HV Battery SOC Estimation Algorithm Based on PSO

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Abstract: In view of the traditional algorithm to estimate the electric vehicle battery state of charge (SOC), lots of problems were caused by the inaccurate battery model parameter estimation error. Particle swarm optimization (PSO) algorithm is a global optimization algorithm based on swarm intelligence, it has intrinsic parallel search mechanism, and is suitable for the complex optimization field. PSO is simple in concept with few using of parameters, and easily in implementation. It is proved to be an efficient method to solve optimization problems, and has successfully been applied in area of function optimization. This article adopts the PSO optimization method to solve the problem of battery parameters. The paper make a new attempt on SOC estimation method, applying PSO to SOC parameters optimization. It can build optimization model to get a more accurate estimate SOC in the case of less parameters with faster convergence speed.

1 INTRODUCTION

Lithium battery has many advantages such as high energy density, high power density, long cycle life and so on. As the energy storage element of electric vehicles, it is used widely. In order to improve the safety and reliability of battery pack, fully play its efficiency, and prolong its life, the battery pack must be managed effectively in using. Battery state of charge (SOC) estimation is the important contents and basis of battery management system (BMS), but the battery is a kind of nonlinear uncertain system, so it is very difficult to estimate battery SOC accurately (Ramadass, 2003).

The SOC of the battery is refers to the amount of residual capacity of charged battery, SOC estimation is the basis of the battery thermal management, balance management, and safety and reliability management; But due to the complexity of lithium ion battery structure, the charged state by the working current of battery, battery internal resistance and the surrounding environment temperature, self-discharge, and the influence of factors such as aging, all of that makes the SOC estimation difficult (Takeno, 2004). Particle swarm optimization (PSO) algorithm is a global optimization algorithm based on swarm intelligence, has intrinsic parallel search mechanism, and is suitable for the complex optimization field. The paper make a new attempt on SOC estimation method, applying PSO to SOC parameters optimization, It can build optimization model to get a more accurate estimate SOC in the case of less parameters, faster convergence speed. (Kang, 2014)

2 PSO ESTIMATION METHOD

2.1 Particle swarm optimization theory

PSO is evolutionary computation technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling. Recently, PSO algorithm has been gradually attracted more attention over another intelligent algorithm. (Shi, 2008) It was proved to be an efficient method to solve optimization problems, and has successfully been applied in the area of function optimization, neural network training and fuzzy control systems, etc. (Plett, 2004/2006)

2.2 The main model of Particle swarm algorithm

PSO is colony intelligence which simulates the swarm flock in search of food, each individual is to

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be a particle of the flock, representative with space position and speed of two-dimensional vector. In the process of looking for food (problem solving), and each particle according to the current location, itself has experienced the best location (individual optimum) and the entire population of optimal location optimal (global optimum) to determine the flight direction of next step.

The basic PSO algorithm model is the foundation of other improved model, its core idea is the group of individuals experience learning by itself and social experience for reference, and group of other individuals in the information exchange and sharing, dynamic change itself, the speed of the optimized group.

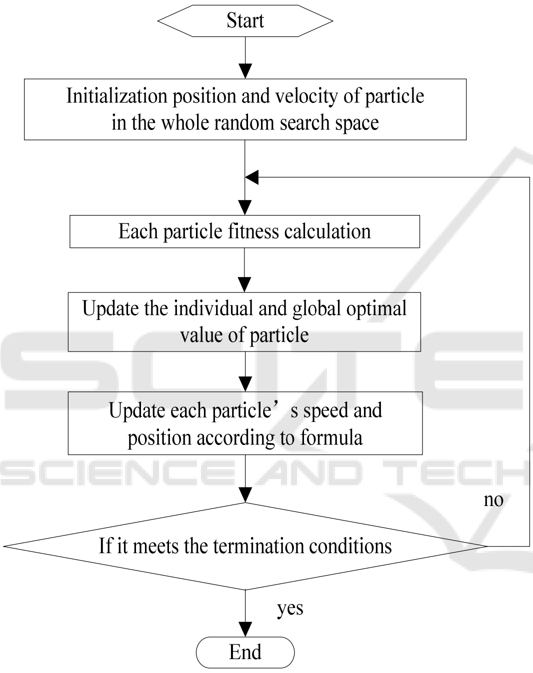


Figure 1: PSO Model algorithm process

3 LI-ION BATTERY SOC ESTIMATION METHOD

At present, There are many different kinds of battery model, Thevenin model of battery has the characteristics of simple operation, and can well reflect the dynamic and static characteristics of the battery, so in this paper, this model is adopted to establish the equation of the battery.

3.1 Modelling of key parameters for SOC estimation

The type of new energy car battery system, the system is composition of cells with P parallel and S series, single series battery module in four dimensional space vector.

Table 1: Key parameters of SOC estimation

Symbol	Description	Values
V	Voltage	2.75V~4.2V
C	Capacity	--
R	Resistance	--
T	Temperature	-20℃~55℃

3.2 Model algorithm process

The specific calculation steps are as follows.

i) The initial time, $t = t_0$. There are many battery blocks as particles. Assuming that the quantity of block is S, and $soc_i = \langle C_i, V_i, T_i, R_i \rangle$ $i = (1, 2, \cdots S)$. The initial particle swarm, $SOC_i = (soc_1(t), soc_2(t), soc_3(t), \cdots soc_S(t))$, $soc_i(t) = \langle C_i(t), V_i(t), T_i(t), R_i(t) \rangle$. Initialize individual particle experienced the optimal position (individual optimal), record for $pbest_t(t)$, initialize group particle experienced the optimal position (global optimal), record for $gbest_t(t)$.

ii). $t = t+1$, update the voltage, the temperature, the resistance, the capacity of particle, get particle swarm on the next moment, through the following formula 1, formula 2, formula 3 and formula 4.

$$V_i(t+1) = V_i(t) + \omega_1 rand(\ )\left[pbest(t) - p(t)\right] + \omega_2 rand(\ )\left[pbest(t) - p(t)\right] \quad (1)$$

$$T_i(t+1) = T_i(t) + \omega_3 rand(\ )\left[pbest(t) - p(t)\right] + \omega_4 rand(\ )\left[pbest(t) - p(t)\right] \quad (2)$$

$$R_i(t+1) = R_i(t) + \omega_5 rand(\ )\left[pbest(t) - p(t)\right] + \omega_6 rand(\ )\left[pbest(t) - p(t)\right] \quad (3)$$

$$C_i(t+1) = C_i(t) + \lambda_1 V_1(t+1) + \lambda_2 T_1(t+1) + \lambda_3 R_1(t+1) \quad (4)$$

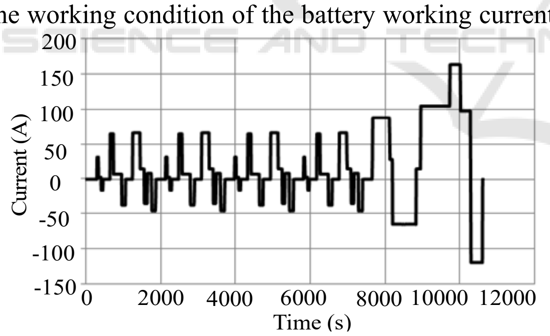
Typically, the first for the original voltage of battery module, reflects the battery state of a moment, namely under the voltage influence of the last time. The second reflects their thinking, which is the current state of the battery module from their own experience. The third part reflects the perception, the group cooperation and information sharing among the battery module. The battery module according to the needs of the three parts for better search of the optimal residual capacity ω_1 , ω_2 , … ω_6 .. For learning factor, the main regulating speed with their choice of optimal partner selection and optimal location affect weight, rand () is a random number between [0, 1].

iii) If t > Maximum iterations or match the end conditions, then it terminated after the output calculation, or cycle through the second step.

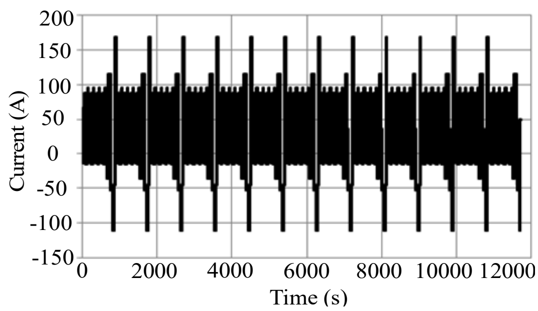
4 THE EXPERIMENT AND SIMULATION ANALYSIS

In this paper, the PSO algorithm's superiority in battery state estimation through the battery charge and discharge at the set condition experiment is verified. The subjects for the lithium ion power battery in a company.

Battery figure 2 (a) and (b) as shown in the condition of current charge and discharge, the experimental data of the sampling frequency of 1Hz.Figure 2 (a) for a battery charge and discharge current, charge and discharge cycle figure 2 (b) as the working condition of the battery working current.

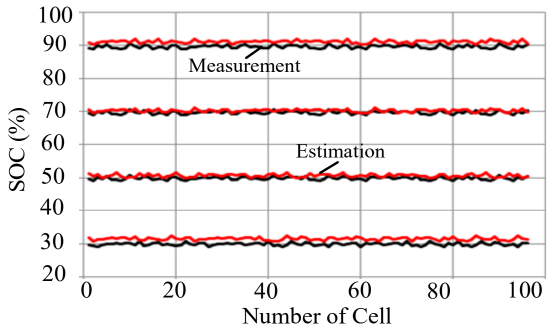


(a) Single driving cycle

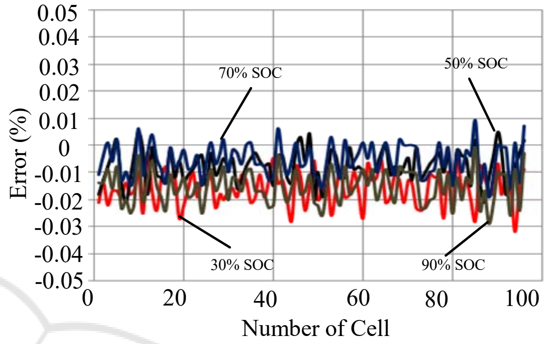


(b) Driving cycle of entire

Figure 2: Driving cycle condition

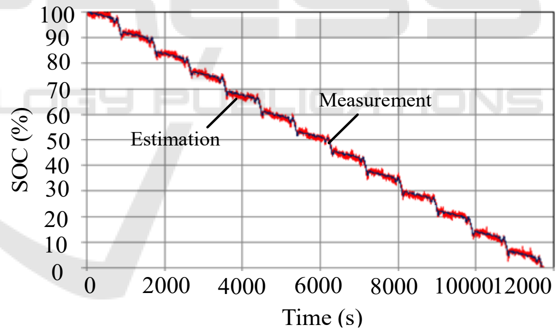


(a) SOC of cells estimation curves

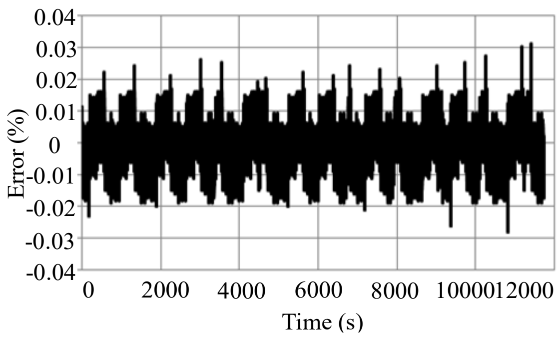


(b) Estimation error curves

Figure 3: SOC of cells on individual optimum



(a) SOC of pack estimation curves



(b) Estimation error curves

Figure 4: SOC of battery pack on global optimum

According to the estimation performance, the parameters for estimating SOC was optimized by using PSO algorithm, so it can improve the estimation precision obviously.

5 CONCLUSIONS

HV battery is a kind of strongly nonlinear uncertain system, so it is very difficult to establish battery model accurately. In this paper, based on Thevenin model of battery, the battery model is set up adopting PSO to optimize the key parameters for the battery SOC estimation. The estimated and experimental results show the PSO method is robust and the estimation precision can be improved base on more accurate battery model.

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