

Analysis of Isolated and Non-Isolated Zeta Converter based on Battery Charger

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Abstract:- Conventional battery chargers are due to the non-linear nature of a diode-bridge rectifier used for the AC-DC conversion. A single phase non-isolated zeta converter topology is designed and implemented for charging a 100 Ah, 48 V lead acid battery [1]. The challenges of non-isolated zeta converter topology is reduced heat loss and smooth charge of battery. The simulation results show that THD of the input current is low as compared to isolated zeta converter. The proposed converter is controlled using the sliding mode controller (SMC). By proper tuning the controller changes the charging mode from constant current to constant voltage. The analysis between the isolated and non-isolated battery shows that the non-isolated battery charger can achieve the increasing state of charge and smooth charging. percent italics mode

1 INTRODUCTION

The major concerns with the conventional vehicles are the phenomenal hike in conventional fuel prices as well as public health issues [1]. EV are constantly influencing the modern transportation system paid to their energy saving mechanism and reduced the pollution in the environment. The lead acid batteries are normally used for heavy duty operations involving many 100s of amps. The charge these batteries we specifically need chargers rated to handle high ampere charging levels for long periods of time. The high power lead acid battery used for charging large high current lead acid batteries in the order of 100 to 500 Ah, once the battery gets fully charged. Through non-isolated zeta converter is similar to that of a buck/boost converter, it has an advantage of non-inverted output. It has a wider range of duty ratio than any other converter. The converter exhibit improved power factor, low input current distortion, low output current ripple and wide output power range [11]. A non-isolated zeta converter is a fourth order DC-DC converter capable of amplifying and reducing the input voltage levels without inverting the polarity. The SOC is defined as the percentage of the remained charge inside the battery or the full charge, which is one of the most important parameters on batteries. Accurate SOC estimation owns a great significance to the vehicle. Its estimation is a key research area and it should be exploited within designed limits. Common SOC estimations are current integration method, open circuit voltage method, discharge test method, resistance prediction method. The non-isolated zeta converter is operated in discontinuous conduction mode so it reduces the diode reverse recovery time and zero current switching. The low transformer is not presented so the system weight

and losses are reduced and also improve the efficiency. The sliding mode controller (SMC) is a nonlinear control method that alters the dynamics of a nonlinear system by application of a discontinuous control signal that forces the system to slide along a cross of the system's normal behavior.

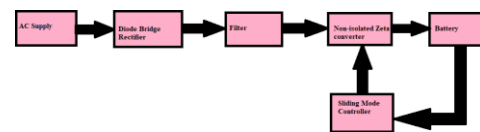


Figure 1: Proposed system block diagram

2 PROPOSED NON-ISOLATED ZETA CONVERTER: CONFIGURATION AND OPERATION

It consists of a Diode bridge rectifier powered by a single phase AC supply at its input. An uncontrolled DC voltage is produced at the output of the rectifier. This uncontrolled DC voltage works as the input of non-isolated zeta converter. This converter provides a controlled and regulated DC output voltage as well as the mains current is sinusoidal which conforms to the improved Power Quality (PQ) standard. The major concern of an EV battery charger is the presence of low AC ripple constant in charging current. The ripple current flow through the battery because of the huge capacitance in the battery circuit and it takes care of the reliable battery operation. So it increases the internal temperature of the battery due to excess heat. Therefore, a large amount of ripple current is reduced, which reduces the life cycle of the battery. So, designing the AC-DC converter of battery charger to meet the permissible ripple current requirements of the battery with use of a non-isolated topology. A non-isolated zeta converter is a fourth order non-linear system with regard to energy input and the same as seen in the buck-boost converter and with regard to the output. A non-isolated zeta converter modes are depending on inductance value, load resistance and operating frequency, here only continuous conductor current i_{L1} . The analysis uses the following assumption,

Semiconductors switching devices are considered to be ideal.

- Converter operating in continuous current mode.

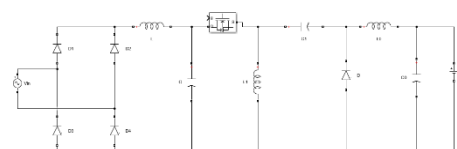


Figure 2: Proposed circuit diagram

Line frequency ripple in the DC voltage is neglected.

$$\dot{X} = Ax + BU \tag{1}$$

$$Y = Cx + DU \tag{2}$$

3.1 Operation

Mode-1:

The first mode is obtained when the switch is ON and instantaneously, the diode D is OFF condition as shown in fig(3). During this period, the current flow through the inductor L1 and L2 are drawn from the voltage source Vs. The capacitor C2 is charging condition. This mode is the charging mode.

Mode-2:

In this mode of operation starts when the switch is OFF condition and diode D is ON position as shown in fig(3). In this mode of operation is the inductor L2 is transfer the stored energy into load R (battery). So the battery going to discharging mode.

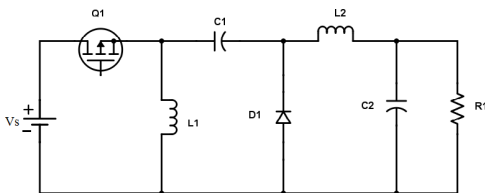


Figure 3: Equivalent diagram

not more an hour. Basically it must have the following parameters for the safe charging which does not required special step chargers.

- Fixed current or constant current (1/10th of battery Ah rating)
- Fixed voltage or constant voltage (17% higher than battery printed voltage)
- Over charge protection (cut-off when battery gets charged to the above level)
- Float gets charge (optional, not compulsory at all)

4 State space equation

The DC-DC voltage non-isolated zeta converter is assumed to the continuous conduction mode (CCM). It exist two circuit states with in one switch period T. First state condition when switch is turned on (DT) and another switch is turned off [(1-D)T]. The general state space mathematical model of the non-isolated zeta converters is given by

The second state condition the switch is off (1-D)T. In this mode the inductors L1, L2 are in discharging state. L1 is discharging its stored energy into the capacitor C1 and the inductor L2 transfer energy to the output section. Using ON state and OFF state equation, the system state

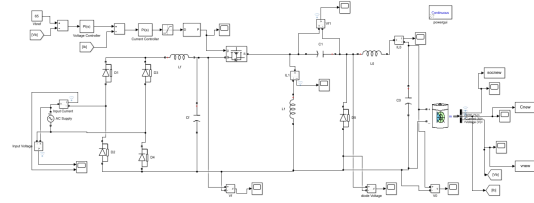


Figure 4: PI controller simulink block

space equivalent equation become to be,

$$\begin{bmatrix} \dot{X1} \\ \dot{X2} \\ \dot{X3} \\ \dot{X4} \end{bmatrix} = \begin{bmatrix} 0 & 0 & (1-D)/L1 & 0 \\ 0 & 0 & D/L2 & -1/L2 \\ (1-D)/C1 & -D/C1 & 0 & 0 \\ 0 & D/C2 & 0 & -1/C2 \end{bmatrix} \begin{bmatrix} X1 \\ X2 \\ X3 \\ X4 \end{bmatrix} + \begin{bmatrix} D/L1 \\ D/L2 \\ 0 \\ 0 \end{bmatrix} \begin{bmatrix} U \\ U \\ 0 \\ 0 \end{bmatrix}$$

The output equation is $Y = x4$ so the matrix form of

$$\text{output is, } Y = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \\ x4 \end{bmatrix}$$

5 Simulation Result

The performance of controller by reference load voltage variation is analyzed under the load variation is 48V the output voltage, output current and state of charge can be regulated by the controller.

5.1 PI controller

The PI controller is use in this decades. It perform the satisfactorily during transient under limited operating range. The PI-controller gives the gate signal to the non-isolated zeta converter. This control signal is used for the uni-polar PWM switching of the proposed non-isolated zeta converter. The uni-polar PWM switching signal has the advantages of low harmonic content in the output voltage.

The output current waveform of PI controller is easy to charge the battery but it will slow to reach the state of charge in full this result shown in fig(5). The output voltage waveform of PI controller shown in fig(6) and it

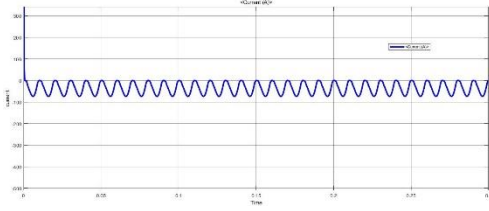


Figure 5: Output current wave form of PI controller

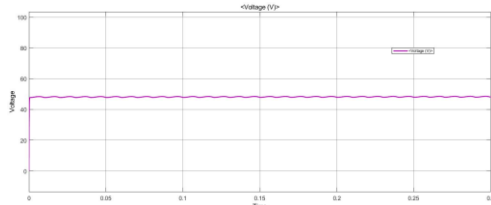


Figure 6: Output voltage wave form of PI controller

output voltage range is 48V. The THD of PI controller used non isolated zeta converter is 5.50% shown in fig(7). The THD percent in input current.

5.2 Sliding mode controller

The SMC shown the potential to be insensitive to the parameter variations and external disturbances. A non-isolated zeta converter is used to SMC in the closed loop control system shown in fig(8). The SMC surface value is zero this controller is satisfied.

$S = k_p e + k_i e + k_d e$ * *
 The output current wave form of SMC is charge in fast and the no distortion in output shown in fig(9). The output voltage is 48 V and in this voltage is used to reference voltage to develop a uni-polar PWM switching sig-

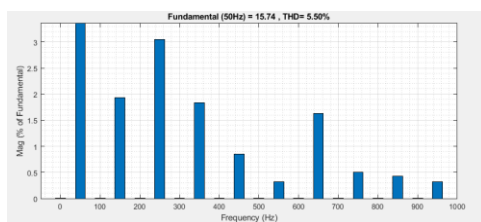


Figure 7: THD of PI controller

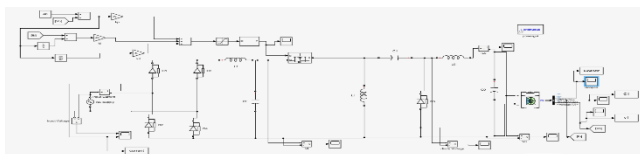


Figure 8: Sliding mode controller simulink block

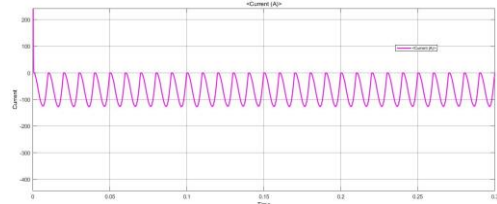


Figure 9: Output current wave form of sliding mode controller

nal shown in fig(10). This range of voltage level is controlled by the storage of the battery. The THD of input current is lower than the PI controller. The THD percentage is 0.01% shown in fig(11).

Comparison of the PI and sliding mode controller is shown in fig(12). In this figure result is state of charge comparison is explained. The SOC is easy and fast to reach the 100% range in the waveform. The SMC is fast to reach the full and PI controller is Reach in slowly. And in this condition SMC result is very smooth charging is regulated and the battery life time is increased.

5 CONCLUSION

The performance comparison between SMC and PI controller is done and simulation result using non isolated

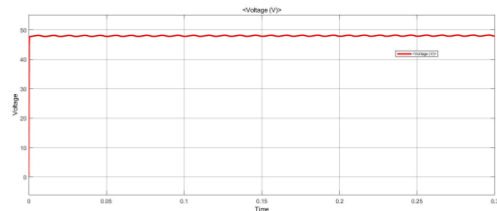


Figure 10: Output voltage wave form of sliding mode controller

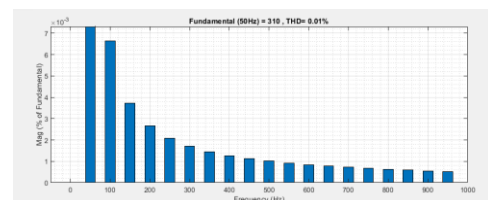


Figure 11: THD of sliding mode controller

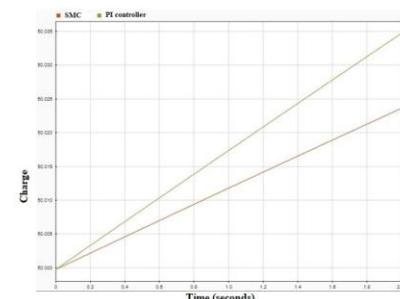


Figure 12: Comparison waveform of SOC

zeta converter under the load voltage variation. The sliding mode controller used in proposed system is very fast to reach the state of charge in full compared to PI controller. The SMC is regulated the output voltage and output current and it under any disturbance in supply side or load side. The battery charge is smooth in SMC as compared to PI controller. The smoothing of battery charging it increases the life of battery.

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