Design of PFC with Buck Boost Converter for Plug-In Electric Vehicles and Battery Charging Applications

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Abstract- **The wireless charging system working principle is same as transformer. It consists of transmitter and receiver, the AC supply is converted into high frequency alternating current, which is supplied to transmitter coil. Then it produces an alternating magnetic field which cuts the receiver coil and the receiver coil generates AC power output. The important thing in the wireless charging system is to maintain the resonance frequency between transmitter and receiver in order to make it effective. With the high modernization and electrification of industry, people now have a higher requirement for the power quality. For instance, personal computers, electronic devices, cell phones, they each has a basic requirement for power quality. Because of the wide application of power electronic devices, there are reactive power and harmonics in the power grid. The main research content of this paper is the design of boost power factor correction circuit and design of its control system. So we can conclude that the existence of harmonic current pollute power grid so much and we have to take some actions to eliminate or restrain harmonic current.**

Index terms- PFC, Buck Boost, MATLAB, Electric Vehicle, THD

I. INTRODUCTION

The AC-DC rectifier with power factor correction (PFC) takes an important role not only in energy saving but also in reduction of the total harmonic distortion (THD). Harmonics standards, such as IEC61000-3-2 [1], JIS-C-61000-3-2, etc., are offered to limit the harmonics generated from the electronic products. For example, the electronic products with output power above 75 W need to pass the corresponding harmonics tests. Consequently, the active buck PFC rectifier is presented. Such a rectifier can transfer a high input AC voltage to a low DC voltage. However, as the input voltage is lower than the output voltage, there is no
making zero-crossing distortion occur. Consequently, even if this rectifier operates in the CCM, the PF is relatively low and the THD is relatively high. Based on the aforementioned, the input current, thus making zero-crossing distortion occur. Consequently, even if this rectifier operates in the CCM, the PF is relatively low and the THD is relatively high. Based on the aforementioned, the active buck-boost PFC rectifier is proposed. In the CCM, such a PFC rectifier possesses relatively high variations in output voltage due to step-up/step-down of the input voltage. However, the output voltage of this rectifier is negative. Consequently, its industrial applications are limited. The wireless charging system working principle is same as transformer. It consists of transmitter and receiver, the AC input current, thus making zero-crossing distortion occur. Consequently, even if this rectifier operates in the CCM, the PF is relatively low and the THD is relatively high. Based on the aforementioned, the active buck-boost PFC rectifier is proposed. In the CCM, such a PFC rectifier possesses relatively high variations in output voltage due to step-up/step-down of the input voltage. However, the output voltage of this rectifier is negative. Consequently, its industrial applications are limited. The wireless charging system working principle is same as transformer. It consists of transmitter and receiver, the AC supply is converted into high frequency alternating current, which is supplied to transmitter coil. Then it produces an alternating magnetic field which cuts the receiver coil and the receiver coil generates AC power output. The important thing in the wireless charging system is to maintain the resonance frequency between transmitter and receiver in order to make it effective. To retain the resonant frequency, the compensation networks are added on both sides. The receiver side is then AC power, which is rectified to DC and fed to the battery via the Battery Management System (BMS). Boost circuit is a basic DC-DC conversion circuit. Boost circuit has many advantages like continuous inductor current, less distortion of current waveform and less RFI and EMI noise, so boost circuit is widely used in different power design. But for basic boost circuit, there are some perspectives we can improve such as power factor and circuit transmission efficiency. Because of the wide application of power electronic devices, there are reactive power and harmonics in the power grid. One of the methods to solve this problem is to apply active power factor correction technique. This technique brings active switch into conversion circuit, through the control of on and off of active switch. There are three kinds of non-isolated converter widely utilizes in the There are three kinds of non-isolated converters widely utilized in the active rectifier: boost, buck, and buck-boost converters. Among them, the active PFC boost rectifier is commonly employed. As electricity gets more and more important in people's life, there are increasing number of power devices with different features The power we get from national grid is 110V and 60 Hz. But most of the power devices require a different input from what we get from national grid, so we have to make some conversion of the voltage and current.

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II. BLOCK DIAGRAM OF BUCK BOOST CONVERTER WITH PFC CONTROLLER

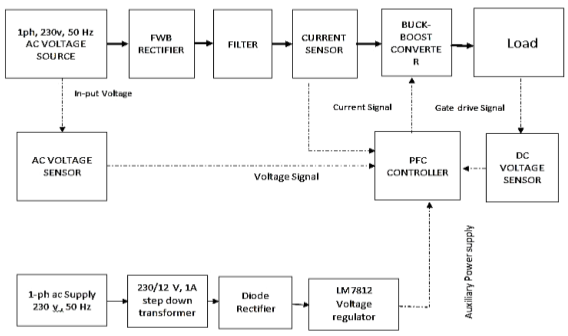

Figure 1: Block diagram of buck boost converter with PFC controller

The ac voltage is measured using same voltage divider technique. These sensors (i.e., input ac voltage, current, and output voltage) are the integrated part of the power factor controller (PFC).

A suitable power factor controller is selected to control the pulses to the buck-boost controller. The active power factor controllers specifically designed for use as a pre converter in electronic ballast and in off–line power converter applications. These integrated circuits feature an internal start-up timer for stand–alone applications, a one quadrant multiplier for near unity power factor, zero current detector to ensure critical conduction operation, transconductance error amplifier, quick start circuit for enhanced start-up, trimmed internal bandgap reference, current sensing comparator, and a totem pole output ideally suited for driving a power MOSFET. Also included are protective features consisting of an overvoltage comparator to eliminate runaway output voltage due to load removal, input undervoltage lockout with hysteresis, cycle–by–cycle current limiting, multiplier output clamp that limits maximum peak switch current, an RS latch for single pulse metering, and a drive output high state clamp for MOSFET gate protection. These devices are available in dual–in–line and surface mount plastic packages.

BUCK BOOST CONVERTER

Buck-Boost converter is a type of DC-DC converter (chopper) with a constant output voltage. It may be more or less than equal to the input voltage magnitude which depends on the mode of operation. The buck-boost converter is identical to the fly-back circuit, but instead of the transformer, the only difference is the single inductor is used. There are two types of converters in buck-boost converter based on the operations that are buck converter and the boost converter. These converters can produce the range of output voltage than the input voltage with the change in duty cycle. The DC-DC converter working operation is based on the input resistance inductor which causes unpredictable variance in the input current. If switch is ON, the supply power is fed by the inductor and stored in the form of magnetic energy. This dissipates energy to the load if switch is OFF. The capacitor values of output circuit are assumed to be high. The objective is to maintain the constant voltage at the load terminal. Ratings of buck boost converter is 240V AC to 60V DC output. In simulation we are using resistive load. Which act like a discharged battery. In hardware we can use lead acid battery of 12V DC. The resistive load to be used is of the rating 10 Ohm, 25 Watts.

Power factor correction (PFC) schemes are to ensure that these systems can operate at their maximum efficiency. PFC circuits help to use of power in efficient way, decrease operating costs and improve performance. This PFC controller consists of two control modes, voltage control mode and current control mode. This controller calculates the firing angle need to be generated to make voltage and current almost in phase. To make the input power factor close to the unity and to accurately charge the battery. This is done to improve the performance of the battery and also the life cycle.

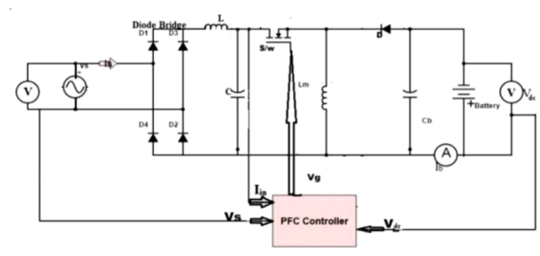

Fig 2: Proposed Buck boost convertor.

Unlike other conventional PFC converters, the proposed non-inverting buck-boost based PFC converter has both step-up and step-down conversion functionalities to provide positive DC output-voltage. It is the combination of a buck converter and a boost converter has both step-up and step-down conversion functionalities to provide positive DC output-voltage. This converter operates in the buck or boost mode, which is dependent on the level of the instantaneous input voltage Vin(t). When the level of the instantaneous input voltage Vin(t) is higher than the DC output voltage V0, the converter operates in the buck mode; otherwise, the converter operates in the boost mode. However, the buck-boost PFC converter with the buck boost mode cannot be used to achieve high power factor, which is caused by the constant on-time of CCM. There is increment of the inductor-current during the on time in the buck and boost mode and the instantaneous values of the incremental are different. Therefore, these differences at the transitions between the modes cause the distortion on the inductor current. In order to reduce the turn-on switching-loss in high frequency applications, the CCM current control is employed to achieve zero current turn-on for the power switches. It is operated in the buck-boost mode to eliminate the distortion of the inductor current.

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BUCK-BOOST CONVERTER

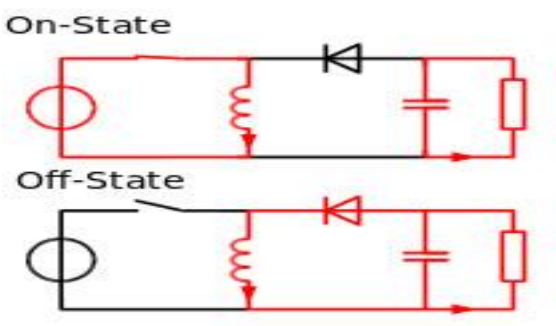

Fig 3: Buck boost converter

The main application of a step-down/step-up or buck-boost converter is in regulated de power supplies, where a negative-polarity output may be desired with respect to the common terminal of the input voltage, and the output voltage can be either higher or lower than the input voltage. A buck-boost converter can be obtained by the cascade connection of the two basic converters: the step-down converter and the step-up converter. In steady state, the output to-input voltage conversion ratio is the product of the conversion ratios of the two converters in cascade (assuming that switches in both converters have the same duty ratio):

$$\frac{V0}{Vd} = D \times \frac{1}{1 - D}$$

This allows the output voltage to be higher or lower than the input voltage, based on the duty ratio D. The cascade connection of the step-down and the step-up converters can be combined into the single buck-boost converter shown in figure. When the switch is closed, the input provides energy to the inductor and the diode is reverse biased. When the switch is open, the energy stored in the inductor is transferred to the output. No energy is supplied by the input during this interval. In the steady- state analysis presented here, the output capacitor is assumed to be very large, which results in a constant output voltage v,(t) = V_2.

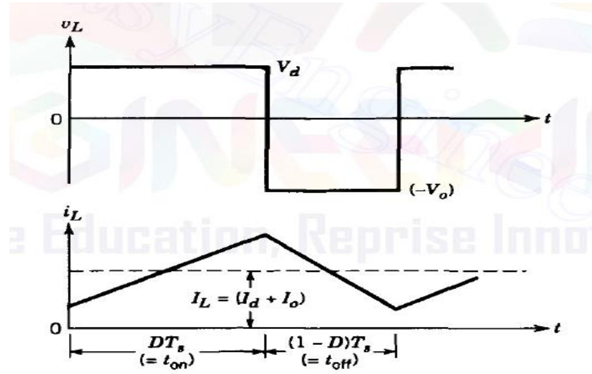

Fig 4: Waveforms in continuous conduction mode (CCM)

III. SIMULATION OF BUCK BOOST CONVERTER IN OPEN LOOP

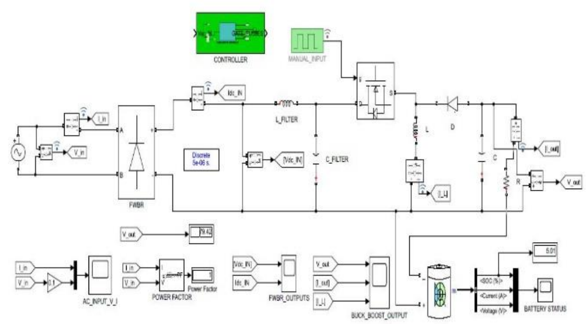

Fig 5: Simulation of buck boost converter in open loop

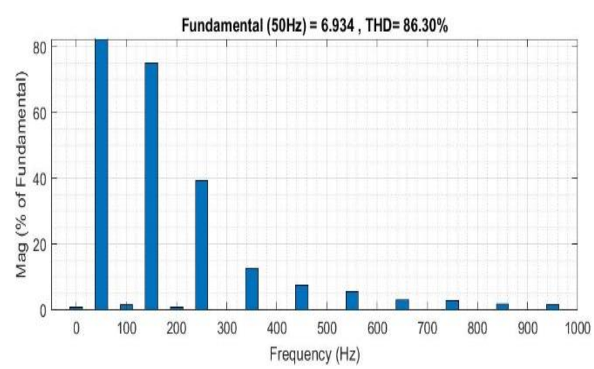

Fig 6: THD spectrum of supply current in open loop

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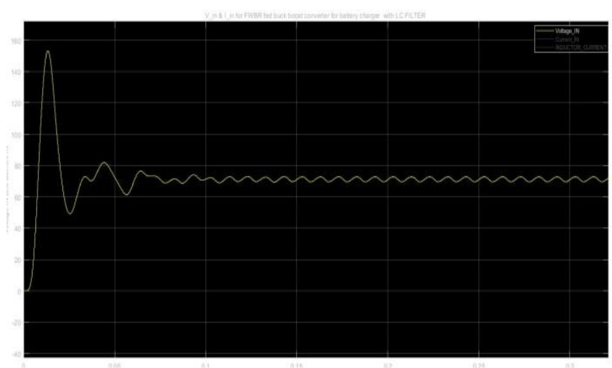


Fig 7: Converter in open loop without DC

SIMULATION OF BUCK BOOST CONVERTER IN OPEN LOOP

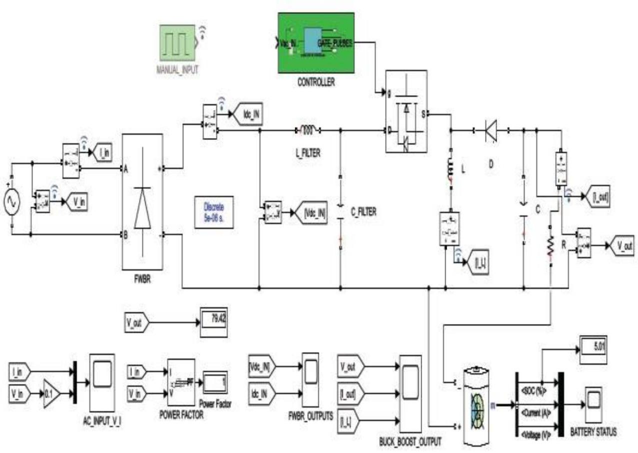
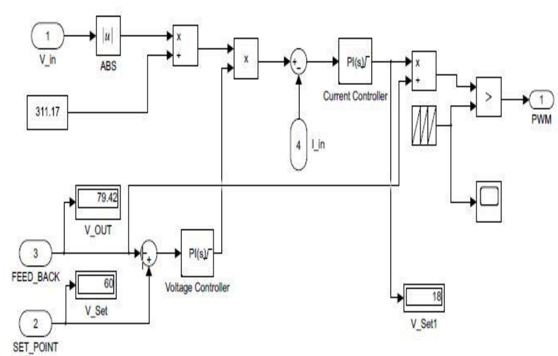


Fig 9: Simulation of buck boost converter in open loop



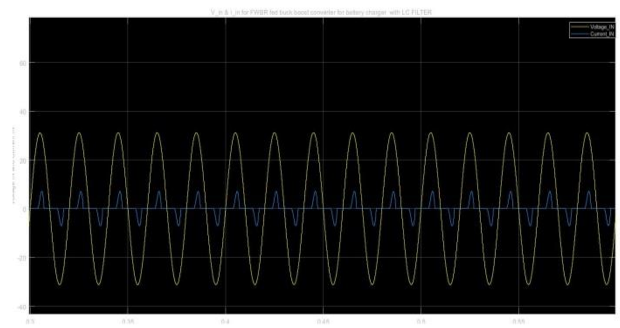


Fig 8: Converter in open loop DC

Fig 10: Simulation of buck boost converter in closed loop

PID CONTROLLER

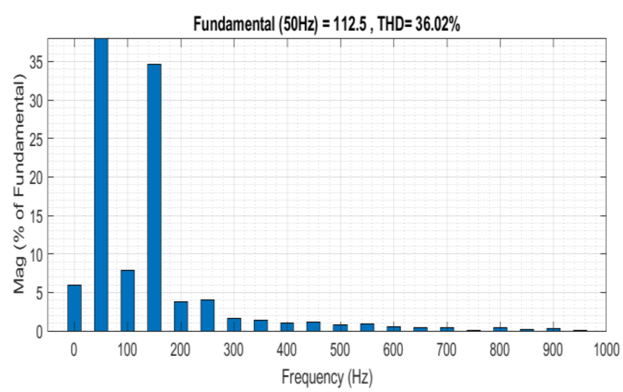


Fig 11: THD spectrum of supply current in closed loop

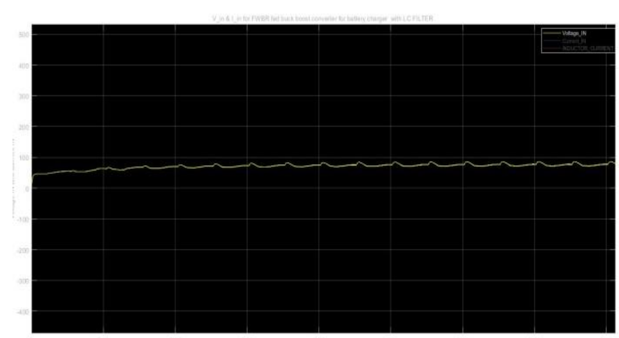


Fig 12: Converter in closed loop without DC

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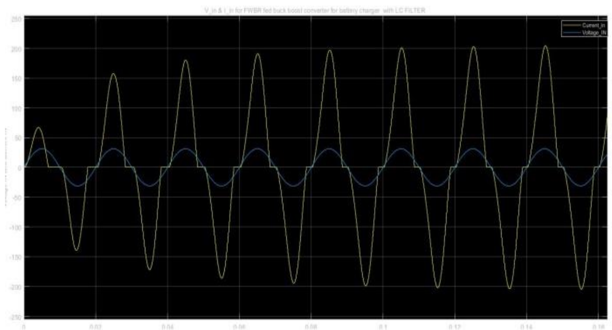

Fig 13 : Converter in closed loop DC

VOLTAGE IN AND CURRENT IN FOR FWBR WITH LC FILTER

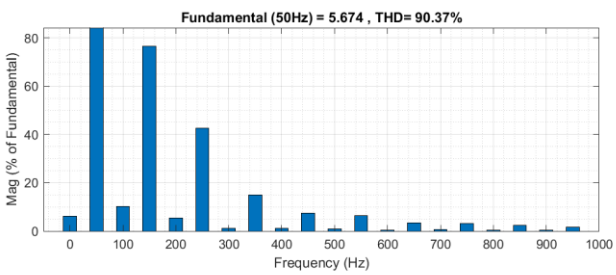

Fig 14: Voltage IN and Current IN for FWBR with LC filter THD

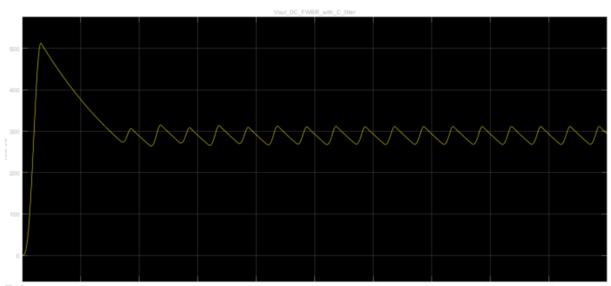

Fig 15: Without DC for FWBR with LC filter

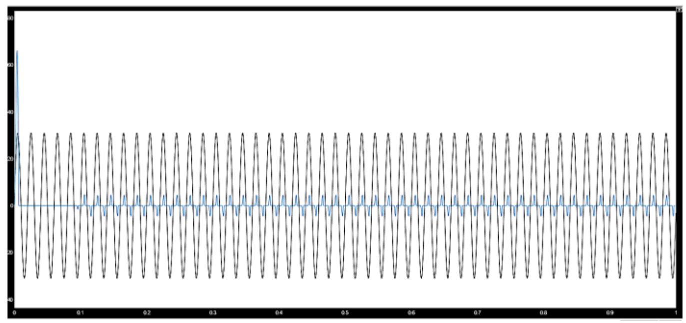

Fig 16: Voltage IN and Current IN for FWBR with LC filter

VOLTAGE IN AND CURRENT IN FOR FWBR WITH C FILTER

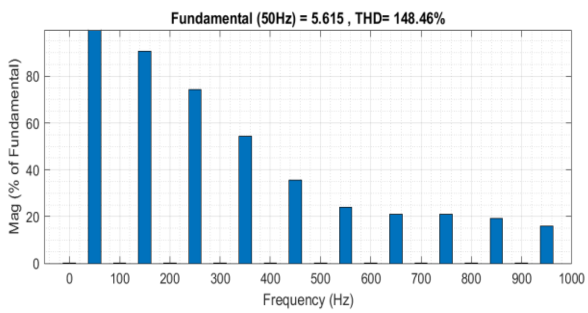

Fig 17: Voltage in and current IN for FWBR with C filter THD

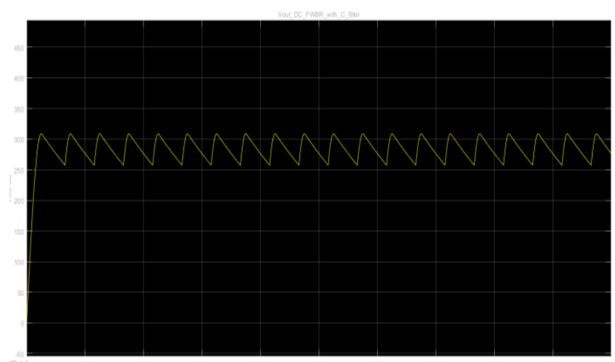

Fig 18: Without DC for FWBR with C filter

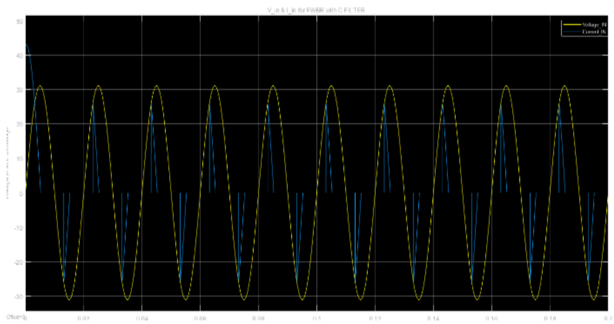

Fig 19: Voltage IN and Current IN for FWBR with C filter

FWBR WITHOUT FILTER

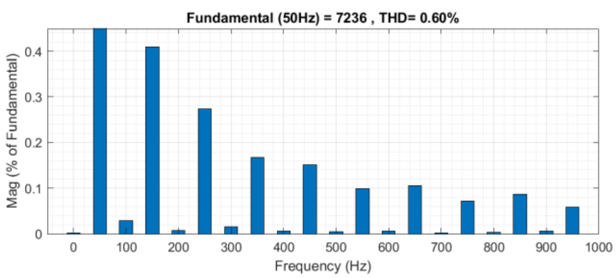

Fig 20: Voltage IN and current IN for FWBR without filter THD

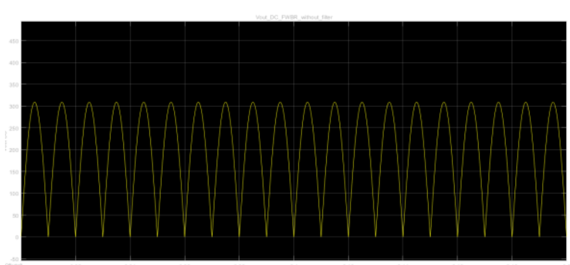

Fig 21: Without DC for FWBR without filter

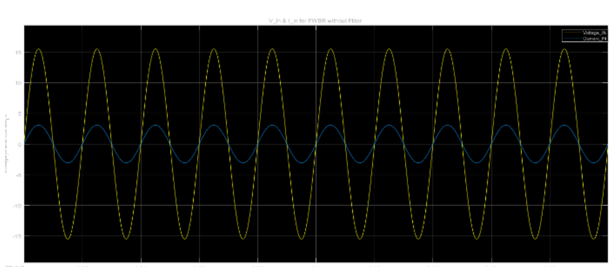

Fig 22: Voltage IN and Current IN for FWBR without filter

A lower power factor causes a higher current flow for a given load. As the line current increases, the voltage drop in the conductor increases, resulting in a lower voltage at the equipment. With an improved power factor, the voltage drop in the conductor is reduced, improving the voltage at the equipment.

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