# A Smart and Green Charging Station Using the Buck Converters for the Electrical Vehicle (EV)

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**Abstract:** The paper presents on the green and smart charging station for the electrical vehicle to meet up the energy crisis and free from environmental contaminations as cost effective solution of the energy market and commercial success. The backup storage system of the electric vehicles improve demand response curves with a quickest smart charging station during the off peak hour load of the power system by virtue of which battery storage system hurls to manage power demand during the peak hour load of the power grid. The smart quick charging stations reduces the major drawbacks in terms of the charging phenomena of storages batteries because it takes huge time to recharge the backup system contributing the abnormal power loss , hazardous fume and gas emission. So the method of the charging system plays an important role to strengthen the battery life. Due to the revolution of the P-MOSFET and fabrication technology, the constant voltage and current charging method are invited both for the Buck SMPS based quickly and smart charging stations as effective solutions.

**Keywords:** P-MOSFET technology; smart & green charging; faster operation; robust reliability.

**List of symbols**

C = Input capacitor filter of the converter
$C_b$ = Output capacitor of the buck converter
D = Duty cycle
f = Supply frequency of the AC source
$f_s$ =Switching frequency of the Buck converter
$I_0$ = Load current
L= Inductor of the converter
R1= Load resistance
$t_{off}$ = Off time of the gate pulse
$t_{on}$ = On time of the gate pulse
$V_0$ = Load voltage
$V_s$ = Input voltage of the converter
$V_{sw}$= Maximum voltage stress across power switch

## 1 INTRODUCTION

A storage battery may be charged up either slowly or swiftly depending on the type of the charging methods. In case of slow charging, it takes long time for the full charges. The fault detection and



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safety precautions are totally covered and implemented by the low cost P-MOSFET technology to sustain overcharging and permissible temperature rise for the reliable and smart operations. Here, the designers make confident to use a 24V lead acid battery storage system and the soft switching buck converter unit to regulate the terminal voltage of battery for the tight regulations. A buck converter unit which is a low power DC to DC power converter using P-MOSFET devices is used to preserve huge tight regulations in terms low power loss , high efficiency , robust reliability and huge wider range of the input voltages and power consumption for the faster computations in a special domain of applications [1-4].

The power loss in the contact resistance of the normal charger unit which depends on the square of the current passing through it so it may be eliminated contactless P-MOSFET as new aspects of fabrication technology for the wider revolution of low power consumption P-MOSFET fed by compact SMPS [5-8].

In order to optimize system efficiency, faster computations and robust reliability, the air gap of the inductor coil ensures to reduce by the lowering power consumption of the P-MOSFET during charging through the electric vehicle [9-11].

On the other hand, it must be accurately placed over the SMPS charger unit. The storage battery charging system is also equipped with smart protection unit to protect storage battery against overcharging, deep charging, and undercharging and anomalous temperature rise of the prototype [12-14].

## 2 CHARGING AND DISCHARGING TIME OF THE EV

The charging time of the storage battery is investigated as massive challenging issues for the profitable frontrunner of the electric vehicles (EV). A standard storage battery is taken more time usually 10 to 12 hours to charge up using common level (L-1) of the charger units.

The utilization of the special charge of level 2 (L-2) reduces charging time 4 to 6 hours. But two charging systems are taken is very long time as major drawbacks of the charging systems.

The revolution of the faster P-MOSFET devices are used for the faster charging applications to save time as grand success of P-MOSFET based SMPS charging system. It also takes very less time than the common charging technique taken about 15 to 30 minutes to charge a storage battery during the on grid time. Again, it discharges using same time for the off grid time for the suitable managements of demand response and saving of the electricity using electrical vehicle as open market policy.

### 2.1 Method of Charging of the System

The storage battery chargers are designed typically around two approaches of charging method namely, constant voltage charging and constant current charging. The constant voltage charging utilizes here as robust technique for the applications.

The method of quick charging saves huge time of charging and discharging with battery life and operations. An internal series resistance of the battery is used to control current which pass through the battery as soon as the battery voltage charged up by the terminal voltage of the Buck converter which also inborn limits current due to presence of the buck inductor. These operations prevent power loss of the charging systems. The rectifier fed buck converter is shown in the Fig. 1 as smart charge controller or smart charger unit using the Matlab-Simulink model.

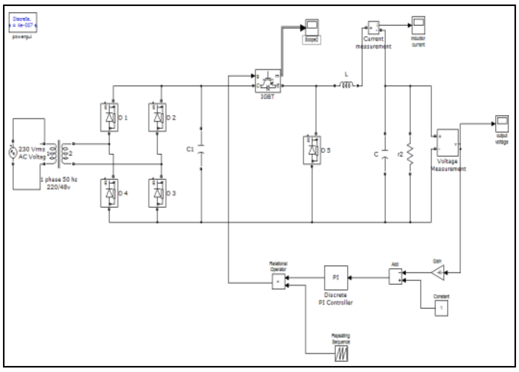

Fig. 1. Diode Rectifier fed buck power converter system.

### 2.2 The Basic Operation of the Buck Converter

The modelling of the buck converter using P-MOSFET devices is focused to strengthen quick charging station for the EV.

The modes of the operations are highlighted in the Figs. 2 and 3 to examine the performance of the EV.

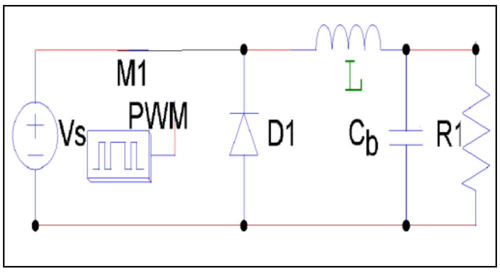


Fig. 2. Buck converter during ON state of the main switch.

The equation may be written in terms of the buck inductor and current passing through the inductor (L) as:

$$V_s - V_o = L\frac{di}{t_{on}} \qquad (1)$$

Load current passes through the freewheeling diode during the off period of the power switch as shown in the Fig. 3.

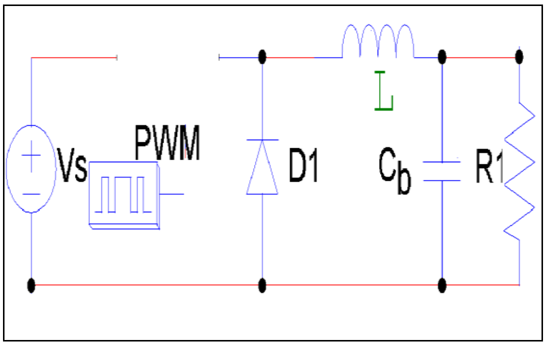


Fig. 3. Buck converter during off state of the main switch.

The equation may be written in terms of the buck inductor and current passing through the inductor (L) during the off time of buck converter as:

$$V_o = L\frac{di}{t_{off}} \qquad (2)$$

When the ripple current of the buck power converter remains constant, now the combination of the equation (1) & (2) yields as:

$$(V_s - V_o)t_{on} = V_o t_{off} \qquad (3)$$

The duty cycle (D) of the power switch may be defined as:

$$D = \frac{t_{on}}{(t_{on} + t_{off})} = \frac{t_{on}}{T} = t_{on} f_s \qquad (4)$$

When the time period of the gate pulse is given as:

$$T = (t_{on} + t_{off}) \qquad (5)$$

Now, the combinations of the equation (3) & (4) yields as:

$$V_o = {}^{t_{on}}\!/_{T}\, V_s = DV_s \qquad (6)$$

In order to find out the expression of the power inductor may be written after simplification of the Equations (2), 4 & (5) yields as:

$$L = \frac{(1\text{-}D)V_o}{\Delta i\, f_s} \qquad (7)$$

If other parameters of the Equation (6) remain constant, then power inductor is inversely proportional to the switching frequency of the buck converter as:

$$L \propto \frac{1}{f_s} \qquad (8)$$

The load power (P) may be expressed in terms of the output capacitor ($C_b$) of the converter as:

$$P = \frac{1}{2} C_b V_o^2 f_s \qquad (9)$$

## 3 DESIGNING THE SMART CHARGER AS BUCK CONVERTER

The power inductor value of the buck converter using the Equation (7) as:

Given that load voltage. $V_o$ =24V, duty ratio=0.5, T=20μS and peak to peak ripple current is restricted to $\Delta i = 3\,\%$. Hence, the value of the power inductor is given by:

$$L = \frac{(1\text{-}D)V_o}{\Delta i\, f_s} = \frac{(1\text{-}D)VT}{\Delta i} = \frac{(1\text{-}0.5)24}{0.03} * 20 * 10^{-6} = 8 \text{ mH}$$

Similarly, the capacitor value may be designed by the given values for load power (P) =100W and from the Equation (9) as:

$$C_b = {}^{2PT}\!/_{V_o^2} = \frac{2*100*20*10^{-6}}{(24)^2} = 7\ \mu F$$

Charging current of the battery in terms of the load resistance (R1) is given as:

$$I_b = \frac{V_o}{R1} \qquad (10)$$

If we consider the constant voltage charging, the battery ($I_b$) is inversely proportional to the load resistance given as:

$$I_b \propto \frac{1}{R1} \qquad (11)$$

The Equation (11) does not signify the constant power and current charging of battery of the smart charger.

The output capacitor (C) acts as a power filter to make ripple free from the load voltage. The input capacitor of the converter is used to improve the input power factor of the rectifier.

### 3.1 Choice of the Modes of the Operation

There are two types mode of operation of the converter are used either discontinuous conduction mode (DCM) or continuous conduction mode (CCM) of operation. In this paper, the buck power converter works under the continuous conduction mode (CCM) at which output current never goes to zero value. The power inductor get charged by storing energy during on time of the power switch and it get discharge energy to the load during off time of the power switch as pulse width modulation techniques (PWM) and closed loop operation as shown in the Fig. 4 at the inductor current is not zero or not touched the time axis.

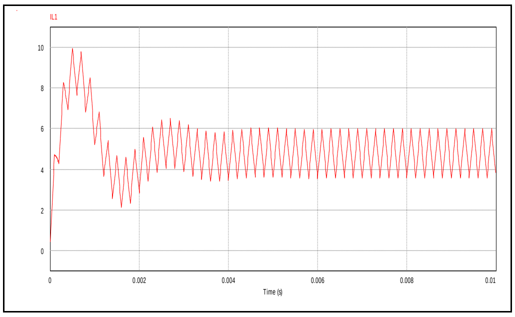

Fig. 4. Inductor current during the CCM of operation.

The voltage stress across the main switch of the converter is equal to the supply voltage of the converter when the parasitic effects of switch are totally neglected during the PWM operations. It is evidently observed at the Fig. 5.

In order to select the voltage rating of the power switch, the stresses should study to build prototype of the converter before selection of the switch along with data sheet of the manufacture. The voltage across the power switch ($V_{sw}$) is shown in the Fig. 5 during hard switching actions.

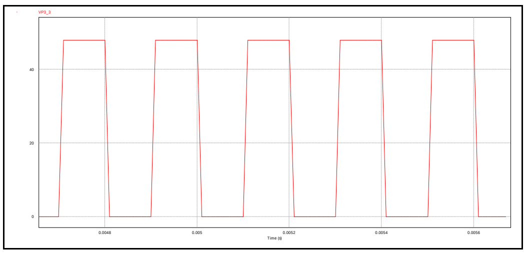

Fig. 5. Voltage stress across the power switch.

### 3.2 Effects of the Smart Chargers on the Demand Response

Electricity price per unit consumption is to be considered as lower price during the off peak hours of the power grid when the power demand is short particularly during night and early morning of a day and it is also top requirements of the electric power during peak hours of a day.

In the present scenario of the power market, the power demand may be controlled through the smart chargers of the electric vehicles. The consumer harvests electricity using storage systems of the electric vehicles as per requirements. The consumers exchange their demand by charging and discharging their storage systems to sell excess electricity and buy power as per requirements of the open market policy of the electricity.

The demand for the electricity in demand response is considered as varying prices of the power market just as share markets. A consumer may ask for whether the users are willing to purchase electricity at higher price during the peak hour of the load. The prices of the electricity during this time discourages to customer to use electricity due to higher price of electricity in the market.

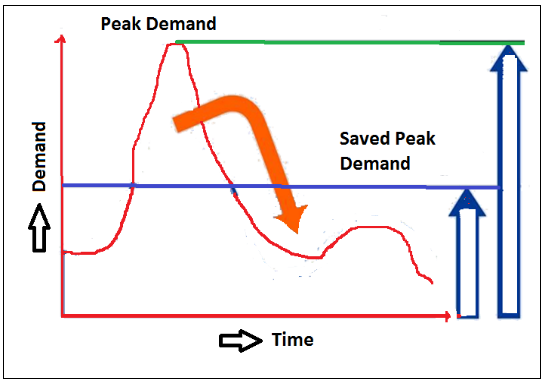


Fig. 6. Demand response curve of the power system.

In this approach, the consumers may reduce their demand in self controlled techniques or sells excess electricity to power grid to earn financial benefit. As a result, the peak demand of the system decreases using a series storage system of electric vehicles. These types of the system may reduce peak demand of electrical power and saving the peak demand as shown in the Fig. 6 as wider clarification.

If a series of the electric vehicle are charged during off peak hours of a day then the price of charging will be lower as open market policy of the power market and a series of the storage of the electric vehicles (EV) systems are used to charge battery which may be used to supply the domestic load during peak hours as shown in the Fig. 6 as the distributed generators.

If EVs are charged during peak hours it will invite ruthless networks of the grid, volatile system of the peak demand, abnormal voltage variation of distribution inviting sizeable increase of power loss and bad power quality.

So charging of the EV systems during off peak hours not only decreases the peak demand of the system but also improves power quality of the electricity to fulfill the demand shortage so that the generation units runs with full capacity to meet up demand to accomplish the maximum efficiency and robust reliability of the smart and green charging systems.

### 3.3 Results

The closed loop PWM techniques are utilized to drive the switch to regulate and accurate the load voltage due to wider variations of the input voltage and load for achieving the tight regulations as shown in the Fig. 7 at which the load voltage is observed at 24V at steady state using the transient analysis for the smart battery charging purposes and tight regulations.

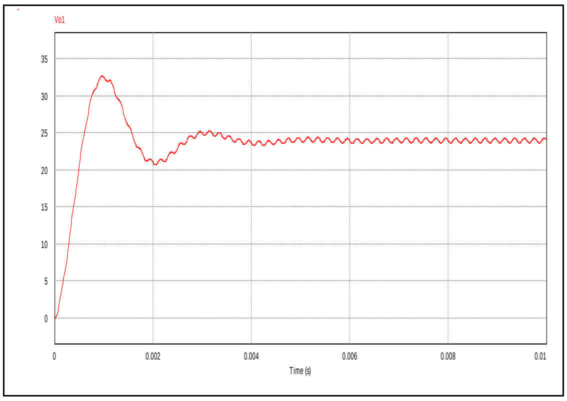

Fig. 7. Load voltage of the converter.

The load versus efficiency curved drawn to predict the improved performance of the smart and green charging converter over wide variations of load and input voltage variations. The no load to full load efficiency is computed to plot the load versus percentage efficiency curved as shown in the Fig. 8.

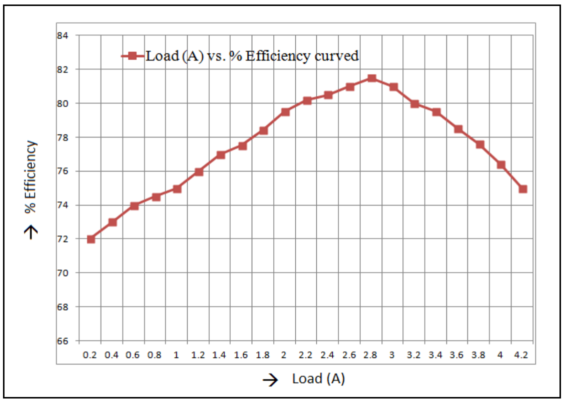


Fig. 8. Load vs., % efficiency graphs of the converter.

The load versus efficiency curved of the system plays an important role to improve the demand response of the power system at which the charging systems of the electric vehicles are introduced to sell storage power to nearby grid cracking down the monopole business of the power utilities.

The smart charging system may be treated as integral part of energy saving element through the buck converter unit.

## 4 CONCLUSIONS

The performance analysis is carried out on the smart and green charging station using the P-MOSFET devices for electrical vehicle (EV) which is best suited for the practical and smart grid applications to improve the demand response curved. It also invites robust reliability and frees from the environmental contaminations upto marks. The load versus efficiency curved envisages efficient and soft charging system for the industrial and consumer product as the faster EV charging stations.

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