment are processed through power converters. For agricultural and household applications, popular topology/technique is the use of a single-phase front-end rectifier with DC-DC boost converter followed by a 3-phase inverter with a filter in star or delta connection. But as the power levels increases it has its own drawbacks such as, poor power factor (pf), high harmonic distortion on AC mains current, unregulated output bus voltage and losses, overheating in input side transformers, shunt/output capacitors, power cables and in the ac machines.

Due to undesirable power factor, the peak current in input side increases and it requires larger devices and larger wire size. This increases the weight, volume and overall cost of the system. It does not meet the requirement of IEC 61000-3-2 and IEEE-519 standards for Total Harmonic Distortion (THD) and power factor in the electrical equipment.

The single-phase to three-phase conversion technique using rotary and static phase converters have its pros and cons when used in high power applications. The conventional technique for unity power factor correction is the front-end rectifier followed by boost converter. But this type of converter endures high conduction as well as switching losses due to hard switching of the devices [1].

The front end rectifier with resonant converters scheme such as parallel resonant converters, quasi-resonant converters etc. were proposed in many literatures. But due to variable switching frequency and resonant behavior of current and voltage waveforms, these converters involve high circulating energy, which increases the conduction losses. The variable frequency creates problem for magnetic design, Electromagnetic Interferences (EMI) and output filter capacitor design [2, 3].

The power converters for low power and high efficiency have advanced from pulse width modulated converters to resonant converter and soft switching converters. But due to presence of parasitic, higher switching frequency and hard switching condition, the PWM converter suffers from high switching losses and switching stress in the circuits [4]. For reducing switching losses, there are other techniques [5] which achieve soft switching operation with the help of commutation circuits and auxiliary switches. It reduces the switch losses and EMI to some extent. But the conduction loss is still present in the circuit. Their efficiency is very poor which is not suitable for high power applications.

Various active and passive power factor techniques have been proposed in literature [6, 7]. These technique control the quantity of power drawn by the load in order to get unity power factor and low harmonic content in the input AC current. But active unity power factor correction technique is unable to reduce the switching loss and conduction loss in the switching devices/elements. It also draws huge pulsating current due to direct connection of diode and output electrolytic capacitor. For higher power application the efficiency and power factor of these converters are very low and thus are not suitable for agricultural and rural applications.