Soft Switching Control of Power Factor Correction for Distribution System

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Abstract: A boost Power Factor Correction (PFC) front end converter followed by a full bridge transformer-isolated dc/dc converter is popular in offline dc power supply. In this configuration switching losses are high and overall efficiency is reduced. For solving this problem individual soft-switching techniques are required for both the converters. A dc power supply system that uses a new Zero-Voltage Switching (ZVS) strategy to get ZVS function is proposed here. A soft-switching dc power supply system with high input power factor and stable dc output voltage is presented with simple and compact configuration. The proposed circuit is not only operated at constant frequency, but all semiconductor devices are operated at soft switching without additional voltage stress. A significant reduction in the conduction losses is achieved, since the circulating current for the soft switching flows only through the auxiliary circuit and a minimum number of switching devices are involved in the circulating current path, and the rectifier in the proposed converter uses a single converter instead of the conventional configuration composed of a four-diode front-end rectifier followed by a boost converter. An average-current-mode control is employed in proposed dc power supply system to synthesize a suitable low-harmonics sinusoidal waveform for the input current.

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INTRODUCTION

Isolated AC/DC converters are frequently employed in service interfaced systems such as power supplies in telecommunication and data centers, plug-in hybrid electrical vehicles (PHEVs) and battery electric vehicles (BEVs)[1]. A low-cost and stout ac to dc converter consisting of a line frequency diode bridge rectifier with a large output filter capacitor requires a harmonic affluent ac line current. As a consequence, the input power factor is derived [2]. The converters with high power factor are highly required in industries. Most of the Power Electronic (PE) systems which get connected to AC efficiency mains use diode rectifiers at the input. The nonlinear nature of diode rectifiers causes considerable line current harmonic production; thus, they corrupt power quality, enlarges losses, collapse of some crucial medical equipment, etc[3].

The flaccid filter method to PFC is restricted to applications where the size and weight of the converter are not main concerns. For overcoming this problem, a boost PFC front-end converter followed by a transformer isolated dc–dc converter is the most extensively employed in offline power supplies, and full-bridge transformer-isolated dc/dc converter is the most extensively applied in medium-to-high power dc/dc power conversion[4]. Operating from a high input voltage needs a soft transition topology to diminish the switching losses and decrease the high frequency electro magnetic interference (EMI) caused by a high voltage changes [5]. Soft switching techniques are used for overcoming the hard switching problem [12]. To diminish switching stresses, losses, and electromagnetic interference (EMI), soft-switching techniques have been building up for power converters since the 1970s. There are several topologies, they use soft-switching for inverters [7].

As the frequency of switching raises thus do the switching losses and electromagnetic interference (EMI) noises. Switching losses and EMI noises of PWM converters are primarily generated during turn-on and turn-off transients. Resonant converters commutate with both zerovoltage- switching (ZVS) and zero-current-switching (ZCS) to decrease switching losses and

EMI noises [6]. Switch-mode power supplies has become lesser and lighter, because the switching frequency has enlarged. However, as the switching frequency has increased, the intervallic losses at turn-on/off have also increased. As a consequence, this loss carries increasing loss of complete system. Thus, to decrease these switching losses, a soft switching technique is proposed, which engages an extra auxiliary circuit[8].

Higher switching frequency causes lots of periodic losses at turn ON and turn OFF, ensuring in growing losses of the entire system. Hence, various converters have been given that employs resonance to reduce switching losses. Many researches with resonance have offered a zero-voltage and zero-current switching (ZVZCS) converter that do zero-voltage switching (ZVS) and zero-current switching (ZCS) concomitantly [4]. Soft-switching methods/ topologies are favored in each conversion phase as they facilitate extra decline of the losses and the amount of the system [1]. Though, all existing soft-switching inverters utilize extra active devices to attain soft-lively devices to attain soft-switching, thus growing costs and control complexity and reducing reliability. These soft-switching technologies are prior to, the Resistor, Capacitor, Diode snubber circuit had been broadly used in PWM inverters to reduce switching stresses and EMI. The conventional RCD snubber is lossy and massive, and it is hard to pertain to highfrequency switching PWM inverters since the losses in the snubber raises proportionally with the switching frequency [7].

Two techniques which incorporate a soft switching function are Zero voltage transition and Zero current transition. Furthermore ZVT methods can eliminate the turn on capacitive losses and thus MOSFETs are favored [12]. The Zero-Voltage-Transition (ZVT) and Zero-Current-Transition (ZCT) methods in which auxiliary circuits are used to aid the switches to function under soft switching condition are most motivating method [9]. Throughout this circuit, all of the switching devices attain soft-switching under zero-voltage and zero-current settings.

Thus, the periodic losses produced at turn-on and turn-off can be declined [8]. By means of soft switching techniques clarify the presentations of the dc to dc power converters in various classifications and the items where to boost up the circuit efficiency of the power converters by virtue of which circuit complicacy and excess cost contribution arise chaotically, supporting switch, additional control element, inactive elements are implemented. Still various papers reveal up to 96% efficiency without including switching losses of secondary switch and related other passive components [13].

PFC control methods for single phase boost converter may be categorized as current control and voltage control. Current control is the most common control approach since the main purpose of PFC is to oblige the input current to outline the shape of line voltage. Because of the requisite, the PFC current control methods acquire their rapid growth to meet the European standards fulfillment for the low frequency current harmonics directive [14]. Power factor correction (PFC) circuits are integrated in PE systems. Previously, to diminish rectifier-generated harmonics, exclusive and massive filter inductors and capacitors were installed, but they effectively abolish only definite harmonics .The active power line conditioners are usually hard switched; therefore, the components are subjected to high-voltage pressure which boosts additionally with raise in the switching frequency. Also, hard switching consequences in minute efficiency, bulky EMI, etc.,[3].

Passive power factor correction technique: Among the diode rectifier input port and the AC mains line of AC/DC converter in passive PFC techniques, an LC filter is included. Active power factor correction techniques: To form the input current in this approach of active PFC techniques in phase by means of the input voltage. Switched Mode Power Supply (SMPS) system is utilized. Hence, unity power factor can be achieved. The Active PFC techniques can be classified as follows 1) PWM PF correction, 2) Resonant power factor correction, 3) Soft Switching Power Factor Correction[4].

Between the input port and the AC mains line of the diode rectifier of AC/DC converter an LC filter is inserted. Active power factor correction techniques: In active PFC methods, to figure the input current in phase with the input voltage we apply a Switched Mode Power Supply method. Hence, the power factor can achieve up to unity. The Active PFC techniques can be defined as shown 1) PWM power factor correction, 2) Resonant power factor correction, 3) Soft Switching Power Factor Correction[4].

This paper presents a new single-phase soft-switching parallel boost power factor correction (PFC) converter with a active snubber cell. In which to diminish the switching losses, for the main switches turn ON by ZVT and turn OFF with ZCT perfectly together, and for the secondary switch, turn ON with ZCS and also turn OFF with ZCS is achieved, with no important add to the cost and difficulty of the converter for the switches. A switch mode converter with parallel connection is a eminent approach. Phase changing of two or extra boost converters attached in parallel is involved and functioning at the identical switching frequency. Advantages of this approach include, overall efficiency is high, reduction of the development cost due to the modular design, reduction of conduction losses . All of the simulation employment is achieved in MATLAB – Simulink.

POWER FACTOR CORRECTION

The cosine of the angle between voltage and current in an Ac circuit is stated as the Power factor. There is normally a phase difference Ø among the voltage and current in an Ac circuit. If the circuit is inductive, the current lags after the voltage and power factor is denoted as lagging. Where leading is stated as, the current leads the voltage and the power factor in the capacitive circuit.The ratio of real power to apparent power is the standard definition of power factor. With the cosine angle between them the real or average power is calculated as the product of the voltage and current magnitudes multiplied, whereas the product of the root mean square values for the apparent power.

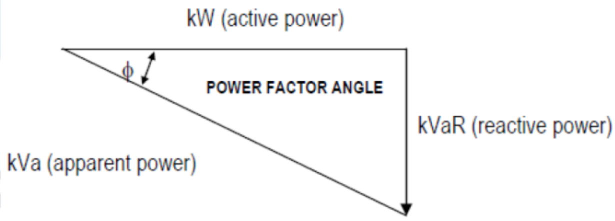

Fig 1: Power Triangle

Power Factor is usually specified as a number between 0 and 1, and is equal to the ratio of reactive power to active power, or Cosine ϕ, as presented above. The increase in power factor number makes the system more efficient. Thus, a system with a Power Factor of 0.9 is much more efficient than the power factor with 0.6.

$$\text{Power Factor} = \frac{Real\ Power}{Apparent\ Power}$$

A high power factor is generally required in a transmission system to decrease transmission losses and to improve voltage regulation at the load. To regulate the system power factor to close to 1.0 is often needed. The load produces purely sinusoidal current and voltage in a linear system. By only the phase difference between voltage and current the power factor is found out. When two sinusoidal signals are considered with the same frequency, power factor can be clear in terms of the phase angle between them, i.e.,

$$Power\ Factor = \cos\emptyset$$

The phase angle representation alone is not valid, because of the non linear performance of the active switching of power devices in non linear systems similar to power electronic systems. Typical biased line current draws a non linear load from the line. The *PF* for sinusoidal voltage and non-sinusoidal current can be said as

$$\text{Power Factor} = \frac{V_{rms}\, I_{1rms}}{\mathrm{V_{rms}\ I_{rms}}} \cos\emptyset$$

$$\text{Power Factor} = \frac{I_{1rms}}{\mathrm{I_{rms}}} \cos\emptyset$$

$$\text{Power Factor} = \mathrm{K_f} \cos\emptyset$$

Where, K_f is given as the purity factor or the distortion factor

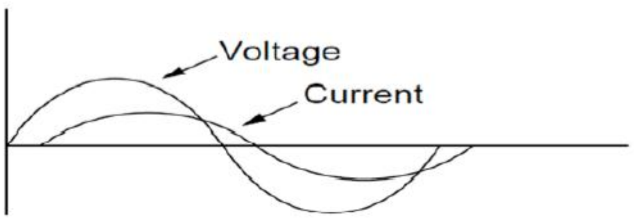

Fig 2: Traditional poor power factor (the current either leads or lags the voltage)

Poor Power Factor should be modified as it considerably raises costs. The purpose of a power factor correction circuit is to power the converter to look alike a resistive load to the line. A resistive load has zero degree phase displacement amongst its current and voltage waveforms (and no added harmonics).

RECTIFIER AND BOOST CONVERTER

The circuit scheme of the proposed power factor correction converter consists of an full wave bridge AC-DC rectifier and a modified boost converter. From a sinusoidal ac input waveform a rectified ac output generated is the purpose of the full wave rectifiers. It ensures this by means of the nonlinear conductivity characteristics of diodes to direct the path of the current.

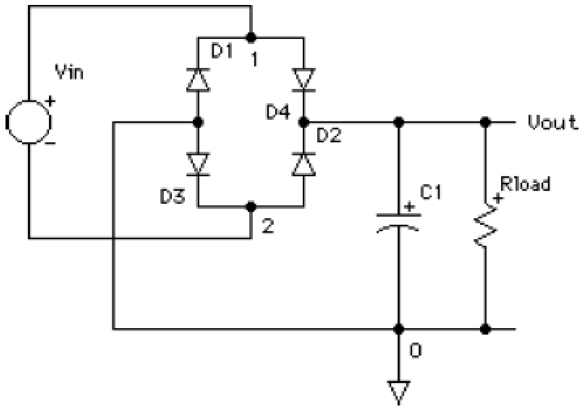

Figure 3. Filtered full wave rectifier

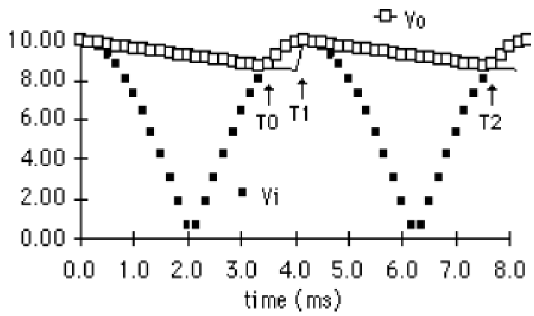

Figure 4. Output (Vi) and input (Vo) of a filtered full wave rectifier

The filtered full wave rectifier is obtained from the FWR by calculating a capacitor during the output. The FWR output is the outcome of the addition of a capacitor. The output is presently a pulsating dc, during a peak to peak variation is recognized as ripple. The input voltage magnitude and frequency be obtained during the magnitude relies of the ripple, through the filter capacitance, as well as the load resistance.

For the duration of the time period since T0 to T1, the diode D1 (or D3, based on the segment of the signal) is forward biased then Vi > VC1 (inexact the forward biased diode as a short circuit). When the capacitor C1 get charged due to the voltage across the load R increases. Starting from] T1 to T2, the D1 and D2 diodes are biased reversely (open circuit) as Vcap>Vi, and then the capacitor get discharge over the load R during a time constant of RC seconds. Along a capacitor discharge arc the voltages among times t1 and t2 set. Through which the output voltage is,

$$V_{Out}(t) = V_{mx} e^{\frac{-t+t1}{RC}}$$

The peak to peak (pp) ripple is indicating as the voltage difference between Vmax and Vmin

$$V_{Ripp}(pp) = V_{out}(t1) - V_{out}(t2) = V_{mx} - V_{mn}$$

$$= V_{mx}\left[1 - e^{\frac{-t2+t1}{RC}}\right]$$

If C is huge, such that RC >> T2 - T1,
we can estimate the exponential

$$1 - e^{\frac{-t2+t1}{RC}} \text{ as } 1 + \frac{-t2+t1}{RC}.$$

Then t2 - t1 ~ t/2, somewhere t is the period of the sine wave, now

$$V_{Ripp}(pp) = V_{mx}\frac{t}{2RC} = \frac{V_{mx}}{2fRC}$$

After the rectification of dc voltage is deposit to the boost converter using snubber circuit. A boost converter is just like a particular kind of power converter, here the output DC voltage is greater than that of the input DC voltage. This kind of circuit is used to 'step-up' a source voltage is greater than that the regulated voltage, leasing one power supply to offer different driving voltages. It is a part of switching-mode power supply, its including as a minimum two semiconductor switches (a diode and a transistor) and least one energy storage factor. After the transistor is conducted , the conventional boost converter current is being drawn in excess over the inductor and at the present, the energy is being stored in the inductor. When the transmission of current through the inductor cannot change immediately when transistor stops conducting the inductor voltage flies back or reversed.

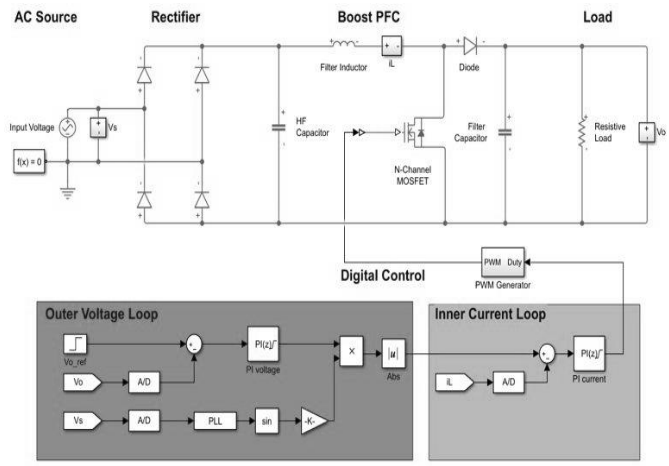

Fig 5: Simulink model of digitally controlled boost power factor correction.

SIMULATION DIAGRAM:

The proposed simulation circuit shows how to correct the power factor using a PFC pre-converter. This technique is useful when non-linear impedances, such as Switch Mode Power Supplies, are connected to an AC grid. As the current flowing through the inductor is never zero during the switching cycle, the boost converter operates in Continuous Conduction Mode (CCM). The inductor current and the output voltage profiles are controlled using simple integral control. During start up, the reference output voltage is ramped up to the desired voltage.

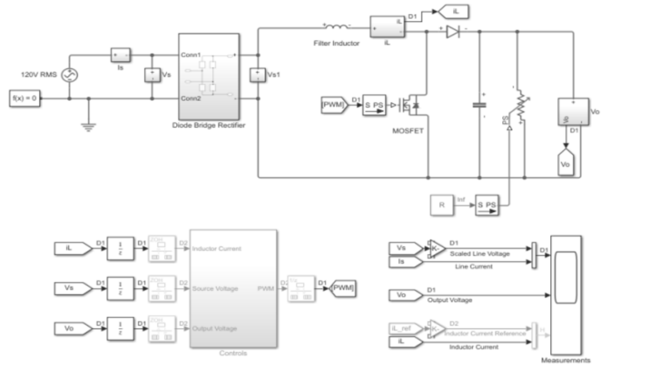

Fig 6: Simulation Circuit for Power Factor Correction for Continuous conduction mode

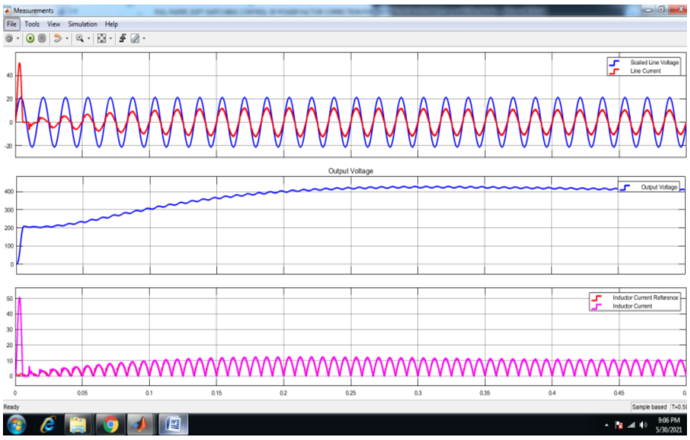

Fig 7: Simulation Results (a)line voltage and current (b)output voltage and (c) Inductor reference and actual current

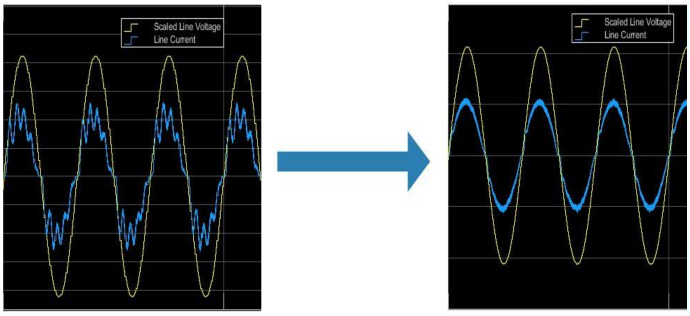

Fig 8 : Harmonic distortion in line current (blue) and after power factor correction (yellow).

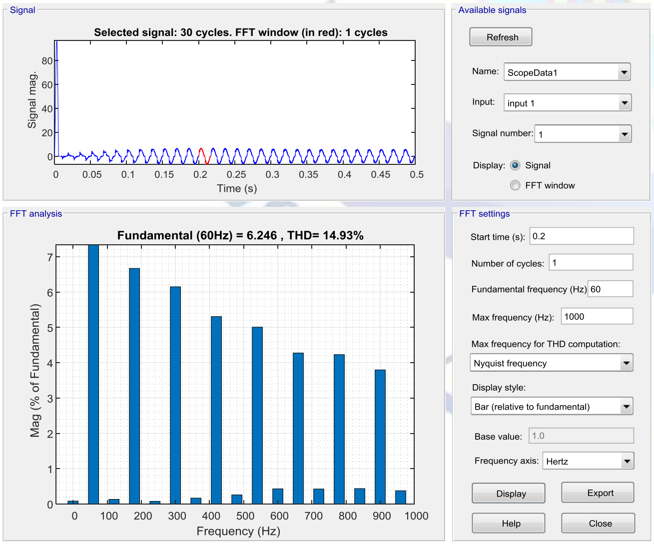

Fig: 9 Current THD

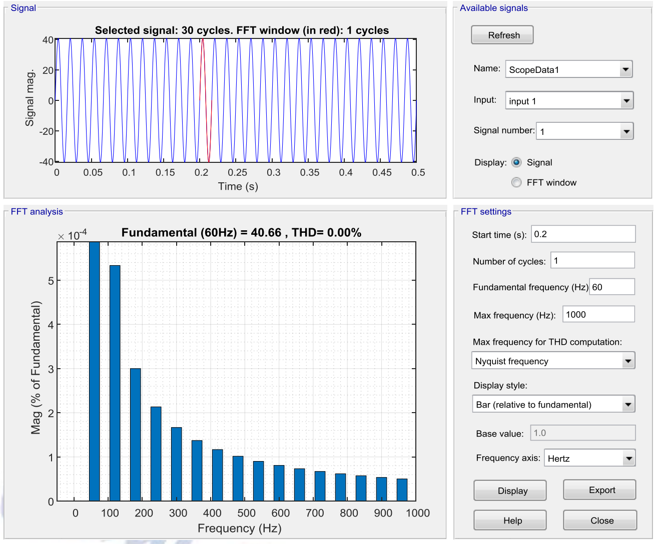

Fig: 10 Voltage THD

CONCLUSION

The main objective throughout the project is to improve the Power Factor with active snubber circuit for the parallel boost converter. Simulations were initially done for conventional boost converter with snubber circuit. The changes in the input current waveform were saw and calculated. A PFC circuit having a parallel boost converter i.e. dual boost converters arranged in parallel was designed with soft switching which is provided by the active snubber circuit. For this idea, only one auxiliary switch and one resonant circuit is operated. The main switches and all the other semiconductors are switched by ZVT and ZCT techniques. The active snubber circuit is applied to the parallel boost converter, which is fed by rectified universal input ac line. This latest PFC converter is achieved with 200 V ac input mains. The diode is added in order to the auxiliary switch path to avoid the incoming current stresses as of the resonant circuit to the main switch. It is noticed that the Power Factor and the efficiency is better for Dual Boost Converter Circuit. Finally, 98% efficiency at full load is achieved and the power factor is reached to 99.97% for the proposed converter. Due to the main and the auxiliary switches have a common ground, the converter can easily control. The proposed new active snubber circuit can be simply functional to the further basic PWM converters and to all switching converters. The proposed converter does not need any further passive snubber circuits.

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