SIMULATION OF TRANSFORMERLESS SINGLE STAGE SINGLE SWITCH HIGH STEPDOWN CONVERTER FOR BATTERY CHARGING APPLICATIONS USING SIMULINK

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Abstract : **This paper explains the Simulink model of a DC – DC converter to step down from a 90 V_{rms} - 308 V_{rms} to 27 V_{dc} using high step-down transformer less single stage single switch step down DC – DC converter which is suitable for numerous DC load applications with power factor closer to unity. The usual practice is to design a separate Boost converter for PFC stage but in this a single stage will do the PFC as well as stepping down low output voltage with duty cycle in acceptable number which is above 20%. Since there is only one power switch switching losses and conduction losses have drastically reduced resulting in better efficiency than compared to other DC – DC converters. Added to this, requirement of transformer has been eliminated which in turn has resulted in reduced cost and increased efficiency. Also the switch voltage stress in not dependent on the variation of load. The DC – DC converter has been simulated using Simulink model and power factor is found to be greater than 0.95 for load variation from 50% - 150% and also for line variation 90 V_{rms} – 308 V_{rms}.**

IndexTerms **-** Direct power transfer (DPT), integrated buck-buck-boost converter (IBuBuBo), power-factor correction (PFC), single stage, single-stage (SS), Simulink.

I. INTRODUCTION

SINGLE-STAGE power-factor-corrected ac/dc converters, which comprises of a stage with power factor correction (PFC) circuitry and added to this a dc/dc converter circuit which share a set of some active power switches, have been put in. The main aim is to reduce the size of the converter, control strategy, and the overall cost. Three main disadvantages are found in the above said converters: 1) additional stress on the switch due to current; 2)voltage stress on power semiconductor switches due to high voltage across the bus; and 3) it produces voltage spikes. Because of these disadvantages these type of converters are used preferably for low power applications.[1]

In recent times there has been a wide improvement in DC – DC converters which does provide with better efficiency but the cost of the magnetics is setting them away from consumer point of view. As in the case of two stage where in many switches needs to be used as compared to a single stage. Generic converter will have two stages to get better power factor, a number of techniques have been introduced. However, most of the proposed techniques usually comprise a boost converter for PFC, followed by a dc–dc converter for output voltage regulation. Hence, for low-output-voltage applications, a high step-down transformer topology would be needed for the output dc–dc stage even when galvanic isolation is not required.[2]

Due to thestringentcurrent-harmonic regulations, which are imposed on single phase ac/dc power supplies, inclusion of a power-factor-correction (PFC) circuit in the power-supply design becomes mandatory. Conventional ac/dc power supply-design uses a cascade connection of a PFC circuit followed by a dc/dc converter. Many single-stage (SS) ac/dc converters have been reported. The SS ac/dc converter reduces cost, size, and complexity in the control loop by combining a PFC cell with a post-dc/dc cell and using one common set of switching-control signal. It is a very attractive solution in lowpower application where the manufacturing cost and size of converter are the major issues. The underlying principle for the SS ac/dc conversion is to force the PFC cell inductor operating in discontinuous conduction mode (DCM) to achieve high power factor automatically without any control loop, whereas the well and tight output regulation is done by post-dc/dc cell working in DCM or continuous conduction mode (CCM).Therefore, only one control loop is needed for the whole circuit. For the sake of circuit simplicity, most of the PFC cells in an SS ac/dc converter are a boost cell for which the output voltage is always greater than the peak input voltage. Also, due to the lack of regulation on the intermediate bus voltage, this voltage usually exceeds 450 V, causing high voltage stress on the bus capacitor and switching devices at high line application. It has been reported that this bus voltage can easily exceed 1000 Vfor the combination of DCM PFC cell and CCM dc/dc cell at light-load condition[3], leading to very limited and costly selections of switching devices and bus capacitor. This is caused by unbalanced power flow from the input voltage source and output load.

Interestingly, both PFC and dc/dc cells operating in DCM mode can keep this bus voltage in a reasonable range (usually greater than 400 V) even at light-load condition.

The SS converter can operate either in continuous conduction mode (CCM) or discontinuous conduction mode (DCM). The operation in CCM offers the advantage of requiring lower root mean- square (rms) currents through the power switches, whichyields higher efficiency.

However, operation in CCM presents the disadvantage of having no relationship between the output power and the duty cycle of the control switch. This finally causes a high bulk capacitor voltage at low output power levels.This is an important disadvantage especially when a universal input voltage range is pursued [15].The other possibility is the operation of a SS dc–dc converter in DCM. In this case, the output power will depend on the dutycycle of the control switch. The operation with both inductors of the ICS and dc–dc converter in DCM is particularly interesting. In this case, the ratio between bulk capacitor voltage and the peak line voltage will depend only on the two inductances ratio, being independent of the output power. This means that a reasonable bulk capacitor voltage can be maintained for the universal input voltage range. Besides, a high bulk capacitance is not necessary, since the voltage ripple across this capacitor, at double line frequency, can be compensated by closed-loop operation. This is due to the fact that the bulk capacitor voltage is independent of the duty cycle. Therefore, the changes on the duty cycle will affect only the output voltage, thus making it possible for a fast output voltage regulation [4]-[6].

II. DESIGN CONSIDERATIONS

Some assumptions are made to simplify the circuit analysis As follows:

1. All components are ideal;
2. Line input source is pure sinusoidal, i.e. *v*in (θ) =*V*pk*sin*(θ) where *V*pk and θ are denoted as its peak voltage and phase angle, respectively;
3. Both capacitors *CB* and *Co* are sufficiently large such that they can be treated as constant DC voltage sources without any ripples;
4. The switching frequency *fs* is much higher than the line frequency such that the rectified line input voltage |*v*in (θ)| is constant within a switching period.

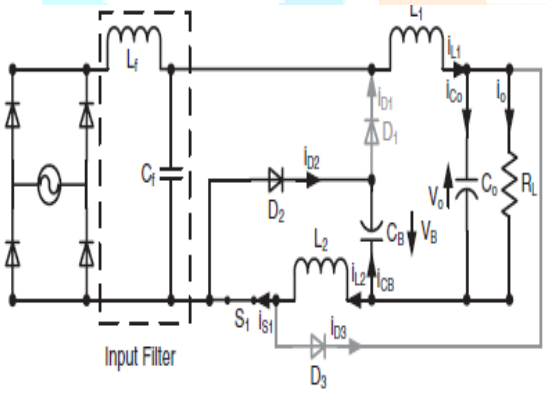

Fig: 1(a)

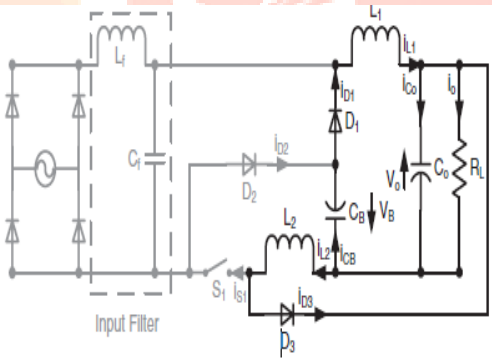

Fig: 1(b)

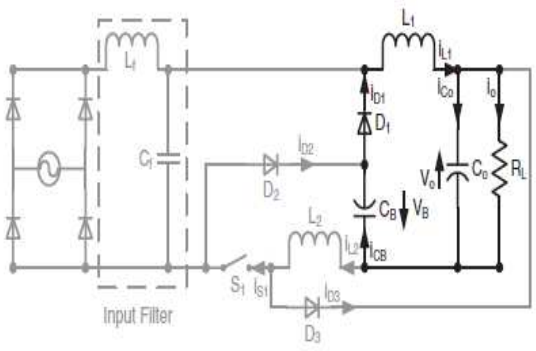

Fig: 2(a)

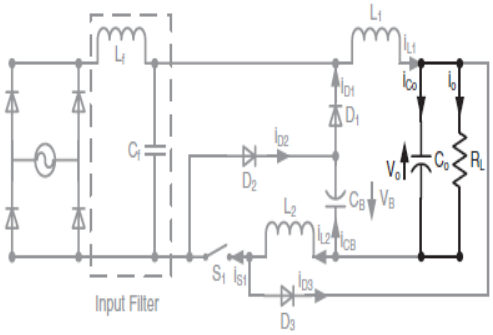

Fig: 2(b)

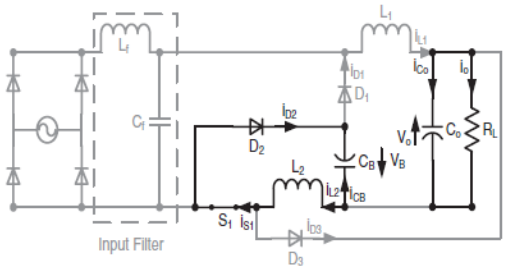

Fig: 3(a)

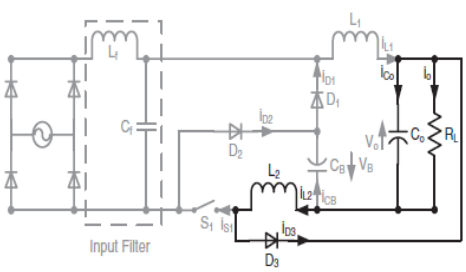

Fig: 3(b)

Fig.1(a), 1(b), 2(a), 2(b), 3(a), 3(b) explains the different modes of operation of the converter. Wherein fig.1(a) and 3(a) shows the circuit operation when the switch is "ON" and fig.1(b), 2(a), 2(b), 3(b) shows the operation of circuit when switch is "OFF". When the switch is ON the inductor L2 stores energy then in the next cycle it releases its energy to the LOAD. Different modes of operation of the circuit can be further understood from the fig.4(a) and 4(b) which gives neat pictorial explanation of different modes of operation. And can be seen that current in L2 increases during d1Ts and releases its energy to the load during d2Ts.

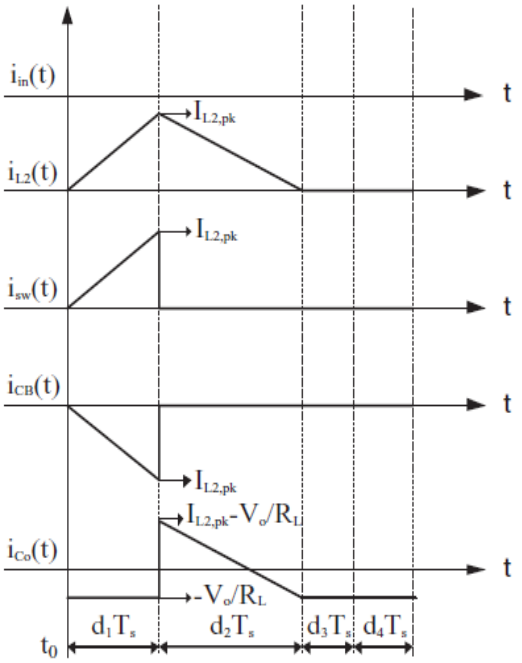

Fig: 4(a)

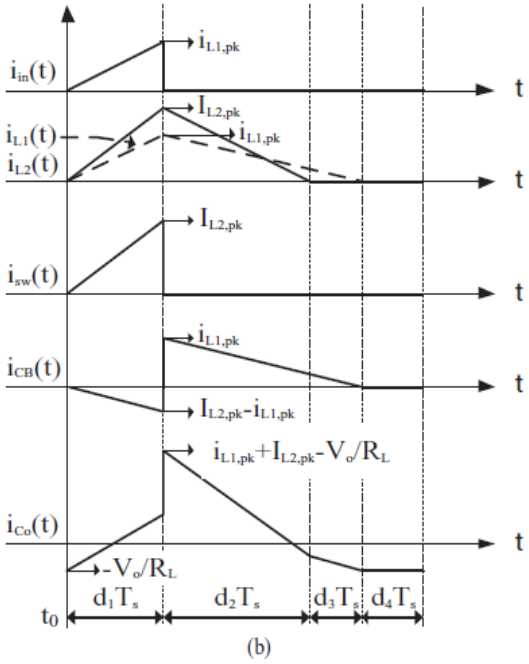

Fig: 4(b)

II. Simulink Model:

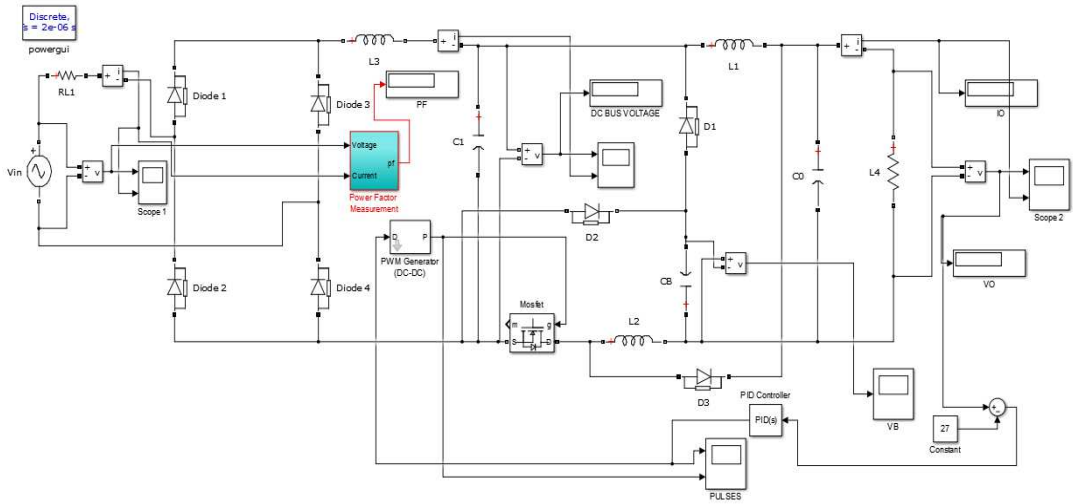

Fig.5. Simulink model of the coverter

Simulation model is developed using MATLAB / Simulink and most of the components is from sim power systems.

III Results and Discussion

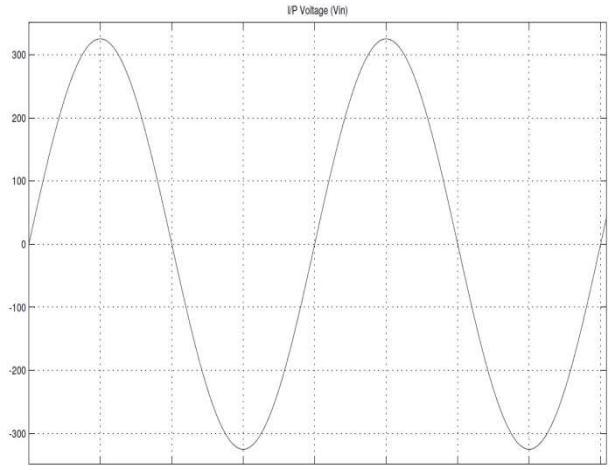

Fig: 5 (a)

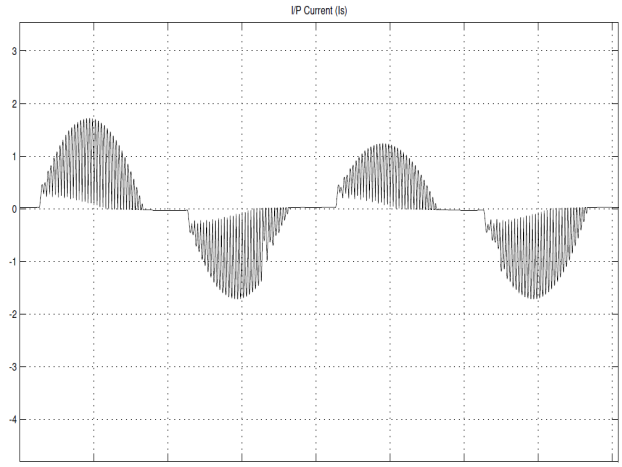

Fig 5(b)

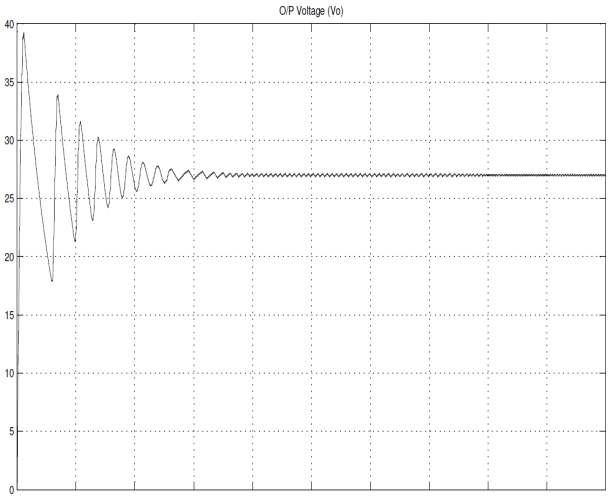

Fig: 6(a)

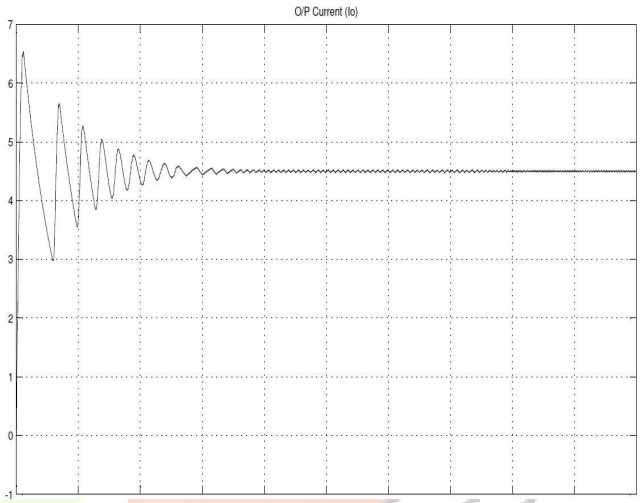

Fig: 6(b)

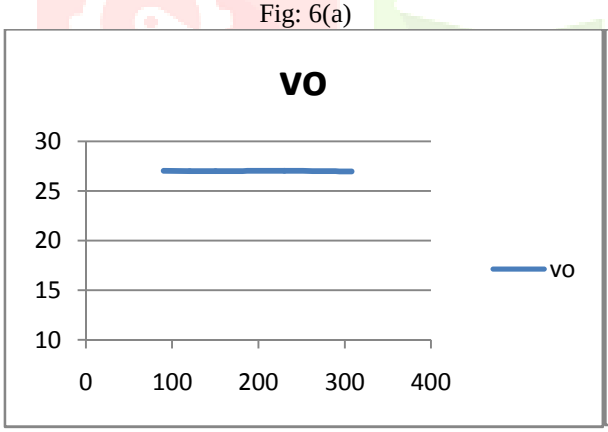

Fig: 7(a) Line variation Vs Output Voltage

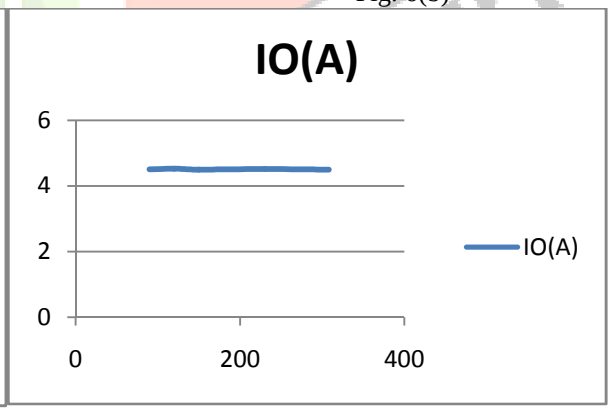

Fig: 7(b) Line variation Vs output current

Fig.6(a) and 6(b) represents the input voltage and input current at 230 Vrms, as can be seen from 6(b) current is made follow the voltage through switching of MOSFET and thus achieve higher power factor of the order of 0.95. Further, Fig.7(a) and 7(b) represents the output voltage and current at 230 Vrms. Whose settling time was somewhere around 1.5 s and maximum peak overshoot of 38 V. As the converter was designed for two battery charging operation the voltage is somewhere around 13.5 V + 13.5 V = 27 V. In this paper current is restricted to 4.5 A keeping in mind to use 45 AH capacity battery since the current for any Lead acid battery should not exceed 10 / 12%. In this case it is restricted to 10% which is comes to around 4.5 A from the simulation maximum peak overshoot is found to be somewhere around 6.5 A.

As can be seen from fig.8 the power factor is found to be constant for varying input voltage in this case universal input has been considered i.e. 90 – 308 Vrms. Also line regulation is found be formidably stable and has a very small effect on the output voltage and current.

IV Conclusion

As simulated the output voltage is at a constant value of 27 V i.e. two batteries in series and output current is fount be constant for varying line voltage for the universal input i.e. 90 – 308 Vrms. Also the very important factor for any SMPS designer is power factor from the simulation it is clear that power factor is almost equal to unity for universal input.

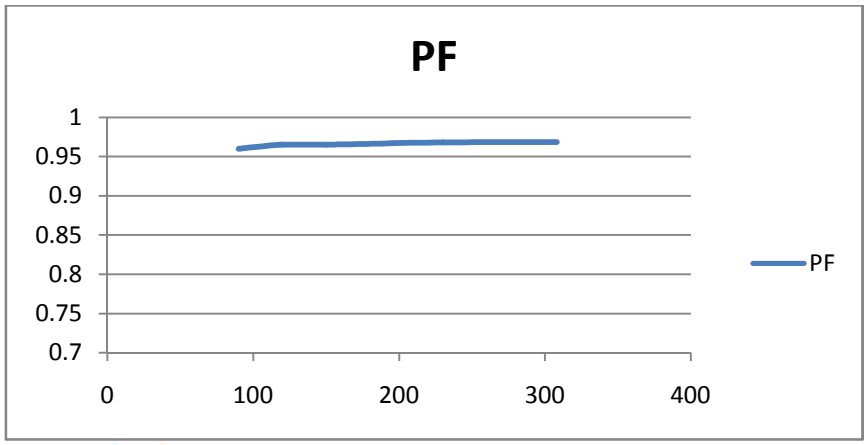

Fig: 8. Line Variation Vs Power factor

V Future Scope

This can be further implemented for larger power applications like LED Street lighting with better settling time and less maximum peak overshoot.

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