A Quick Charging Station for Electric Vehicle with Current Control Technique

M.Ejas Ahamed[1], R.Ramya[2],K.Sudha Priya[3] ,V.Boopathi [4] ,R. Rajesh[5]

[1]*PG Scholar-Department of EEE, Bannari Amman Institute of Technology[1],Sathyamangalam,*

[2]*PG Scholar-Department of EEE, Bannari Amman Institute of Technology[2],Sathyamangalam,*

[3]*PG Scholar-Department of EEE, Bannari Amman Institute of Technology[3],Sathyamangalam,*

[4]*PG Scholar-Department of EEE, Bannari Amman Institute of Technology[4],Sathyamangalam,*

[5]*Assistant Professor Department of EEE, Bannari Amman Institute of Technology[5],Sathyamangalam.*

ABSTRACT

An electric vehicle (EV) fast charging station utilizing pulse frequency current control system is produced in this paper. The current source derived converter design is utilized to demonstrate pulse charging of both positive and negative pulse to accomplish time required for an EV which is under 30 minutes. The positive heartbeat charge allows the high crest current charge: this will prompt to quick charging mode; though, the idle state can control battery temperature rise. The recurrence utilized for pulse charge procedure can be fluctuated relying upon the sort and state of a battery. The utilization of current source converter can offer the acquire adaptation to internal failure capacity and bidirectional power flow. PSIM 9.0.3 is used for simulation and the 50 kW model is produced to accept the proposed idea. The simulation and experimental results outline that the proposed beat recurrence charging procedure requires about 16 minutes to completely charge battery from 20% of SOC at 80% of SOC. The temperature rise of pulse charging system is under 4 °C:these can prompt fast charge and more battery lifetime. The outcomes recommend that the proposed method can be connected for an electric vehicle quick charger station.

Keywords— quick charging; electric vehicle; pulse charge; SOC

1. INTRODUCTION

Recently, electric vehicles (EVs) have grown rapidly as required green energy form the world. More specially, in a large city, air pollution due to CO_2 emission is a worried issue. For instance, Nissan LEAF sales have officially surpassed 100,000 units worldwide in January 2014 catching about 45% market share of EV business. Also, the battery technology for EVs is established to be a high rate charge and discharge. Therefore, higher number of EVs will be used in the next few years. It is estimated that more than 5 million EVs will be utilized by 2020 [1]. Generally, EVs can run for about 150 km; therefore, a charging station is required which has a function like a gas station. There are three important issues for a charging station: quick charge (less than 30 minutes), long battery lifetime (low temperature rise during charge), and adjustment (every vehicle providers can be used).

Constant current (CC) and constant voltage (CV) technique is normally used for a battery charger. CC delivers shorter time for charging a battery with higher temperature rise; whereas, CV offers low temperature rise with longer charging time. With the limit of voltage per cell (V/cell) and maximum charging current (I_{max}) from battery providers, CC and CV method cannot meet the 30 minutes charging time and low temperature rise requirements from EV users.

Immediately, a pulse charging method is an alternative method for a quick charger at high current. A pulse charge method can be inserted higher peak voltage and current with the same of V/cell and I_{max} rated; therefore, a charging time is shorter comparing to CC and CV method [2].

There are some previous researches using pulse charge method for a charger application. The hybrid method between regenerative pulse and equalization charger using a DSP has been established in [3]. The proposed technique used high switching frequency for charging operation which if low ripple current but higher switching losses in power devices: this lead to high temperature rise. A fly back converter with positive and negative pulse charger with power factor correction has been demonstrated in [4]. The results in [4] offered a good power factor and bidirectional power flow; however, the temperature rise of the battery did not explained in the research. Designs of battery pulse charge with varying frequency and duty cycles have been proposed in [5-6].

The proposed method has been designed for a small Li-Ion battery and could be applied for an EV battery. However, the temperature rise and the effect of frequency and duty cycle of pulse signal did not investigate. In addition, a review of charging algorithm for Nickel and Lithium battery charger has been performed in [7]. The methods discussed in [7] are investigated mostly a small size applications for mobile phones, laptop computer, tablet PC, etc. One can see that a few researches have been done for a pulse quick charge technique for an EV.

Therefore, a pulse frequency method of a quick charger is proposed in this research. Suitable duty cycles and frequencies of positive and negative pulses are investigated for a particular EV battery.

Fig. 1 Quick charging station for EVs.

Duty cycle and switching frequency of the advanced paradigm can be controlled to meet the quick charge and longer battery lifetime with different type of batteries. The proposed circuit diagram is an improved version from [8] which can operate in bidirectional power flow through using a current source converter for better fault acceptance capability. PSIM 9.0.3 is utilized for simulation study and the 50 kW prototype is developed to validate the proposed notion. The possible quick charger station is shown in Fig.1. A set of PV cells can also be integrated with a charging station for better energy efficacy.

2. PROPOSED CONTROL PARADIGM

To represent a battery electrochemical action, the impedance method is usually used as clearly explained in [7-8] and will not repeat here. Briefly, a charge transfer resistance in a battery represents to interfacial electrochemical impedance and this resistance is reciprocal to exchange current density (i_o) and the exchange current density can be written by

$$i_o = Fk_0(1-\theta)^{1-\alpha}\theta^{\alpha}c^{1-\alpha} \quad (1)$$

Where

F = the Faraday constant (96487 C/equiv),

k_o = the standard rate constant for heterogeneous reaction,

ɵ = the mole fraction,

α = the transfer coefficient

c = the concentration at the surface of the electrode

As can be seen, in (1) the parameter c can be changed by a charging method as explained in [7].
The pulse frequency can be generated from a modulation between desired positive pulse and negative pulses and a triangle waveform. The positive and negative pulse width can be controlled depending on the battery environments (V/cell and I_{max}) and battery temperature rise (ΔT^o). The temperature rise during charge can effect a battery lifetime as depicted in Fig. 2. Clearly, if a temperature increases about 5 ^{o}C from 25 ^{o}C , a lift time is expected to decrease about 30% in lead acid and about 10% of lithium battery. A circuit operation incorporating with related pulse width signals is illustrated in Fig. 3. The positive pulse width is depended upon V/cell; whereas, the idle state is referred with battery temperature rise. If the battery temperature rise is higher than 4 C^o the idle state

interval will increase to control the battery temperature as depicted in Fig. 4. Fig. 4 also shows a flow chart diagram of proposed quick charging paradigm. As can be seen, temperature rise control is used during constant voltage charging mode: this would not cost battery lifetime.

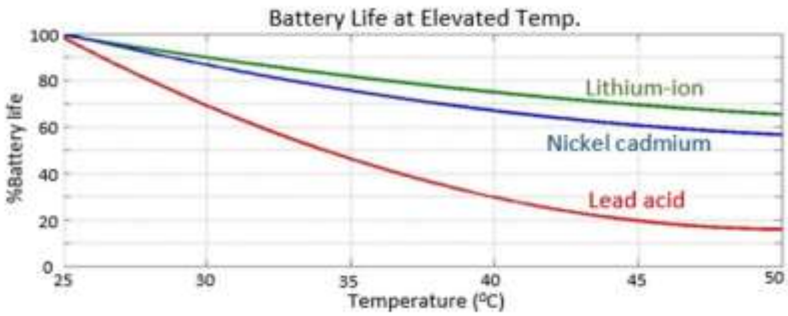

Fig. 2. The temperature rise during charge can effect a battery lifetime.

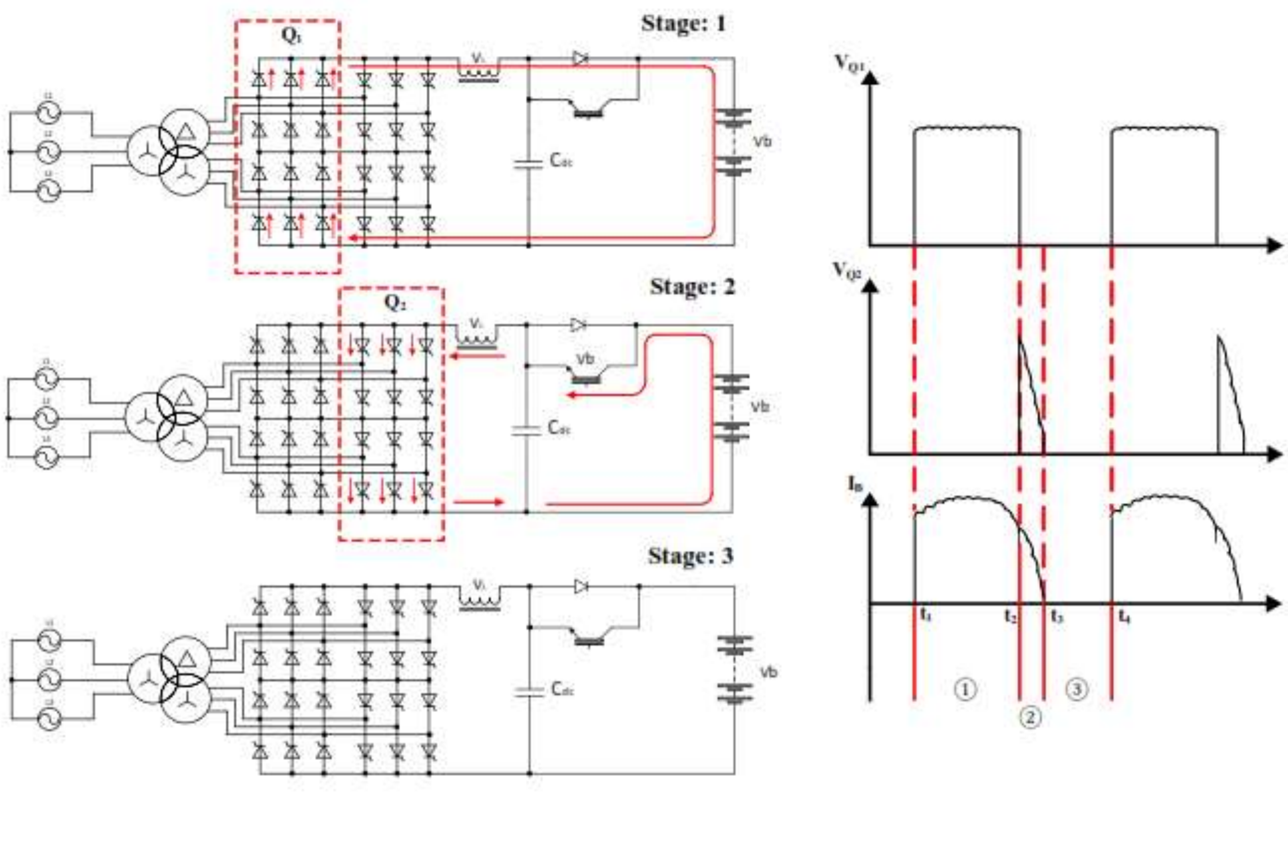

Fig. 3. Proposed Circuit operation

PSIM 9.0.3 is used to simulate the notion of the proposed system as illustrated in Fig. 5. Gate drive signals are generated using pulse width modulation (PWM). There are two reference signals: positive pulse and idle state pulse. Positive and idle state are independently control. As previously mentioned, positive pulse width is depended on voltage per cell (V/cell) and maximum charging current (I_{max}) of battery. Idle state pulse width (d^{-}) is used to control temperature rise of a battery during charging process (ΔT^{O}). Both positive and idle pulses at 50 Hz frequency are modulated with a triangle waveform at 5 kHz. For a particular study, $d^{(+)}$ = 0.5 and $d^{(-)}$ =

0.08 are used. All gate drive signals and modulation signals are depicted in Fig.. 4. The simulation results are shown in Fig..6. As can be seen, battery charging voltage and charging/discharging current are pulse frequency signals and can be controlled V/cell and Imax by adjusting $d^{(+)}$ and $d^{(-)}$. As can be seen, the circuit is based on simple buck-boost converter with bidirectional power flow function. Also, a control algorithm is also simple and possible to implement in a single chip.

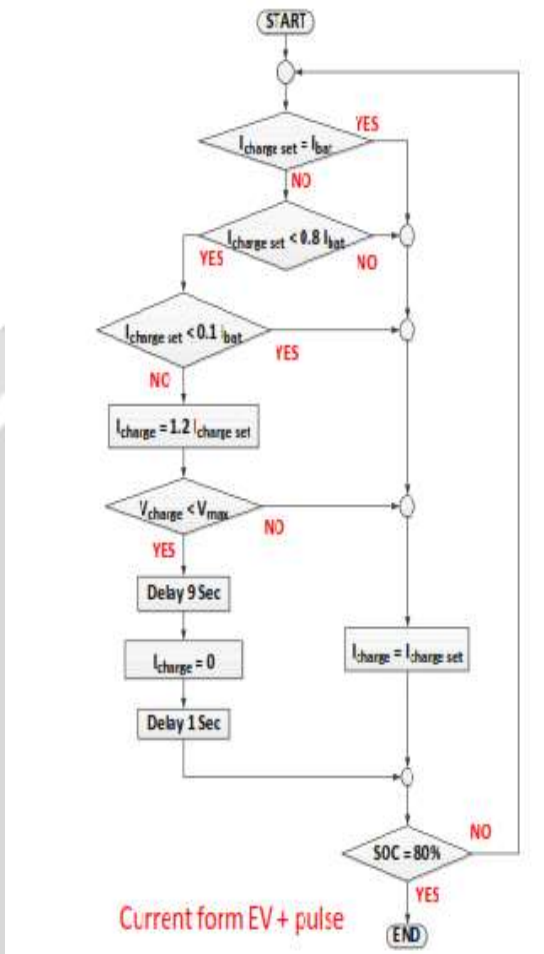

Fig. 4. Proposed control paradigm

3. EXPERIMENTAL RESULTS

The developed 50 kW prototype of a quick charger using pulse frequency technique is shown in Fig. 7. Nisan LEAF 2012 was used to validate the charging time of the developed charger. The LEAF has 24 kWh laminated lithium ion battery and requires 30 minutes at 50 kW charging time for a quick charge mode. The developed current source converter can performed both conventional CC/CV charging mode and pulse frequency charging mode. The developed charger is communicated with the Nissan LEAF via CHAdeMO standard. The suitable frequency and duty cycle (d □) were investigated for this particular battery as shown in Table I. Obviously, 0.75 duty cycle of positive pulse with 25 Hz frequency was selected as a reference signal to modulate with a triangle for generating pulse frequency because they provided less charging time and lowest temperature rise. The selected duty cycle and frequency are selected based on battery measured parameters from the tested Nissan LEAF. The optimal duty cycle for pulse charging technique can be calculated based on charging efficiency and exchange current density as developed by [7-8]. It should be noted that different batteries (types and providers) would have different battery parameters. mode

.

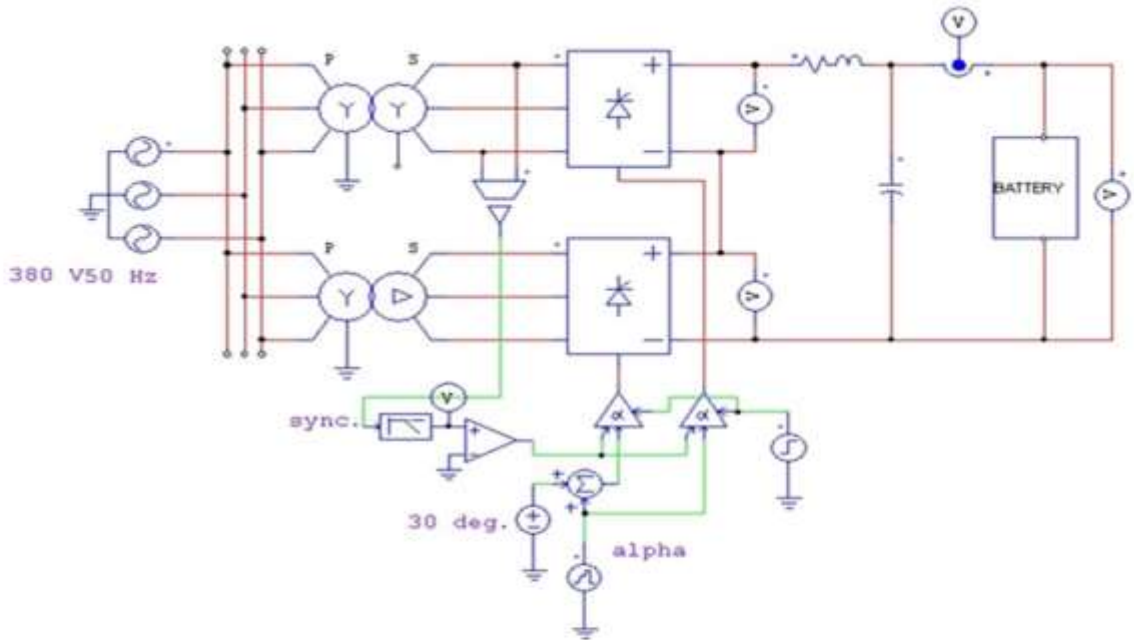

Fig. 5. Simulation model

The developed prototype was also performed conventional CC and CV experiment to compare with the pulse frequency charging mode. Fig. 8and Fig. 9.are experimental results of battery charging and discharging using CC and CV technique. The LEAF was charged from 20% of SOC to 80% of SOC in quick charging mode. As can be seen, the terminal voltage were regulated for both charging methods. The charging process was performed until the tested battery was fully charged.

TABLE 1 SUITABLE REFERENCE SIGNAL PARAMETER FOR BATTERY UNDER TEST

Frequency at 50Hz		d* at 0.75	
Variable d*		Variable Frequency	
d*	Charging time (minute)	Frequency	ΔT (°C)
0.5	325	25	3.275
0.75	250	50	3.575
		100	3.875
		200	3.650

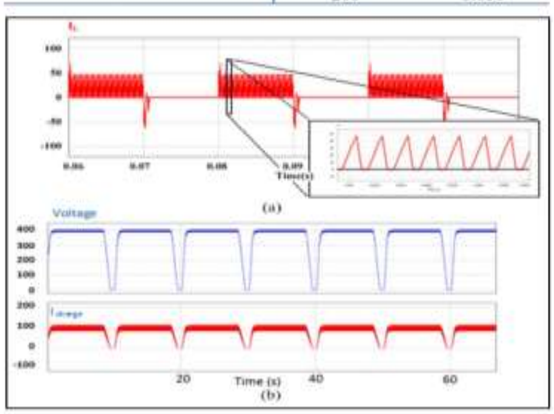

Fig. 6. Simulation results: (a) an inductor current (b) charging voltage and current of a battery.

Fig. 7. A pulse frequency 50 kW charger prototype

The terminal voltage were regulated at 400 V and maximum charging current (I_{max}) was limited at 120 A as shown from Fig. 8 to Fig. 11. Fig. 8 shows the results of conventional CC/CV charging mode. As known, the CC will perform first then the CV mode will operate to keep temperature rise. The charging time required is about 20 min. It should be noted that EVs will control the charging process via CHAdeMO using CAN bus communication. Fig. 9 also shows the magnified view of terminal voltage and current. After that, the pulse frequency charging mode results are illustrated in Fig. 10 and 11. As can be seen, the pulse frequency charge will perform during constant voltage region which is not over the current limitation. The results show that the required charging time is about 16 min. The temperature investigation both at the battery and developed charger were also observed as shown in Fig. 12. In addition, Fig.10 shows the comparison results of charging performance between conventional CC/CV charging method and proposed pulse frequency technique. Clearly, the proposed pulse frequency technique can change the test batteries from 20 percent of state of charge (SOC) to 80% of SOC quicker than conventional CC/CV method about four min. Moreover, the temperature rise of proposed charging technique is less than a CC/CV method about 1 ^{o}C. One can see that the proposed technique can perform better charging performance in term of charging time and temperature rise. The experimental results illustrate that the proposed pulse frequency technique is a promising technique to apply for a quick charger in EVs.

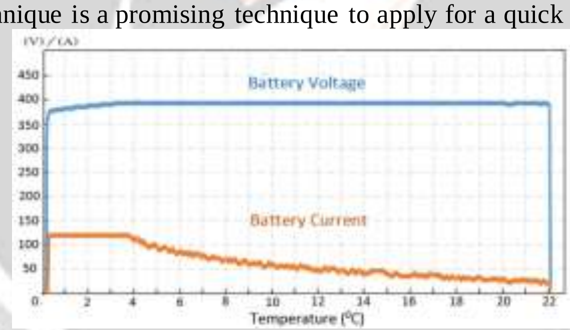

Fig. 8. Voltage and current signals of the tested battery set using Conventional CC/CV method.

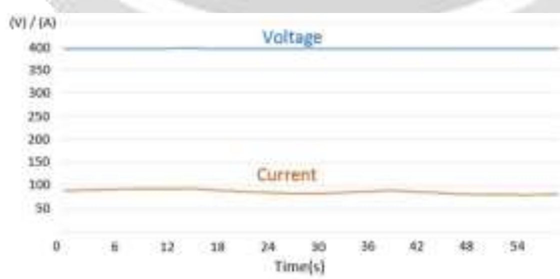

Fig. 9. Magnified view of terminal voltage, current and temperature of the tested battery set using conventional CC/CV method.

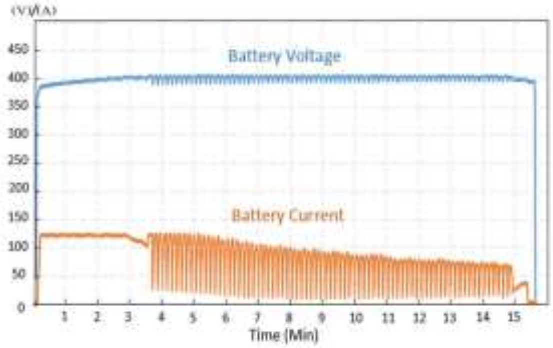

Fig. 10. Voltage and current signals of the tested battery set using proposed pulse frequency technique

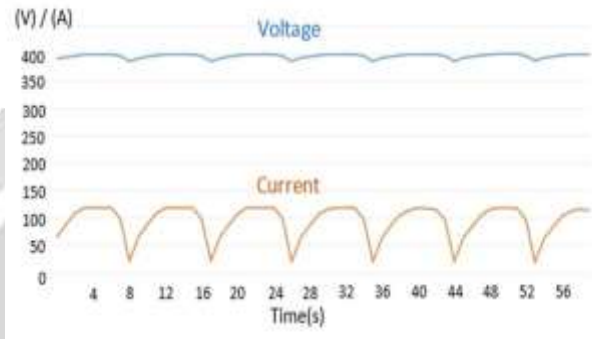

Fig. 11. Magnified view of terminal voltage, current and temperature of the tested battery set using proposed pulse frequency technique

4. CONCLUSIONS

A pulse frequency technique of a quick charger has been developed in this paper. Pulse frequency charging method can offer quicker battery charger relating to conventional CC/CV technique about 4 minutes and lower temperature rise about 1 C^{O}. A simulation study has also been performed to evaluate circuit operation and control paradigm. The suitable reference signal parameters for the battery under test have also been investigated. The proposed pulse frequency charging technique has been performed under Nissan LEAF model 2012. The experimental results also imply that this pulse frequency charging technique can also be applied with other types of EV batteries. An EV battery pack normally consists of several single battery cells; therefore, it is possible to apply this pulse frequency technique in EV charger with carefully battery management. Although a cost of a bidirectional power flow converter will increase for a pulse frequency charger, the extra performance for quicker charging time and low temperature rise during charging process is required for an EV charging station.

5. REFERENCES

[1] Zhipeng Liu, Fushuan Wen, and Gerard Ledwich, “Optimal Planning of Electric-Vehicle Charging Stations in Distribution Systems,” IEEE Transactions on Power Delivery, vol. 28, no. 1, pp 102 – 110, January 2013.

[2] T. J. Liang, T. Wen, K. C. Tseng, and J. E Chen, “Implementation of a Regenerative Pulse Charger Using Hybrid Buck-Boost Converter,” IEEE Power Electronics and Drive Systems, 2001, pp 437 – 442.

[3] Chih-Chiang Hua, Ching-Hsiang Hsu, “Implementation of a Regenerative Pulse and Equalization Battery Charger Using a DSP,” IEEE Power Electronics and Drive Systems, 2005, pp 955 -959.

[4] K. C. Tseng, T. J. Liang, J. E Chen, and M. T. Chang, “High Frequency Positive/Negative Pulse Charger with Power Factor Correction,” IEEE Power Electronics Specialists Conference, 2002, pp 671 – 675.

[5] Liang-Rui Chen, “A Design of an Optimal Battery Pulse Charge System by Frequency-Varied Technique,” IEEE Transactions on Industrial Elactronics, vol. 54 no. 1, pp 398 -405, February 2007.

[6] Liang-Rui Chen, “Design of Duty-Varied Voltage Pulse Charger for Improving Li-Ion Battery-Charging Response,” IEEE Transactions on Industrial Elactronics, vol. 56 no. 2, pp 480 -487, February 2009.

[7] Hussein, H.A.-H., Batarseh, I. "A Review of Charging Algorithms for Nickel and Lithium Battery Chargers" , IEEE Transactions on Vehicular Technology, vol. 60 no. 3, March 2011, pp 1 – 6.