

A MODULAR MULTIPOINT SST WITH INTERGRATED SPLIT BATTERY ENERGY STORAGE WITH TWO WAY DC POWER FLOW IN SIMO DC-DC CONVERTER

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Abstract— The aim of this project is to develop a high-efficiency single-input multiple-output (SIMO) dc–dc converter to have the power flow in both directions. The proposed converter can produce output power source to a controllable dc bus and middle-voltage output terminals. The dc bus can take as the main power for a high-voltage dc load or the front terminal of a dc–ac inverter. Moreover, middle-voltage output terminals can supply powers for individual middle-voltage dc loads or for charging auxiliary power sources (e.g., battery modules). The current flow is possible in both directions hence battery can be charged from another battery also. In existing system a single way boost converter is used so the conversion efficiency is very less. The present system has only one way power flow and intermediate voltages are not available.

Index Terms— single-input multiple-output (SIMO), dc–dc converter, dc–ac inverter, single way boost converter.

INTRODUCTION

Environmental awareness and related concerns has given rise to a high interest towards electrical mobility based on battery energy storage during the recent years. Such an action aims mainly at the significant reduction of co2 and other pollutant emissions. In order to ensure the widespread utilization of such electric vehicles, however, significant effort is still needed regarding their competitive market launching over conventional combustion engine vehicle. The main impediment when it comes to electric vehicles concern the limited battery autonomy in conjunction with the long charging times, most often on-board charges are utilized, fed by the domestic or private grid. When the charging power level increases, however, off-board EV chargers are preferred. Usually installed outside the residential areas in charging stations conceptually similar to the gas filling ones. A solution to the autonomy problem can be given through the utilization of the so called battery swap stations, where the discharged EV battery is directly replaced by a fully charged one. Some of the issues that arise, however, concern the different EV battery type compatibility as well as charged battery availability of the station. A second attractive solution regards the fast and ultra fast EV charging referring to less than thirty and ten minutes respectively. The latter has been driven by the late

high expectations regarding development of batteries using materials that can withstand very high charging rates as well as the development of more advanced battery charging techniques. Both academic and industry have been pushed towards the fast and ultra fast EV charging concept exploration. The main focus has been initially laid on the infrastructure as well as grid impact. In order to not to overload the grid in such a power demanding application, the use of stationary energy storage element has been proposed. Advanced and emerging converter technology, such as Power Electronics Transformers (PETs), are also expected to play a key role in the development of the battery is needed due to split accumulation concept. This leads to redundancy as well as more straight forward battery management system (BMS) design. In addition since a high number of sub modules are needed to block medium voltage on the grid side, different configurations can be chosen on the parallel-connection level in order to achieve a multipoint output, capable of charging different vehicles simultaneously. The converter architecture is therefore referred to as modular Multipoint Power Electronic Transformer (M2PET). In such a case no additional high-power chargers are needed, leading to higher efficiencies due to the equal power split between the existing isolated converters. However, the converter control becomes more complicated, due to the need for all power flow directions handling. The proposed system deals about the charging of electric vehicle battery not only from the charging station but also from another electric vehicle battery. It can be made possible by using the DC/DC bidirectional block. Solid state transformers are used instead of power electronic transformer for attaining higher efficiency.

I. STRATEGIC MODELING

A. Inverter (Electrical)

An **inverter** is an electrical device that converts direct current (DC) to alternating current (AC); the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. There are two main types of inverter. The output of a **modified sine wave** inverter is similar to a square wave output except that the output goes to zero volts for a time

before switching positive or negative. It is simple and low cost (~\$0.10USD/Watt) and is compatible with most electronic devices, except for sensitive or specialized equipment, for example certain laser printers. A pure sine wave inverter produces a nearly perfect sine wave output (<3% total harmonic distortion) that is essentially the same as utility-supplied grid power. Thus it is compatible with all AC electronic devices. This is the type used in grid-tie inverters. Its design is more complex, and costs 5 or 10 times more per unit power (~\$0.50 to \$1.00USD/Watt). The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters was made to work in reverse, and thus was "inverted", to convert DC to AC.

B. Rectifier

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which is in only one direction, a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. When only one diode is used to rectify AC, the difference between the term diode and the term rectifier is merely one of usage, i.e., the term rectifier describes a diode that is being used to convert AC to DC.

C. DC to DC Converters

A DC-to-DC converter is an electronic circuit which converts a source of direct current from one voltage level to another. It is a class of power converter.

i. Electronic conversion (Linear)

Linear regulators can only output at lower voltages from the input. They are very inefficient when the voltage drop is large and the current is high. The inefficiency wastes power and requires higher-rated, and consequently more expensive and larger, components. The heat dissipated by high-power supplies is a problem in itself as it must be removed from the circuitry to prevent unacceptable temperature rises.

ii. Switched mode conversion

Electronic switch-mode DC to DC converters convert one DC voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components or electric field storage components. This conversion method is more power efficient (often 75% to 98%) than linear voltage regulation. Efficiency is beneficial to increasing the running time of battery operated devices.

In addition, each topology may be:

- **Hard switched** - transistors switch quickly while exposed to both full voltage and full current
- **Resonant** - an LC circuit shapes the voltage across the transistor and current through it so that the transistor switches when either the voltage or the current is zero

Magnetic DC to DC converters may be operated in two modes, according to the current in its main magnetic component (inductor or transformer):

- **Continuous** - the current fluctuates but never goes down to zero
- **Discontinuous** - the current fluctuates during the cycle, going down to zero at or before the end of each cycle

A converter may be designed to operate in Continuous mode at high power, and in Discontinuous mode at low power.

D. Terminology

Step-down - A converter where output voltage is lower than the input voltage. Like a Buck converter.

Step-up - A converter that outputs a voltage higher than the input voltage. Like a Boost converter.

Continuous Current Mode - Current and thus the magnetic field in the inductive energy storage never reach zero.

Discontinuous Current Mode - Current and thus the magnetic field in the inductive energy storage may reach or cross zero.

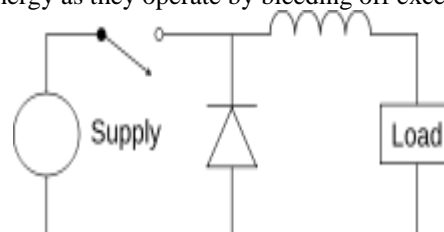
Noise - Since all properly designed DC to DC converters are completely inaudible, "noise" in discussing them always refers to unwanted electrical and electromagnetic signal noise.

E. Types of DC to DC Converter

There are three basic types of dc-dc converter circuits, termed as buck, boost and buck-boost. In all of these circuits, a power device is used as a switch. This device earlier used was a thyristors, which is turned on by a pulse fed at its gate.

i. Buck converter

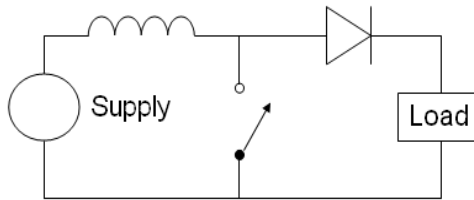
A **buck converter** is a step-down DC to DC converter. Its design is similar to the step-up boost converter, and like the boost converter it is a switched-mode power supply that uses two switches, an inductor and a capacitor. The simplest way to reduce the voltage of a DC supply is to use a linear regulator (such as a 7805), but linear regulators waste energy as they operate by bleeding off excess power as heat.



Buck converter circuit diagram.

ii. Boost converter

A **boost converter (step-up converter)** is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

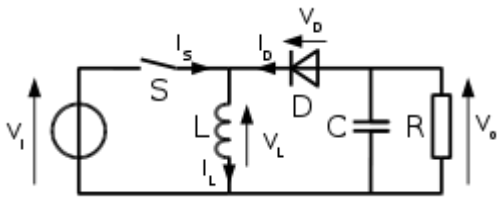


The basic schematic of a boost converter.

iii. *Buck-Boost converter*

Two different topologies are called **buck–boost converter**. Both of them can produce an output voltage much larger (in absolute magnitude) than the input voltage. Both of them can produce a wide range of output voltage from that maximum output voltage to almost zero.

- The inverting topology – The output voltage is of the opposite polarity as the input
- A buck (step-down) converter followed by a boost (step-up) converter – The output voltage is of the same polarity as the input, and can be lower or higher than the input.



Schematic of a buck–boost converter.

F. Control Strategies

In all cases, it is shown that the average value of the output voltage can be varied. The two types of control strategies (schemes) are employed in all cases. These are: (a) Time-ratio control, and (b) Current limit control.

i. *Time- Ratio Control*

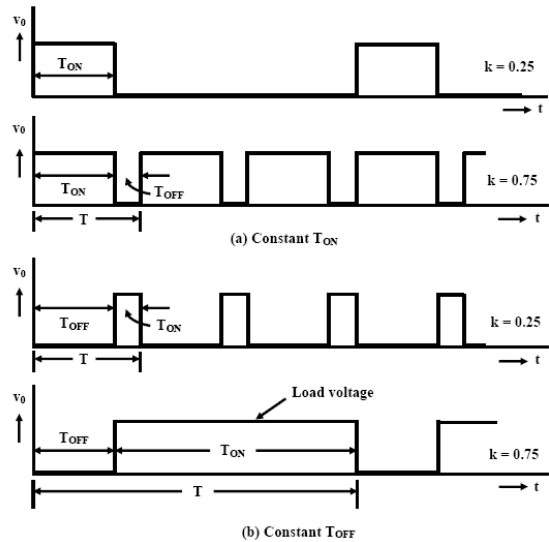
In the time ratio control the value of the duty ratio, $k = TON/T$ is varied. There are two ways, which are constant frequency operation, and variable frequency operation.

ii. *Constant Frequency Operation*

In this control strategy, the ON time, TON is varied, keeping the frequency ($f=1/T$), or time period T constant. This is also called as *pulse width modulation control (PWM)*. Two cases with duty ratios, as (a) 0.25 (25%), and (b) 0.75 (75%) are shown in Fig 1.8. Hence, the output voltage can be varied by varying ON time, TON .

iii. *Variable Frequency Operation*

In this control strategy, the frequency ($f=1/T$), or time period T is varied, keeping either (a) the ON time, TON constant, or (b) the OFF time, $TOFF$ constant. This is also called as *frequency modulation control*. Two cases with (a) the ON time, TON constant, and (b) the OFF time, $TOFF$ constant, with variable frequency or time period (T), are shown in Fig. The output voltage can be varied in both cases, with the change in duty ratio



Duty Cycle For Variable Frequency

There are major disadvantages in this control strategy. These are:

- (a) The frequency has to be varied over a wide range for the control of output voltage in frequency modulation. Filter design for such wide frequency variation is, therefore, quite difficult.
- (b) For the control of a duty ratio, frequency variation would be wide. As such, there is a possibility of interference with systems using certain frequencies, such as signaling and telephone line, in frequency modulation technique.
- (c) The large OFF time in frequency modulation technique, may make the load current discontinuous, which is undesirable.

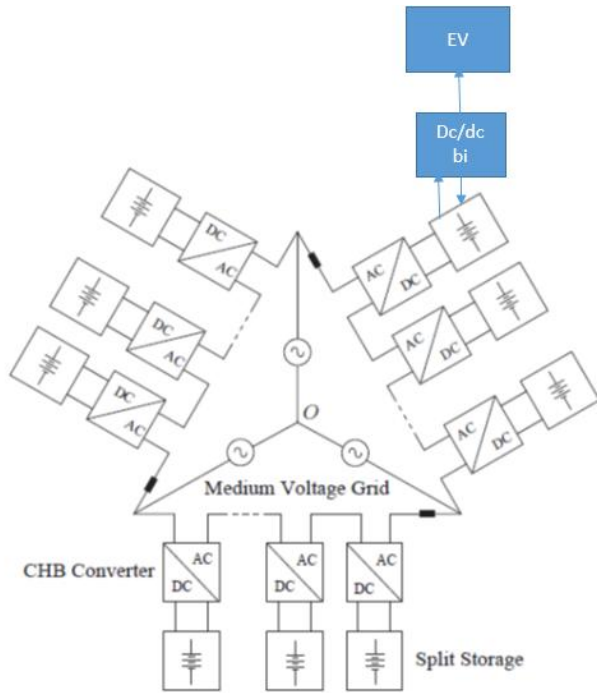
iv. *Current Limit Control*

In the current limit control strategy, the switch in dc-dc converter (chopper) is turned ON and OFF, so that the current is maintained between two (upper and lower) limits. When the current exceeds upper (maximum) limit, the switch is turned OFF. During OFF period, the current freewheels in say, buck converter (dc-dc) through the diode, and decreases exponentially. When it reaches lower (minimum) limit, the switch is turned ON. This type of control is possible, either with constant frequency, or constant ON time

II. OPERATIONAL ANALYSIS

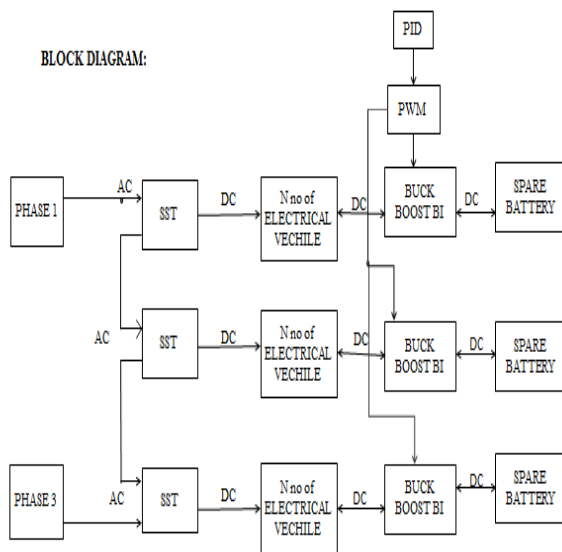
This chapter illustrates about the electrical vehicles charging in forward and reverse direction. The proposed system deals with the two switch boost DC to DC converter with the PWM pulses applied to them in inverted manner. We use totally 16 switches for both directions. This system gives better conversion efficiency is to be proved in simulation done in MATLAB 7.12.

A. *Grid Connected Converters*



Modified Existing System.

The proposed system consists of DC/DC bidirectional. Using this block the battery of E vehicle is charged from another E vehicle without charging station. It is possible only with this block.



Block Diagram For One Arm In Delta Connection

B. Solid State Transformers

Transformers are fundamental components of the power distribution system and are relatively inexpensive, highly reliable, and fairly efficient. However, they possess some undesirable properties including sensitivity to harmonics, voltage drop under load, (required) protection from system disruptions and overload, protection of the system from problems arising at or beyond the transformer, environmental concerns regarding mineral oil, and performance under dc-offset load unbalances. These disadvantages are becoming increasingly important as

power quality becomes more of a concern. With the advancement of power electronics circuits and devices, the all solid-state transformer becomes a viable option to replace the conventional copper- and-iron based transformer for a better power quality. The solid-state switching technologies allow power conversion between different formats such as dc/dc, dc/ac, ac/dc, and ac/ac with any desired frequencies.

i. SST Functionalities

- Protects load from power supply disturbances
- Voltage Harmonics and sag compensations
- Outage compensation and Integrates energy storage
- Protects power systems from the load disturbances
- Load transients and harmonic regulations
- Unity input power factor under reactive load
- Sinusoidal input current for non linear loads
- Protection against output short circuit
- Operates on distributed voltage level

C. Pulse with modulation

This block generates pulses of carrier based PWM, self, commutated IGBTs, GTOs or FETs bridges. Depending on number of bridge arms selected in the generator mode parameter, the block can be used either for single phase or three phase PWM control. It uses one arm bridge 2 pulse, 10000 HZ carrier frequency is used for modulation with modulation index 0.99. Usually the modulation index should be between 0 to 1 ($0 < m < 1$).

D. Demultiplexer

It split vector signals into scalars or smaller vectors. Check ‘bus selection mode’ to split bus signals. Outputs are given to 4 MOSFETS as two pairs. Now the MOSFET M1 and M4 will be ON.

E. Linear Transformer

The M1 and M4 will be in closed position. It leads to power flow in primary side of the transformer which in turn produce power flow in the secondary side of the transformer.

F. PID Controller

A Proportional-Intergal-Derevative controller is a control loop feedback mechanism. A PID controller continuously calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error over time by adjustment of a control variable, such as the position of a control valve, a damper, or the power supplied to heating element, to a new value.

The value of P, I, D is given below
 P=0.01 and it’s a present value
 I=40 and it’s a past value
 D=0 and it’s a future value

Thus derivative value is set to 0 the PID will perform only proportional and derivative operation. The output PID is zero. This output is used as input for the relational operator.

G. Relational Operator

The high frequency carrier wave of a repeating sequence of time-value pairs [0 1/10e3] along with PID output (0) is given as input for relational operator.

The relational operator operates with Boolean signal only. Here >= operator is used.

It checks for zero crossing level.

Hence the output of relational operator is 1.

This output is given as gate pulse of MOSFET 4 and MOSFET 8. Hence these switches will be ON.

H. Logical Operator

For an operation only 2 MOSFET should be in ON condition. For making MOSFET 6 and 7 off logical operator output is NOT and is given to MOSFET 6 and 7.

I. DC to DC Bidirectional Converter

DC to DC bidirectional is used for two way power flow either in forward or reverse direction. Here only Direct Current can be transmitted. By using this block battery can be charged.

- from charging station
- from another electrical vehicle

Based on the amount of power flow in the forward and reverse direction the converter is said to be

- BUCK converter
- BOOST converter

J. Adder

Add or subtract inputs. Specify one of the following :

- a) String containing + or – for each input port, | for the space between ports (e.g. ++|-|+++)
- b) Scalar, > =1, specifies the number of input ports to be summed.

When there is only one port, add or subtract elements over all dimensions or one specified dimension. The output voltage along with the reference voltage of 12v is given to the adder block. The output of adder is 0.4 which is given for PID controller.

K. Source

This block implements a three-phase zero-impedance voltage source. The common node (neutral) of the three source is accessible via input 1(N) of the block. Time variation for the amplitude, phase and frequency of the fundamental can be pre-programmed. In additional, two harmonics can be superimposed on the fundamental. For phasor simulation, frequency variation and harmonics injection are not allowed. Specify order=1 and seq=1,2 or 0 to inject additional fundamental components A and B in any sequence and the value of amplitude is 400 and frequency is 40 HZ.

L. PWM Generator

This discrete block generates pulses for carrier-based PWM, self-commutated IGBTs, GTOs, or FETs bridges. Depending on the number of brides arms selected in the “GENERATOR MODE” parameter, the block can be used either for single-phase or three phase PWM control. The

carrier frequency used here is 1040 Hz and the sample time is set as 4e-6. These signal is given to the demultiplexer.

M. Demultiplexer

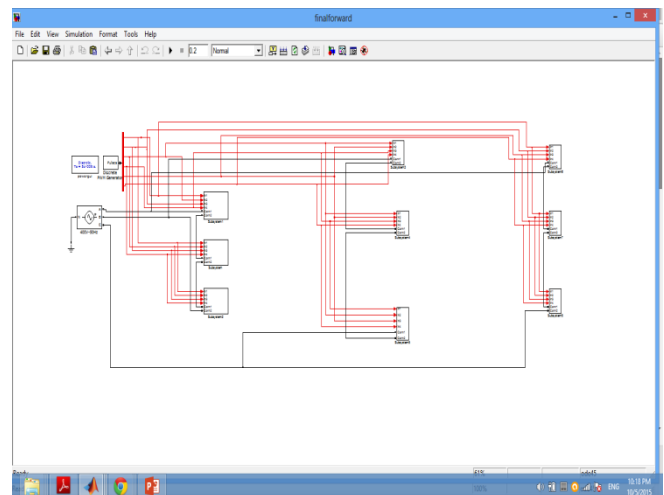
The output of generator is demultiplexed into six output signal. These signals are given along with delta connection.

N. Thyristor

Thyristor in the parallel with the series RC snubber circuit circuit is used for AC to DC conversion. In on-state thyristor model has an internal resistance (Ron) and inductance (Lon). In off-state the thyristors as impedance. Best accuracy is achieved when Tq is larger than the simulation step size. Latching current and turn-off time are not modelled when Lon is set to zero. The value snubber resistance and capacitance is 400 ohms and 240e-9H respectively.

III. SIMULATION RESULTS

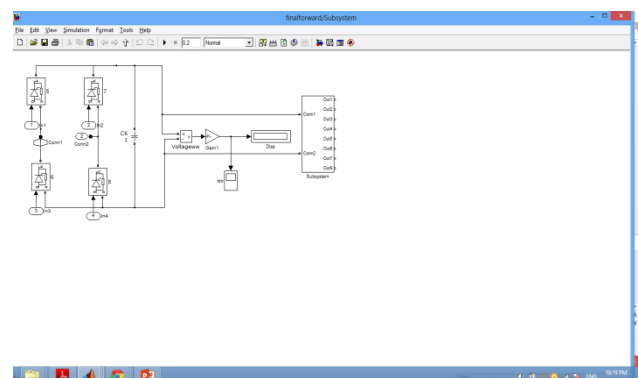
For experimental results, MATLAB is used for simulation and to determine the voltage. The value of resistance increase with increase in the voltage. The delta connection for three phase source with neutral connected to the ground along pulse generator connection as shown in fig the PWM generator output is demultiplexed into 5 outputs.



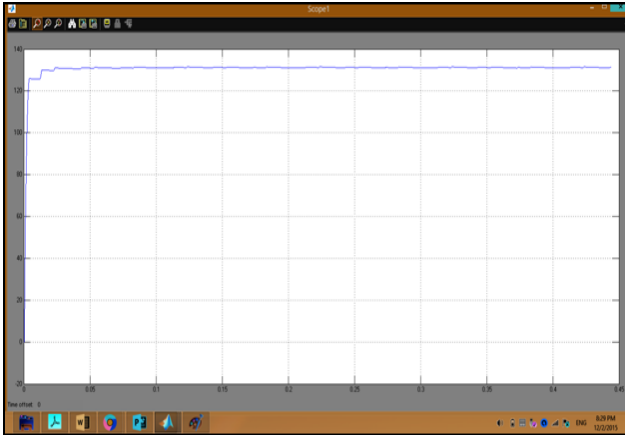
Delta Connection Of Source

A. AC to DC Converter

The input AC is converted into DC by using combination of SCR with snubber circuit.



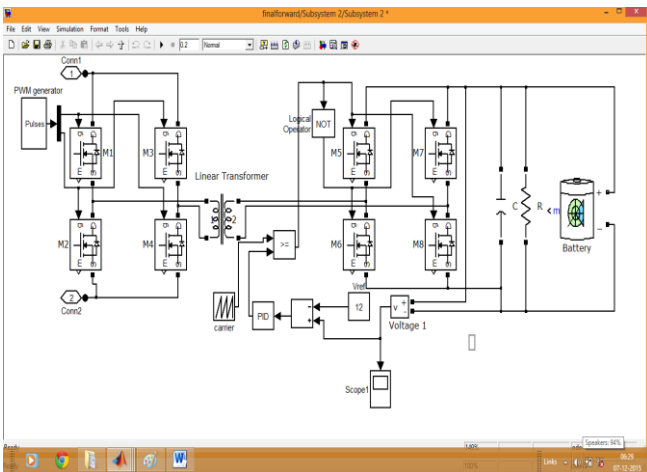
Simulink For Forward DC to DC Converter



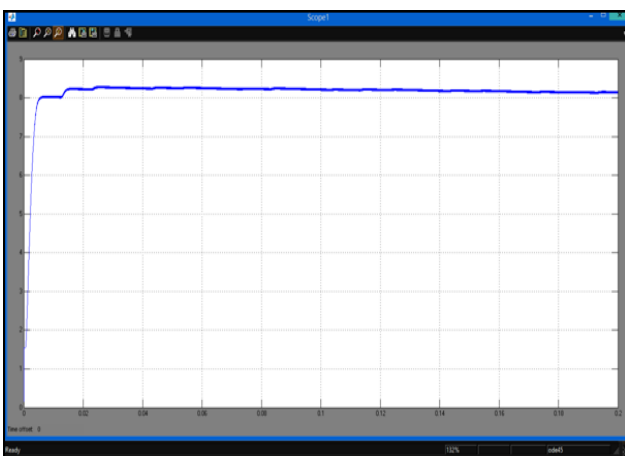
Simulation Output For AC to DC Converter

The voltage obtained is about 130.1 v. This can be connected to 10 number of E vehicles. X axis-Time in sec Y axis-Voltage (v)

B. Forward DC to DC Converter



Simulink Model For Forward DC to DC Converter

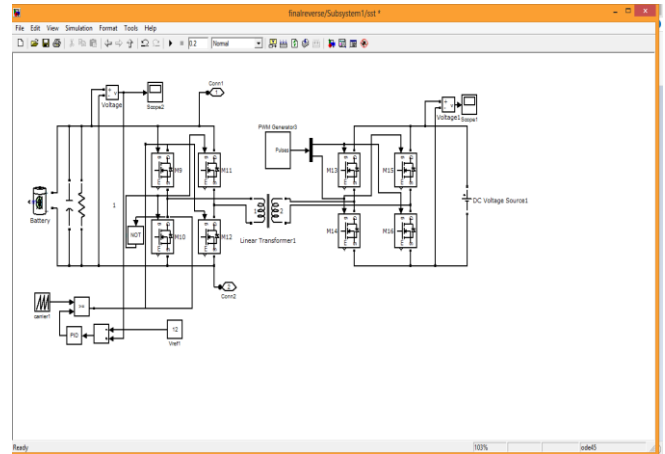


Simulation Result For Forward System

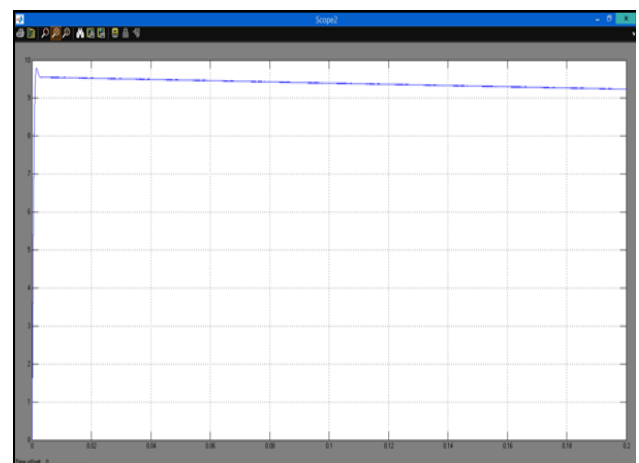
The ripples have to reduced to 0.2v by setting $c=47e-5$ farads and $R=1000$ ohms. The waveform was projected in y axis and found only 0.2 ripples is available in Dc.

X axis – Times in sec, Y axis – voltage (v)

C. Reverse DC to DC Converter



Simulink Model For Reverse DC to DC Converter



Simulation Result For Reverse System

The total voltage obtained is about 12.2v. This can be connected to 10 number of E-vehicle.

X axis-Time in sec Y axis –voltage (v)

IV. CONCLUSION & FUTURE WORK

This study has successfully developed a high-efficiency isolated single-input multiple-output buck converter with step-down operational states, and this coupled-inductor-based converter was applied well to a single input power source plus two output terminals composed of an auxiliary battery module and a high-voltage dc bus. The experimental results reveal that the maximum efficiencies at the step-up state and the step-down state were measured to be 94% and 97%, respectively. The major contributions of the proposed converter are recited as follows: This topology adopts eight power switches to achieve the objectives of high-efficiency power conversion, electric isolation, bi-directional energy transmission, and various output voltage with different levels. The stray energy can be recycled by a clamped capacitor into the auxiliary battery module or high-voltage dc bus to ensure the property of voltage clamping. An auxiliary inductor is designed for providing the charge power to the auxiliary battery module and assisting the switch turned on under the condition of zero-voltage-switching (ZVS). The switch voltage stress at the step-up state is not related to the input voltage so that it is more

suitable for a dc power conversion mechanism with different input voltage levels. The copper loss in the magnetic core can be greatly reduced as a full copper film with lower turns. This high-efficiency converter topology provides designers with alternative electric isolation choices for boosting a low-voltage power source to multiple outputs with different voltage levels, or reversely transmitting the energy of high-voltage dc bus efficiently. The auxiliary battery module used in this study also can be extended easily to other dc loads, even for different voltage demands, via the manipulation of circuit components design. The project can be extended into still more E-vehicle devices to be connected. (at present we have connected 10 vehicles per phase). The control algorithms can be implemented as a micro controller based or DSP based systems. A hardware implementation of the full system may be worked out in future tenure of the project. The system may be implemented as a single chip system with SOC (system on chip) technology.

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