Design of PFC Smart Charger for Electric Vehicle Application

Synopsis

Anjali Gaikwad
Research Student

Prof. Radharaman Shah
Guide

Prof. Radharaman Shah
Head of M-Tech
Tulsiramji Gaikwad Patil College of Engineering and Technology, Nagpur.

1. INTRODUCTION

1.1 Research Background

A Plug-in Hybrid Electric Vehicle (PHEV) is a hybrid vehicle which uses rechargeable batteries or another energy storage device that can be restored to full charge by connecting a plug to an external electric power source such as electric wall socket. A PHEV has the characteristics of both a conventional hybrid electric vehicle which is having an electric motor and an internal combustion engine (ICE) of an electric vehicle.

Most PHEVs on the road today are passenger cars. But PHEV vehicles are also available in the form of commercial vehicles such as vans, trucks, buses, motorcycles, scooters, and military vehicles. The common charger that is used in PHEV includes an AC-DC converter with power factor correction (PFC) followed by an isolated DC-DC converter with input and output EMI filters. The front-end ac–dc converter is a key component of the charger system. Proper choice of this topology is essential to meet the regulatory requirements for input current harmonics, output voltage regulation and implementation of power factor correction. Typical charging infrastructure scenarios include overnight charging at a home garage, overnight charging at an apartment complex, and opportunity charging at commercial facility. The overall transportation system cost can be reduced by providing rich charging infrastructure rather than compensating for lean infrastructure with additional battery size and range.

Modern electronic systems require high quality small Light weight reliable & efficient power supplies. Linear Power regulators whose principle of operation is based on a voltage or current divider are inefficient. High-frequency electronic power processors are used in DC-DC power conversion functions of dc-dc converters are:

- Regulate the dc output voltage against load & line Variations.
- Reduce the ac voltage ripple on the dc output voltage below the required level.
- Provide isolation between the input source & the load (isolation is not always required).
- Protect the supplied system & the input source from electromagnetic interference (EMI).
- Satisfy various international & national safety standards.

1.2 Switching power rectifier

A switching power rectifier in the power system is used to convert one level of electrical energy into another level of electrical energy. Converters in the AC to DC conversion field are the most widespread and the operation of a converter can be explained in terms of the input quantities output quantities and the switching pattern used to obtain the preferred output. In industrial applications where three-phase ac voltages are available it is preferable to use three-phase rectifier circuits as compared to single-phase rectifiers. Three-phase rectifiers have the following advantages compared with single-phase rectifiers

a. higher output voltage for a given input voltage

b. lower amplitude ripples i.e. output voltage is smoother

c. higher frequency ripples simplifying filtering

d. higher power-handling capability

e. higher overall efficiency

Type of semiconductor device used in the rectifier is different following application as

a. Uncontrolled rectifiers - Diodes as the switches
b. Phase-controlled rectifiers - SCR (silicon controlled rectifiers)
c. Pulse-width modulation rectifiers - IGBT.s (insulated gate bipolar transistors) or power MOSFET.s (metal oxide field-effect transistors)

Among three-phase AC to DC rectifiers boost-type topologies are frequently used because of continuous input currents and high output voltages. The ability to control the system to obtain unity power factor operation of a boost rectifier is important feature of the rectifier topology. The power factor (PF) is defined as the ratio of working power to apparent power. The power quality problems such as large values of harmonics poor power factor and high total harmonic distortion are usually associated with operation of three phases AC to DC converters. An increase in the current harmonics and a decrease in the displacement power factor in AC power lines produced by diode and thyristors are a serious problem thereby highlighting the importance of the boost rectifier in minimizing these problems.

Three phase conversion AC to DC application use in various areas in power electronics load flow and electrical drives . Some telecom sectors are also use the application of the rectifier in the signal maintenance. Basically Diode Bridge or Thyristor Bridge has been used in rectifier converter for obtaining DC power from AC source . These bridge functionality widely used to their advantage size control power factor correction reliability etc.

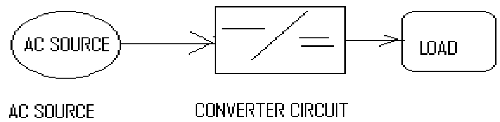


Fig-1.1 AC to DC Converter circuit

Generally these bridge circuits are disadvantageous because of AC grid point of view. Because they injected the unwanted harmonics which is present in nature like noise to the current of relatively high amplitude in to the grid. For controlling this current input hare use Diode bridge topologies consequently lesser harmonics current and use the EMI filter just before the Diode bridge for filtering the noise of the immerging current with the input side.

1.3 PWM Techniques

The fundamental methods of pulse-width modulation (PWM) are divided into the Traditional voltage-source and current -regulated methods. Voltage-source methods more easily lend themselves to digital signal processor (DSP) or programmable logic device (PLD) implementation. However, current controls typically depend on event scheduling and are therefore analog implementations which can only be reliably operated up to a certain power level. In discrete current -regulated methods the harmonic performance is not as good as that of voltage-source methods. A sample PWM method is described below.

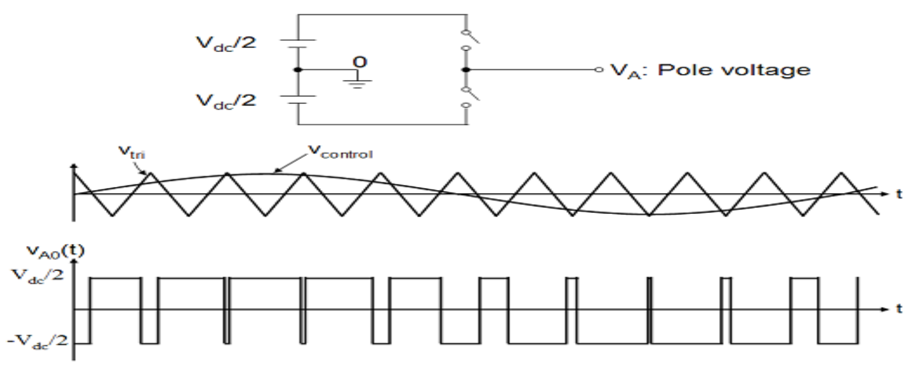


Fig.1.2. Pulse-width modulation

2. BRIEF LITERATURE SURVEY

1) Dênis de Castro Pereira, Wesley Josias de Paula[1]
2) Xuefeng Hu and Chunying Gong[2]
3) Fellipe S. Garcia [3]
4) Wuhua Li, Xiangning He[5]
5) Ping Yang, Jianping Xu, Guohua Zhou, Shiyu Zhang[6]
6) XiaomingGu, Yilei Gu,Lijun Hang, Xiehua Wu,Zhengyu Lu[7]
7) Yungtaek Jang, Milan M. Jovanovic [13]
8) W. Li and X. He[14]
9) Wuhua Li, Jun Liu, Jiande Wu, and Xiangning He[15]
10) Yungtaek Jang, Milan M. Jovanovic[16]
11) Hirohmi Matsuo'), Kimiyoshi Kobayashi", Yutaka Sekine2'[17]
12) Qun Zhao, Fred C. Lee[20]
13) Qun Zhao[22]

2.1) Summary of Literature Review

2.1 Dênis de Castro Pereira, Wesley Josias de Paula[1]:- The major consideration in dc–dc conversion is often associated with high efficiency, reduced stresses involving semiconductors, low cost, simplicity and robustness of the involved topologies. In the last few years, high-step-up nonisolated dc–dc converters have become quite popular because of its wide applicability, especially considering that dc–ac converters must be typically supplied with high dc voltages. The conventional non-isolated boost converter is the most popular topology for this purpose, although the conversion efficiency is limited at high duty cycle values. In order to overcome such limitation and improve the conversion ratio, derived topologies can be found in numerous publications as possible solutions for the aforementioned applications. Within this context, this work intends to classify and review some of the most important non-isolated boost-based dc–dc converters. While many structures exist, they can be basically classified as converters with and without wide conversion ratio. Some of the main advantages and drawbacks regarding the existing approaches are also discussed. Finally, a proper comparison is established among the most significant converters regarding the voltage stress across the semiconductor elements, number of components and static gain.

2.2 Xuefeng Hu and Chunying Gong[2]:- The high-voltage gain converter is widely employed in many industry applications, such as photovoltaic systems, fuel cell systems, electric vehicles, and high-intensity discharge lamps. This paper presents a novel single-switch high step-up nonisolated dc–dc converter integrating coupled inductor with extended voltage doubler cell and diode–capacitor techniques. The proposed converter achieves extremely large voltage conversion ratio with appropriate duty cycle and reduction of voltage stress on the power devices. Moreover, the energy stored in leakage inductance of coupled inductor is efficiently recycled to the output, and the voltage doubler cell also operates as a regenerative clamping circuit, alleviating the problem of potential resonance between the leakage inductance and the junction capacitor of output diode. These characteristics make it possible to design a compact circuit with high static gain and high efficiency for industry applications. In addition, the unexpected high-pulsed input current in the converter with coupled inductor is decreased. The operating principles and the steadystate analyses of the proposed converter are discussed in detail. Finally, a prototype circuit is implemented in the laboratory to verify the performance of the proposed converter.

2.3 **Fellipe S. Garcia [3]:-** The Interleaved Double Dual Boost is a noninsulated, step-up DC-DC converter capable of high voltage gain and suitable to high-power applications. In this paper, the modeling and control design of this converter, valid for an arbitrary number of phases, is presented. The developed approach is then applied to a six-phase Interleaved Double Dual Boost and experimental results are obtained with a prototype operating with input voltage of 60V, output voltage of 360V and with nominal output power of 2.2kW. The applications of this converter include electrical vehicles and renewable energy conversion.

2.4 **Wuhua Li, Xiangning He[5]:-** The photovoltaic (PV) grid-connected power system in the residential applications is becoming a fast growing segment in the PV market due to the shortage of the fossil fuel energy and the great environmental pollution. A new research trend in the residential generation system is to employ the PV parallel connected configuration rather than the series-connected configuration to satisfy the safety requirements and to make full use of the PV generated power. How to achieve high-step-up, low-cost, and high-efficiency dc/dc conversion is the major consideration due to the low PV output voltage with the parallel-connected structure. The limitations of the conventional boost converters in these applications are analyzed. Then, most of the topologies with high-step-up, low-cost, and high-efficiency performance are covered and classified into several categories. The advantages and disadvantages of these converters are discussed. Furthermore, a general conceptual circuit for high-step-up, low-cost, and high efficiency dc/dc conversion is proposed to derive the next generation topologies for the PV grid-connected power system. Finally, the major challenges of high-step-up, low-cost, and high efficiency dc/dc converters are summarized. This paper would like to make a clear picture on the general law and framework for the next-generation non isolated high-step-up dc/dc converters

2.5 **Ping Yang, Jianping Xu, Guohua Zhou, Shiyu Zhang[6]**:- In this paper, a new quadratic boost converter is proposed. Compared with the conventional quadratic boost converter, the new quadratic boost converter employs an additional capacitor-inductor-diode (CLD) cell consisting of an inductor, two diodes and two capacitors. The quadratic boost converter with CLD cell presented in this paper shows an improvement of the voltage step-up ratio over the conventional quadratic boost converter and boost converter. Consequently, it is well suited for extreme high voltage step-up ratio applications. The quadratic boost converter with CLD cell also shows a significant improvement in reduced voltage stresses of switch and diodes over the conventional quadratic boost converter and boost converter. The experimental results of the proposed converter have been presented to verify the analysis results.

2.6 **XiaomingGu, Yilei Gu,Lijun Hang, Xiehua Wu,Zhengyu Lu[7]:-** This paper presents a new topology named **ZVS** resonant reset dual switch forward DCIDC converter, which, compared with resonant reset single switch forward **DC/DC** converter, maintains the advantage that duty cycle ran be more than **SO%,** at the same time disadvantage of high voltage stress for main switches and low eminency are overcome. In addition, soft switching is achieved for all switches of thc presented topology. Therefore, this proposed topology is very attractive for high input, wide range and high eminency applications. In this paper, the operation principle and characteristic of this topology are analyzed in detail. Finally, the advantages mentioned above are verified by experimental result.

2.7 **Yungtaek Jang, Milan M. Jovanovic [13]:-** A novel, two-inductor, interleaved power-factor corrected (PFC) boost converter that exhibits voltage-doubler characteristic when it operates with a duty cycle greater than 0.5 is introduced. The voltage-doubler characteristic of the proposed converter makes it quite suitable for universal-line (90–264 RMS) PFC applications. Because the proposed PFC boost rectifier operates as a voltage doubler at low line, its low-line range efficiency is greatly improved compared to that of its conventional counterpart. The performance of the proposed PFC rectifier was evaluated on an experimental 1.3-kW universal-line PFC prototype.

2.8 **W. Li and X. He[14]:-** The narrow turn-off period of the conventional boost converters limits their applications in high step-up DC–DC conversion. The voltage gain is extended without an extreme duty-cycle by the winding-coupled inductor structure. However, the leakage inductance induces large voltage spikes when the switch turns off. An active-clamp circuit is introduced here to clamp the switch turn-off voltage spikes effectively and to recycle the leakage energy. Both the main switches and the auxiliary switches are ZVT during the whole switching transition. Meanwhile, the output diode reverse-recovery problem is alleviated because the leakage inductance of the coupled inductors is in series with the output diode. Furthermore, a family of ZVT interleaved boost converters for high efficiency and high step-up DC–DC conversion is deduced. The experimental results based on 40–380 V front-end applications verify the significant improvements in efficiency.

2.9 **Wuhua Li, Jun Liu, Jiande Wu, and Xiangning He[15]:-** The fundamental limitations of the current topologies for isolated high step-up dc–dc conversion are summarized. The primary-parallel-secondary-series structure is employed in this paper to handle the large input current, sustain the high output voltage and extend the voltage gain. A novel active clamp boost converter with coupled-inductors is proposed for high step-up applications. The third windings of the coupled-inductors have the function of voltage gain extension and the switch voltage stress reduction. The active clamp circuit serves for the interleaved two phases, which reduces the circuit complexity. Both the main and the auxiliary switches of the proposed converter are zero voltage transition performances during the whole switching transition. Meanwhile, the leakage energy is recycled by the active clamp circuit. The rectifier voltage stress is reduced by the primary-parallel-secondary-series structure. The rectifier reverse-recovery problem is alleviated by the leakage inductance

2.10 **Yungtaek Jang, Milan M. Jovanovic[16]:-** A novel implementation of the high-power-factor (HPF) boost converter with active snubber is described. The snubber circuit reduces the reverse-recovery-related losses of the rectifier and also provides zero-voltage switching for the boost switch and zero-current switching for the auxiliary switch. The performance of the proposed approach was evaluated on an 80-kHz, 1.5-kW, universal-line range, HPF boost converter. The proposed technique improves the efficiency by approximately 2% at full load and low line.

2.11 **Hirohmi Matsuo'), Kimiyoshi Kobayashi", Yutaka Sekine2'[17]:-**

Recently, the clean electric power generation systems have attracted a great deal of social attention to exploit the clean energy resources such as solar array, wind generator, fuel cell and so forth. In this case, the multiple-input dc-dc converter is useful to combine the several input power sources and to supply the regulated output voltage for the load. The novel solar cell power supply system using the buck-boost type two-input dc-dc converter is proposed, in which the solar array and the commercial ac line are exploited as power sources and they are combined by the two input windings **of** the energy-storage reactor. also, its operation principle and performance characteristics are discussed. Furthermore, the solar cell optimum operating point tracker is proposed and examined. **It** is confirmed by the experiment that the proposed solar cell power supply system has the excellent performance characteristics.

2.12 **Qun Zhao, Fred C. Lee[20]:-** Many applications call for high step-up dc–dc converters that do not require isolation. Some dc–dc converters can provide high step-up voltage gain, but with the penalty of either an extreme duty ratio or a large amount of circulating energy. DC–DC converters with coupled inductors can provide high voltage gain, but their efficiency is degraded by the losses associated with leakage inductors. Converters with active clamps recycle the leakage energy at the price of increasing topology complexity. A family of high-efficiency, high step-up dc–dc converters with simple topologies is proposed in this paper. The proposed converters, which use diodes and coupled windings instead of active switches to realize functions similar to those of active clamps, perform better than their active-clamp counterparts. High efficiency is achieved because the leakage energy is recycled and the output rectifier reverse-recovery problem is alleviated

2.13 **Qun Zhao[22]:-** This paper introduces a new family of PWM DC-DC non-isolated converters. The new converters are generated using three-state commutation cells. Comprising two active switches, two diodes and couplcd inductors. The main advantages over thc classical converters arc low conduction and commutation losses, and low input and output current ripple. Due to these features, the new converters are suitable for low voltage and high current applications. Theoretical analysis and experimentation results are presented.

3. PROPOSED METHODOLOGY

1. **Methodology**

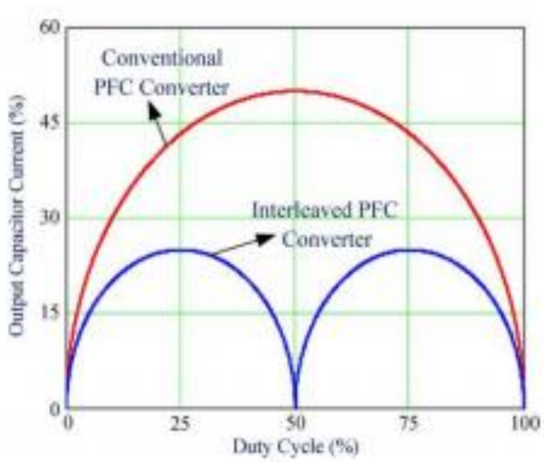
   Normally battery is charged using a DC supply. It consists of more harmonic components. To avoid the harmonic components intermediate converters were used to improve the voltage (amplitude and ripple content). Normally buck converters where used to buck the input DC voltage. Since it contained more harmonics, Interleaved buck converters where used. So Interleaved buck converter with high frequency transformers where used to reduce the ripple content and charge the battery effectively. The proposed

   Battery for charging is "Exide 12V 7AH "

2. PWM technique
3. Inverter (DC to AC converter)
4. Filter

4. PRELIMINARY RESULT & DICUSSION

The interleaved PFC consists of two continuous conduction mode (CCM) buck converters in parallel, which operate 180◦out of phase. The input current is the sum of the inductor currents in LB1 and LB2. Since the inductor ripple currents are out of phase, they tend to cancel each other and reduce the input ripple current. The maximum input inductor ripple current cancelation occurs at 50% of the duty cycle. The picture shows the ratio of the input current ripple to the inductor current ripple as a function of duty cycle.



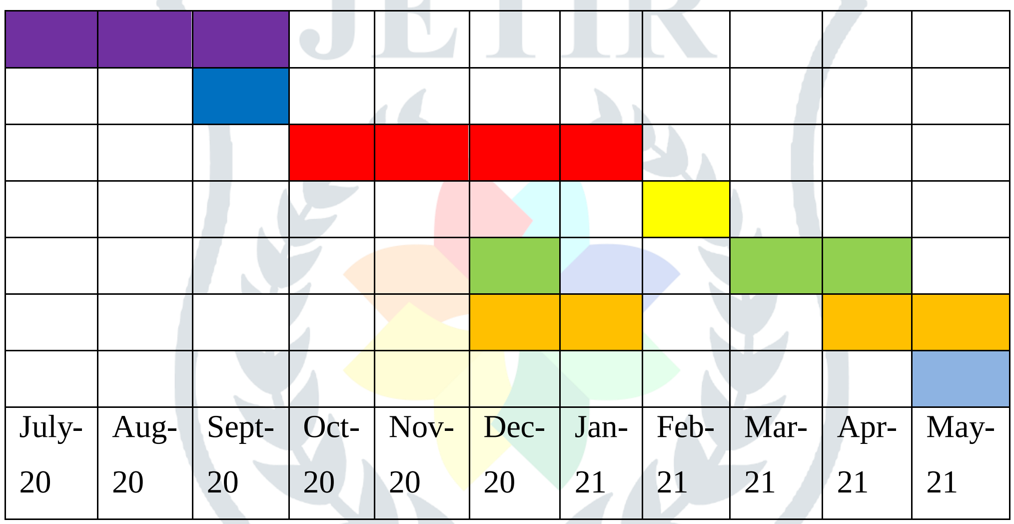
The major limitation of the FBZVS converter has been the limited range of operation over which ZVS can be achieved. When the load current is low, the ZVS of the lagging-leg switches is lost as the energy stored in the leakage inductance of the transformer is insufficient to discharge the switch and transformer capacitances. The loss of ZVS results in increased switching losses and electromagnetic interference (EMI). In the case of high power converters using insulated gate bipolar transistor (IGBT), an external snubber capacitor is connected to reduce the rate of rise of voltage and turn-off losses

5. WORK TO BE DONE

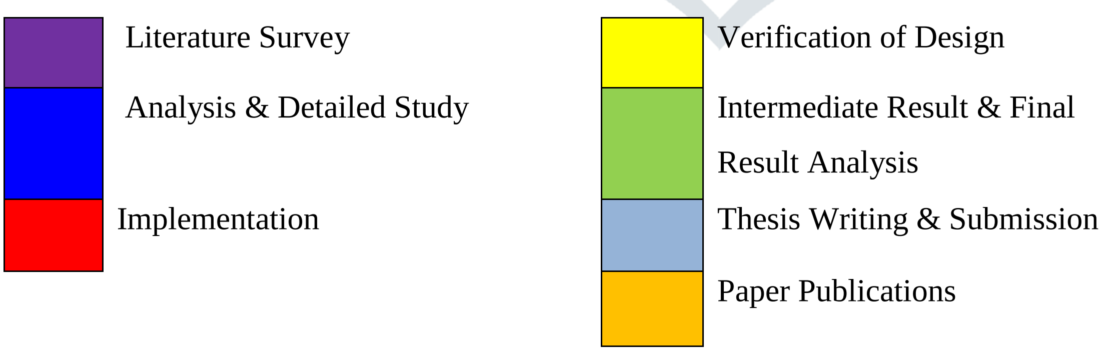
1. To Improve Power Stability.
2. To improve power efficiency.
3. To reduce power loss
4. PFC

6. PLAN OF RESEARCH

Research Planning



Duration in Months



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