Design of Dynamic Power-Supplying Rescue Implementation Strategy Based on the Common Route of Intelligent Electric Vehicles

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Abstract. In order to solve the problem of breaking down caused by the shortage of electric energy in intelligent electric vehicles, the dynamic power-supplying rescue implementation strategy based on the common route was designed. The detailed rescue request information of vehicles which needed electric energy were designed; The assessing procured for rescue ability of vehicles which received the rescue request was also designed. The rescue implementation strategy will make up for the mileage defect of intelligent electric vehicle to some extent, and will have very good application value.

1. Introduction
At present, the charging stations are not universal and specific energy of battery is not high enough. Therefore, the limited range is still one of the main factors restricting the full popularity of pure electric vehicles. We are often afraid that the running electric vehicle on the road will break down because of the lack of electricity. To solve this problem, a vehicle-to-vehicle (V2V) dynamic charging technology was invented[1][2]. As early as 2012, an intelligent electric vehicle -- Ant 1.0 concept car was designed by Chery Company. The concept was that one Ant 1.0 concept car could charge the other one by combination mode when one of them lack of electricity. With the development of intelligent automobile technology, the driving technology of following a car automatically at close distance (within one meter) will become a reality[3-6]. So the implementation strategy of dynamic power-supplying rescue for vehicles which lack of electrical energy on the common path will be feasible. That is, the charging process can be carried out in the running on the road without the special rescue vehicle and the charging station. The dynamic power-supplying rescue method can save time, manpower and material resources, and eliminate the driver's anxiety about range, too. However, the intelligent electric vehicles which have the dynamic power-supplying rescue function need two conditions: first, the vehicles need to have the piloting and following function; second, the vehicles need to have the vehicle-to-vehicle charging interface.

2. Overall implementation strategy
When electricity energy is not enough for an intelligent electric vehicle to reach the destination, the driver needs to decide whether to choose the dynamic power-supplying rescue mode. If this mode has been chosen, the vehicle control system will continuously send out wireless signal of the rescue request for dynamic power supply to the surrounding intelligent electric vehicles. The intelligent electric vehicles which receive the rescue request will calculate and audit the rescue ability based on
the parameter information of the two vehicles. If the audit passes, the two drivers contact with each other to determine the remuneration and meeting venue. Finally, two vehicles connect by electricity and CAN bus, then they can start to drive together after meeting.

3. Dynamic power-supplying rescue request
The intelligent electric vehicle which lacks electric energy is called LE-IEV for short and the intelligent electric vehicle which is rich in electric energy is called RE-IEV for short in the following. In order to get help from RE-IEV as soon as possible, the rescue request parameters sent by the LE-IEV were designed and listed in the Table 1:

| Parameter                                | Unit | Parameter                                | Unit |
|------------------------------------------|------|------------------------------------------|------|
| Destination                              |      | Battery pack rated voltage               | V    |
| Route                                    |      | Front face area                          | m²   |
| Passenger weight                         | kg   | Drag coefficient                         |      |
| Curb weight                              | kg   | Vehicle charger rated power              | kW   |
| Dump energy                              | kWh  | Reward                                   | ¥    |
| Minimum average speed demanded           | km/h | Average discharge efficiency of power cells |      |
| Total efficiency of transmission systems |      | Efficiency of drive motor and controller |      |
| Energy consumption per unit mileage      |      | Wh/m                                     |      |

In Table 1, the parameters such as destination, route, passenger weight, reward and minimum average speed demanded by the LE-IEV can be set up in the terminal system of the vehicle by driver. However, other parameters can be found out from the network database according to the brand and the type. And curb weight plus passenger weight equals total weight.

4. Examination of rescue request
The terminal systems of the vehicles which have received the rescue request need to assess the feasibility of providing aid to the LE-IEV according to the parameter information firstly. The flow chart of the examination process of rescue request is shown in Figure 1: (1) to judge weather the output voltage matches to the input voltage of the LE-IEV; (2) to judge weather the routes of two vehicles have common part; (3) to judge weather the RE-IEV can provide enough electric energy for the two vehicles; (4) to judge weather the RE-IEV can provide enough power for the two vehicles. (5) to judge weather the owners of two vehicles agree on the reward.

4.1. Judgement of the routes of two vehicles
According to the route and destination which the LE-IEV provided, the terminal system of the RE-IEVs judge whether they have the common part, and estimate the mile number of the common part which they drive together.

4.2. Estimation of electric energy of two vehicles
If the two vehicles have common drive route, the driver of the RE-IEV will enter his/her receptive minimum average speed; And the terminal system of the RE-IEV will estimate that if they have enough electric energy to reach their destination. There are two estimation methods. The estimation equation sets of the first estimation method can be established as follow[7,8]:

...
Fig. 1. Flow chart of examination process of rescue request

\[
\begin{align*}
E_{B1} &= \left( m_1 g f_1 + \frac{C_{D1} A_1 u^2}{21.15} \right) \frac{s_1}{\eta T_1 \eta_{MC1} \eta_{D1}} 3600 \\
E_{B2} &= \left( m_2 g f_2 + \frac{C_{D2} A_2 u^2}{21.15} \right) \frac{s_2}{\eta T_2 \eta_{MC2} \eta_{D2}} 3600 \\
E_{S2} &\geq E_{B1} + E_{B2} - E_{S1} \\
u &= \max(u_{\text{min}1}, u_{\text{min}2})
\end{align*}
\]

(1)

Where \( E_{S1} \) is the remainder electric energy of the LE-IEV; \( E_{B2} \) is the remainder electric energy of the RE-IEV; \( E_{B1} \) is the electric energy needed by the LE-IEV for reaching its destination; \( E_{B2} \) is the electric energy needed by the RE-IEV for reaching its destination; \( m_1 \) is the total mass of the LE-IEV; \( m_2 \) is the total mass of the RE-IEV; \( g \) is the acceleration of gravity; \( f_1 \) is the coefficient of rolling resistance of the LE-IEV; \( f_2 \) is the coefficient of rolling resistance of the RE-IEV; \( C_{D1} \) is the drag coefficient of the LE-IEV; \( C_{D2} \) is the drag coefficient of the RE-IEV; \( A_1 \) is the front face area of the LE-IEV; \( A_2 \) is the front face area of the RE-IEV; \( u_{\text{min}1} \) is the receptive minimum average speed of driver of the LE-IEV; \( u_{\text{min}2} \) is the receptive minimum average speed of driver of the RE-IEV; \( u \) is average speed for estimating the electric energy in formula, and it equals to the bigger one between \( u_{\text{min}1} \) and \( u_{\text{min}2} \). \( \eta_{T1} \) is the mechanical efficiency of transmission systems of the LE-IEV; \( \eta_{T2} \) is the mechanical efficiency of transmission systems of the RE-IEV; \( \eta_{MC1} \) is the efficiency of the drive motor and control unit of the LE-IEV; \( \eta_{MC2} \) is the efficiency of the drive motor and control unit of the RE-IEV; \( \eta_{D1} \) is the battery discharge efficiency of the LE-IEV; \( \eta_{D2} \) is the battery discharge efficiency of the RE-IEV; \( s_1 \) is the full mileage of the LE-IEV. \( s_2 \) is the full mileage of the RE-IEV.

Electric energy can also be estimated based on energy consumption per unit mileage which derived from data statistics. Therefore, The second computational formula can be established as follow[7]:

\[
\begin{align*}
E_{B1} &= e_1 \cdot s_1 \\
E_{B2} &= e_2 \cdot s_2 \\
E_{S2} &\geq E_{B1} + E_{B2} - E_{S1}
\end{align*}
\]

(2)

Where \( e_1 \) is the electric energy consumption per unit mileage of the LE-IEV, and \( e_2 \) is the electric energy consumption per unit mileage of the RE-IEV.
4.3. Estimation of power

When the power of the RE-IEV is estimated, there are two working conditions needed to be considered.

(1) The first working condition: The RE-IEV doesn’t need to charge the battery of the LE-IEV, only needing to provide power to the LE-IEV for running together at the same speed on the common route. When driving-together is over, the LE-IEV can reach its destination by using its remainder electric energy. The electric energy transmission routes of two vehicles are shown in Figure 2. The electric energy supplied by the RE-IEV will be transformed to driving force by motor directly, instead of being stored in battery. The first working condition identification formula is:

\[ E_{st} \geq \left( m_1 g f_1 + \frac{C_{D1} A u^2}{21.15} \right) \frac{s_1 - s_T}{3600 \eta_{f1} \eta_{MC} \eta_{D1}} \]  \hspace{1cm} (3)

Where \( s_T \) is the mileage of road on which two vehicles run together[8].

\[ P_2 \geq \frac{u}{3600 \eta_{f1}} \left( m_1 g f_2 + \frac{C_{D1} A u^2}{21.15} \right) + \frac{u}{3600 \eta_{f2}} \left( m_2 g f_2 + \frac{C_{D2} A u^2}{21.15} \right) \]  \hspace{1cm} (4)

Under this condition, the output power of RE-IEV must be greater than the sum of the two vehicles’ power which is used to overcome driving resistance. The expression formula of output power of RE-IEV is:

\[ P_{e2} \geq \frac{u}{3600 \eta_{f1}} \left( m_1 g f_1 + \frac{C_{D1} A u^2}{21.15} \right) + \frac{u}{3600 \eta_{f2}} \left( m_2 g f_2 + \frac{C_{D2} A u^2}{21.15} \right) \]  \hspace{1cm} (5)

**Figure 2.** The electric energy transmission route of two vehicles under the first working condition.

**Figure 3.** The electric energy transmission route of two vehicles under
(2) The second working condition: The LE-IEV also can not reach its destination by using its remainder electric energy, even providing power by RE-IEV as in the first working condition. While they are driving together on the common route, the RE-IEV must charge the battery of the LE-IEV, and also provide power to the LE-IEV for running at the same speed and at the same time. The electric energy transmission routes of two vehicles are shown in Figure 3. The expression formula of output power of RE-IEV is:

\[
E_T = \left( \frac{m_1 g f + C_D A u^2}{21.15} + \frac{m_2 g f + C_D A u^2}{21.15} \right) \eta_f \eta_m \eta_d \frac{s_T}{3600}
\]

\[
P_{e2} \geq \frac{u}{3600 \eta_f} \left( \frac{m_1 g f + C_D A u^2}{21.15} + \frac{u}{3600 \eta_f} \left( \frac{m_2 g f + C_D A u^2}{21.15} \right) + \frac{P_{ec}}{\eta_c} \right)
\]

Where \( E_T \) is the electric energy needed by the LE-IEV for distance of \( s_T \).

The expression formula of output power of RE-IEV can also be shown as follow based on electric energy consumption per unit mileage:

\[
P_{e2} \geq \frac{u}{3600 \eta_f} \left( \frac{m_1 g f + C_D A u^2}{21.15} + \frac{m_2 g f + C_D A u^2}{21.15} \right) + \frac{P_{ec}}{\eta_c}
\]

\[
E_T = e_1 \cdot s_T
\]

\[
P_{e2} \geq \frac{u}{3600 \eta_f} \left( \frac{m_1 g f + C_D A u^2}{21.15} + \frac{m_2 g f + C_D A u^2}{21.15} \right) + \frac{P_{ec}}{\eta_c}
\]

\[
E_T + E_{s1} + \frac{P_{ec}}{u} \geq E_{B1}
\]

Where \( \eta_c \) is charge efficiency, \( P_{e2} \) is the output power of the RE-IEV, \( P_{ec} \) is the input power to the battery of the LE-IEV.

If RE-IEV can satisfy the above conditions, it will response to the request from LE-IEV. Then the LE-IEV can choose one suitable RE-IEV and give its position, license plate number and contact information. They can meet at a place where they have agreed on, then the two vehicles connect together by electric and communication.

5. Conclusion

In this paper, the detailed dynamic power-supplying rescue implementation strategy based on the common route was designed for intelligent electric vehicles. The implementation strategy can make up for the mileage defect of intelligent electric vehicles to some extent and eliminate people's anxiety of range. With the application and popularization of shared driverless electric vehicles in future, the dynamic power-supplying rescue method will be more practical and have a very better application prospect in view of integrated management.

References
[1] Zhilong Wang, Xiaohui Ma, et al. Electric vehicle dynamic charging system: China, 20182036813.2(P). 2019.01.04.
[2] Pengwei Fang, Jian Huang, et al. A vehicle-to-vehicle charger: China, 201610223041.6(P). 2016.07.13.
[3] Zhenpo Wang, Fengchun Sun. Electric Vehicle Power Battery System and Application Technology[M]. Beijing: Machinery Industry Press. 2012.02.
[4] Park B S, Yoo S J, Adaptive leader-follower formation control of mobile robots with unknown
skidding and slipping effects[J]. International Journal of control, Automation and Systems, 2015,13(3):587-594.

[5] Morbidi F, Mariottini G L, Prattichizzo D. Brief paper: Observer design via immersion and invaria for vision-based leader-follower formation control[J]. Automatica, 2010, 46(1):148-154.

[6] Alvarez D, Gomez J V, Garrido S, et al. 3D robot formations path planning with fast marching square[J]. Journal of Intelligent and Robotic Systems, 2015, 80(3): 507-523.

[7] Shengmin Cui. New Energy Vehicle Technology[M]. BeiJing: Beijing University Press. 2014.02.

[8] Zhisheng Yu. Automobile Theory[M]. BeiJing: Automobile Theory. 2009:1-27.