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POWER QUALITY IMPROVEMENT USING SINGLE PHASE FRONT END CONVERTER

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Abstract— This paper presents the design and simulation of single phase front-end converter in order to improve the power quality in terms of the power factor and reduces harmonics by implementing a close-loop control method. The line voltage is also to be boosted using a boost inductor. In all inverter controlled drive applications and in wind power conversions, the use of two stage power conversion i.e. power conversion from AC-DC and DC-AC is unavoidable. For such applications this PWM rectifier can be used for primary AC-DC conversion. Sinusoidal pulse width modulation (SPWM) method has been used to achieve high power factor and to reduce the harmonics. The simulation results are presented which is carried out with MATLAB/ Simulink.

Keywords: Front End Converter, SPWM, PID Controller, Simulink.

I. INTRODUCTION

Converters or rectifiers are extensively used in various application like power supplies, DC motors drives, front-end converters in variable speed drives, SMPS, Hvdc transmission lines and more etc. traditionally the converters have been dominated by the use of diode bridges or phase controlled rectifiers. These converters or rectifiers act as non-linear loads on the power system and draw currents which are rich in harmonics and have poor power factor. Thus creating power quality problem for the power distribution networks. As frequency of these converters increases, the Switching losses and source harmonics are increase with it. Passive power filters can reduce these harmonics up to some limit, but it cannot overcome non-characteristic harmonics. Passive filters have also other limitations which can overcome by the use of active filters.

The most efficient method of doing this is by Pulse Width Modulation (PWM) control used within the converter. Using PWM rectifier we can be able to control both input side AC source current and the output side load voltage. The use of front End converter topologies have also become extensive in the power quality improvement techniques because of their excellent performance like sinusoidal inputs currents with negligible THD, high supply power factor, regulated and near to ripple free dc output voltage, reduced voltage stress, reduced stresses and hence low EMI emission.

In this paper a closed loop single phase front-end converter is implemented to give near unity power factor and to also reduce the total harmonics distortion in the line current while also producing a less ripple boosted voltage at load. This in the end will satisfy the norms set by IEEE-219 and IEC 555. A PI controller is used to obtain the firing sequence so as to achieve the desired control. Matlab Simulink software is used to prepare the simulation.

II. COMPONENTS OF POWER QUALITY

Electrical and electronic equipments rely on the quality of power for them to operate as expected. This section will cover two important components which are power factor and total harmonic distortion. In general, power factor should be as close to one as possible and total harmonic distortion should be as low as possible.

Total Harmonic Distortion

Non-linear loads and power converters change the nature of the current so that it is no longer sinusoidal. Switching power supplies, in which the power element rapidly transitions between a fully-on and a fully-off state, can be especially non-linear. THD standards for current are important because those higher-frequency current components have various undesirable effects on electrical systems, including increased total currents, increased core losses in motors, and electromagnetic interference with other electronic equipment.

The harmonic distortion created by a load is obtained by measuring the current at each harmonic frequency (multiples of the mains supply frequency which is normally 50Hz or 60Hz for the public supply network).

POWER FACTOR

The basic idea is that power factor is the amount of real power delivered to a system divided by the amount of apparent power delivered to the system..

where PF is the power factor, P is the real power, and S is the apparent power. |S| = IRMS × VRMS, and PF indicates the fraction of the apparent power that is actually used by the system.

The two key aspects of the system that affect the power factor are the harmonic distortion (this is called the distortion factor) and the phase relationship between the AC voltage and current (the cosine of this phase difference is called the displacement factor). The more sinusoidal the current is, the closer to unity the distortion factor will be.

III. SINE PULSE WIDTH MODULATION (SPWM)

The acronym SPWM stands for "Sinusoidal pulse width modulation" is a technique of pulse width modulation used in converters. An inverter generates an output of AC voltage from an input of DC with the help of switching circuits to reproduce a sine wave by generating one or more square pulses of voltage per half cycle. If the size of the pulses is adjusted, the output is said to be pulse width modulated. With this modulation, some pulses are produced per half cycle. The pulses close to the ends of the half cycle are constantly narrower than the pulses close to the center of the half cycle such that the pulse widths are comparative to the equivalent amplitude of a sine wave at that part of the cycle. To change the efficient output voltage, the widths of all pulses are amplified or reduced while keeping the sinusoidal proportionality. With PWM (pulse width modulation), only the on-time of the pulses are changed during the amplitudes.

SPWM techniques are characterized by constant amplitude pulses with different duty cycles for each period. The width of these pulses are modulated to obtain converter output voltage control and to reduce its harmonic content. Sinusoidal pulse width modulation is the mostly used method in motor control and converter application. In SPWM technique three sine waves and a high frequency triangular carrier wave are used to generate PWM signal. The switching signal is generated by comparing the sinusoidal waves with the triangular wave. The comparator gives out a pulse when sine voltage is greater than the triangular voltage and this pulse is used to trigger the respective converter switches. The phase outputs are mutually phase shifted by 1200 angles. The ratio between the triangular wave & sine wave must be an integer N, the number of voltage pulses per half-cycle, such that, 2N= fc /fs. Conventional SPWM signal generation technique for three phase voltage source converter.

This is a technique that utilizes a triangular carrier wave modulated by a sine wave and the purposes of convergence decide the exchanging purposes of the power gadgets in the converters.

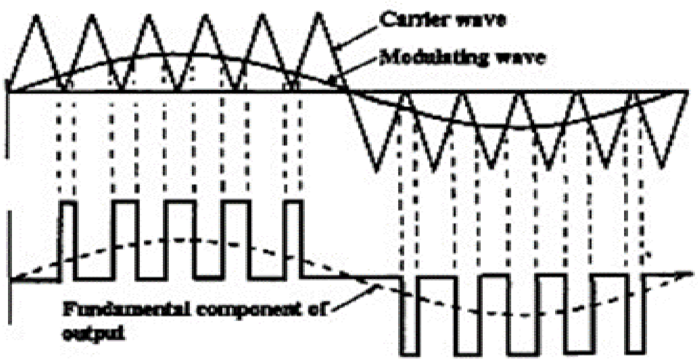


Fig.1 SPWM technique

IV. IMPLEMENTATION & RESULTS.

The setup includes a sinusoidal pwm control which were both discussed earlier. However, the appropriate values of the power components need to be calculated as per our need and requirement. The value of inductor is calculated according to the voltage drop in line due to inductive reactance. The voltage drop have been taken to be 3% of the line voltage. Meanwhile the value of the capacitance that is connected in the dc link is governed by the maximum voltage tolerable and the maximum ripple current at switching frequency and operating temperature of the converter.

The feedback of the output voltage is taken out and compared and corrected using the PI which is multiplied with the input side voltage and compared to a carrier signal which then produces a switching pattern.[1][2][3].

As stated earlier, the topology used is a single-phase front-end converter with an inductor connected at the source side and a dc link capacitor connected across the load. The components were designed for 150W output power with a peak line voltage of 100V at 60Hz.

Data used:

Voltage = 100   Frequency = 60   Inductance = 7.5mH   Ref Voltage = 150

Capacitance = 2000µF   P gain = 0.001   I gain = 0.1   RL = 45

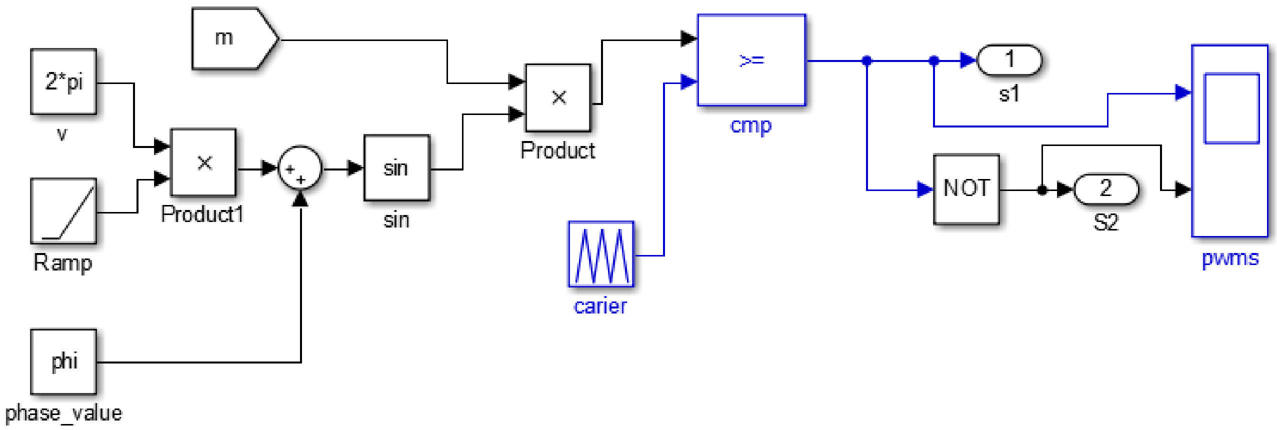


Fig.2 Simulink Model of SPWM

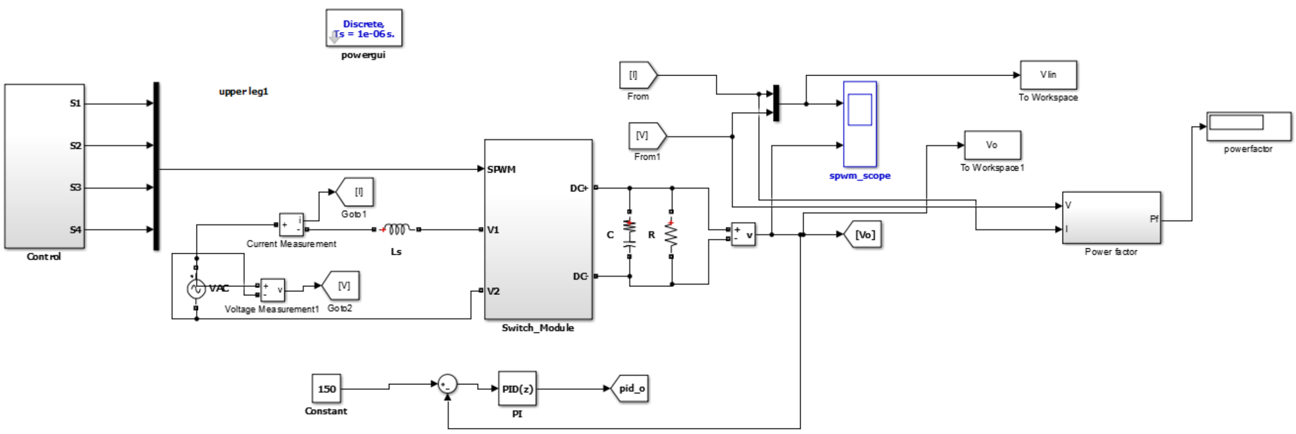


Fig.3 Simulink Model of the System.

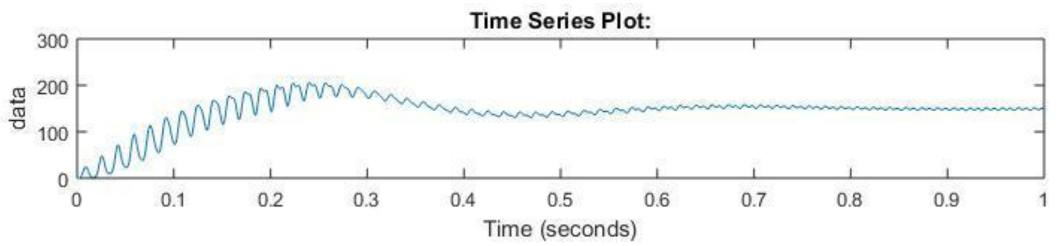


Fig.4 Output Voltage

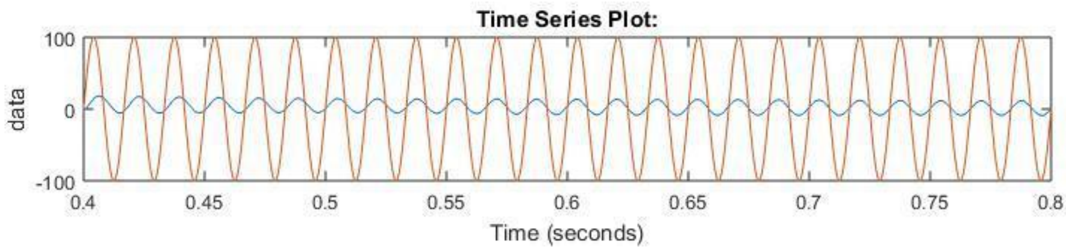
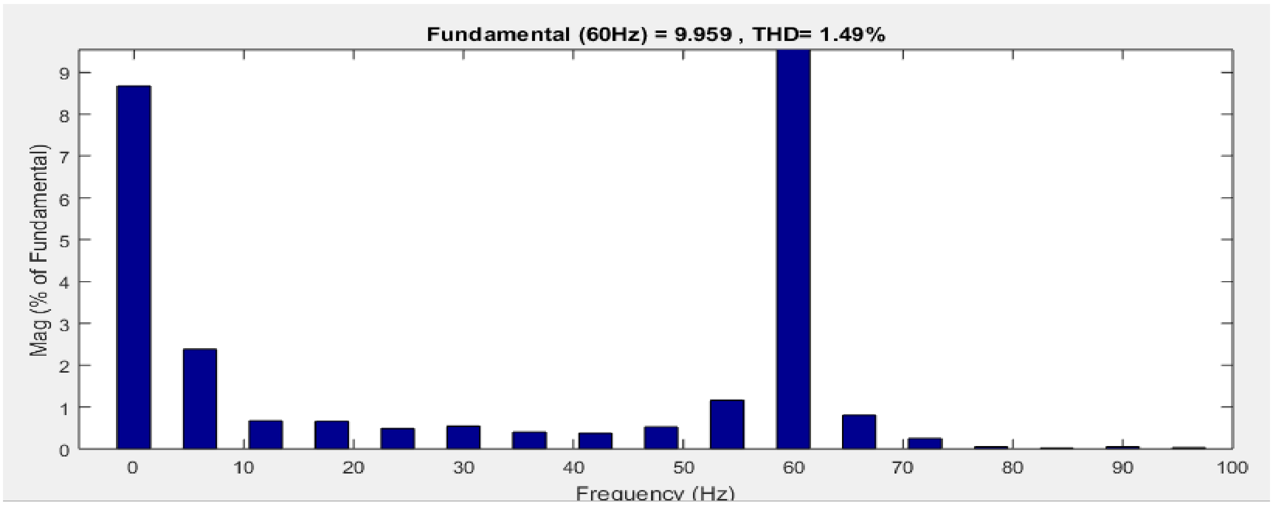


Fig.5. Source Voltage and Source Current



Power factor = 0.9 THD = 1.49% .

Fig. 6 . Graph of THD.

V. CONCLUSIONS

As presented in this paper, the two methods have been implemented successfully using Matlab/Simulink tool. When no control is applied to an open loop PWM converter the power factor is nowhere close to unity and the source current is also rich in harmonics. However when control is applied, the power quality is improved. For SPWM the harmonics was reduced to 1.46% and unity power factor is achieved. It is however important to note the values of the PI controller affects both the nature of source current (harmonics) and the time taken to reach the reference voltage.

The main objective fulfilled from the results is that by achieving near to unity power factor which gives it an edge over the conventional rectifiers. The converter is highly suitable for medium voltage and medium power industrial applications. The converter does not allow the harmonics and reactive power to flow in the system. The target application of the converter can be as a front end rectifier in inverters for ac drives and mainly as excitation systems for synchronous alternators which are primarily SCR based.

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