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State Assessment Method and Results of Electric Emergency Diesel Engine Power Supply Vehicle

Zi-chong ZHANG*, Jian FANG and Hong-bin WANG

Guangzhou Power Supply Co., Ltd, Guangzhou, People's Republic of China

*Corresponding author

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Abstract. Diesel engine power supply vehicle plays an important role in emergency electric repair of sudden disasters. Its reliability largely determines the efficiency of restoring power supply. This paper proposed a deduction system state assessment method based on performance testing, and evaluated 47 diesel engine power supply vehicles. The state assessment found that more than half of the power supply vehicles were not in normal state, and the transient performance of the power supply vehicles deteriorated seriously, requiring maintenance and repair. The factors that affect the state deterioration of power supply vehicles are studied, and it is found that the state deterioration of power supply vehicles with long service time and small rated capacity is more obvious.

Introduction

When urban power outages caused by natural disasters or other reasons, power enterprises need to quickly repair and restore power supply, and emergency power generation equipment needs to be used in this process. If the reliability of emergency power generation equipment is insufficient and quality problems occur, it will bring great hidden dangers and adverse effects to emergency repair work [1]. Emergency power supply vehicle is a common emergency power generation equipment, mainly including diesel engine power supply vehicle and UPS power supply vehicle [2], which is widely used in power grid emergency power supply and power supply protection [3,4]. However, the existing electric emergency diesel engine power supply vehicles have problems such as insufficient product detection capability and nonstandard operation and maintenance management, which make many power supply vehicles unable to meet the working requirements of rapid power recovery.

In order to evaluate the state of the power supply vehicle and guide the operation and maintenance management, this paper studied the state assessment method of the electric emergency diesel power supply vehicle, and made the state assessment and result analysis on 47 diesel power supply vehicles in a power supply bureau. The research is expected to lay a foundation for the formulation of technical standards, technical specifications and operation and maintenance guidance for emergency power generation equipment, improve the management level of emergency power generation equipment and enhance the reliability of equipment.

State Assessment Method

The reliability can be improved by evaluating the condition of the equipment and arranging maintenance according to the condition [5,6]. This paper adopted a deduction assessment method based on the performance test results to evaluate the state of diesel engine power supply vehicles. The deduction value obtained according to the importance and deterioration degree of the state quantity was taken as the quantitative assessment standard, and the state of emergency power supply vehicles was measured according to the total deduction value [7].

State Quantity Selection. Referring to the relevant technical specifications of diesel engine power supply vehicles, the state quantities are selected. These state quantities can effectively reflect the

performance state of diesel engine power supply vehicles and are convenient to obtain, with clear judgment standards. As shown in Table 1, according to the different aspects of the performance of the power supply vehicle, the selected state quantity is divided into four categories: appearance structure, monitoring and control, safety performance and operation performance.

Table 1. Classification of status quantities of power supply vehicles.

Appearance structure	The surface of the whole vehicle; Carriage door lock; Blinds; Chassis auxiliary support device; Lighting fixtures; Cable; Cable winch; Firefighting facilities; Terminal phase sequence
Monitoring and control	Monitoring panel; Unit parameter monitoring; Running condition monitoring; Log records; Automatic start loading; Automatic unloading and shutdown; Automatic control
Safety performance	Insulation resistance; Overload protection; Short circuit protection; Reverse power protection; Emergency shutdown
Operational performance	Start-up performance; Steady state deviation; Transient deviation; Voltage imbalance; Frequency drop; Voltage changes in cold and hot states; Voltage total harmonic distortion rate; Continuous operation

Assessment of State Quantity. The deduction value calculated according to the importance degree and deterioration degree of the state quantity is taken as the assessment standard of a single state quantity, i.e.

$$Ai=Bi \times Ei \quad (1)$$

In the formula, Ai is the deduction value of a certain state quantity; Bi is that basic score of the state quantity; Ei is the weight of the state quantity.

The basic score depends on the degree of deterioration of the state quantity. The deterioration degree of state quantity can be divided into 4 Grades from light to heavy, which are Grade I, Grade II, Grade III and Grade IV respectively, and the corresponding basic deduction values are 2, 4, 8 and 10. The weight depends on the importance of the state quantity. The state quantity that has relatively little influence on the equipment performance and safe operation is called the general state quantity, and the weight is set at 1 and 2. State quantities that have relatively great influence on equipment performance and safe operation are called important state quantities, and their weights are set at 3 and 4. See Table 2 for the corresponding situation of the weight of the state quantity, the degree of deterioration and the points to be deducted.

Table 2. Score of state variables and its weight and deterioration degree.

Degree of deterioration of state quantity	Basic points deduction	Points to be deducted from state quantity			
		Weight 1	Weight 2	Weight 3	Weight 4
Ⅰ	2	2	4	6	8
Ⅱ	4	4	8	12	16
Ⅲ	8	8	16	24	32
Ⅳ	10	10	20	30	40

Assessment of State Rating. The state level of the power supply vehicle is divided into four levels, namely:

(1) Normal state: Indicates that each state quantity of the equipment is stable and within the standard value specified in the regulations, and can operate normally;

(2) Attention status: The single (or multiple) status values of the equipment develop towards the direction of approaching the standard limit, but do not exceed the standard limit, and can still continue to operate, but the monitoring during operation should be strengthened;

(3) Abnormal state: If the single important state quantity changes greatly and is close to or slightly exceeds the standard limit, the operation shall be monitored and power failure maintenance shall be arranged in due course;

(4) Serious state: The single important state quantity seriously exceeds the standard limit, and power failure maintenance shall be arranged as soon as possible.

In order to determine the state level, firstly, the deduction value of a single state quantity is obtained according to Table 2 and Eq. 1, and then the deduction value of the state quantity subordinate to the

same category is superimposed to obtain the total deduction value of the four categories. The corresponding relationship between the deduction value of the state quantity and the state of the power supply vehicle is shown in Table 3. When the total deduction value or the single deduction value of any state quantity reaches the range specified by the state grade, the performance of the category is regarded as the corresponding state grade. The overall assessment of emergency power supply vehicles shall integrate the assessment results of various types. When the appearance structure, monitoring and control, safety performance and operation performance are all normal, the overall assessment shall be normal. As long as one of the four types of performance has attention state, abnormal state or serious state, the overall assessment shall be the most serious state.

Table 3. Score of state variables and state grade.

Assessment criteria	Normal state		Attention status		Abnormal state	Critical state
	Total points deducted	Individual points deduction	Total points deducted	Individual points deduction	Individual points deduction	Individual points deduction
Appearance structure	≤30	≤10	>30	12~20	>20~24	≥30
Monitoring and control	≤30	≤10	>30	12~20	>20~24	≥30
Safety performance	≤30	≤10	>30	12~20	>20~24	≥30
Operational performance	≤30	≤10	>30	12~20	>20~24	≥30

Evaluate Samples and Test Results

In this study, various performance indexes of 47 sample diesel engine power supply vehicles were tested and their states were analyzed. The performance testing methods refer to China's national standard GB/T 20136-2006 "General Test Methods for Internal Combustion Engine Power Stations", communication industry standard YD/T 502-2007 "Diesel Generator Set for Communication" and other relevant standards and relevant technical agreements of a power supply bureau [8-10].

The detection mainly includes 14 key items: Appearance inspection, function inspection, steady-state voltage deviation, steady-state frequency band, transient voltage deviation and voltage recovery time, transient frequency deviation and frequency recovery time, voltage imbalance, frequency drop, voltage total harmonic distortion rate, insulation resistance, overload protection function, emergency stop function, continuous operation and phase sequence inspection. Statistics are made on the test results of diesel engine power supply vehicles, and the unqualified rate of each test item is obtained as shown in Fig. 1.

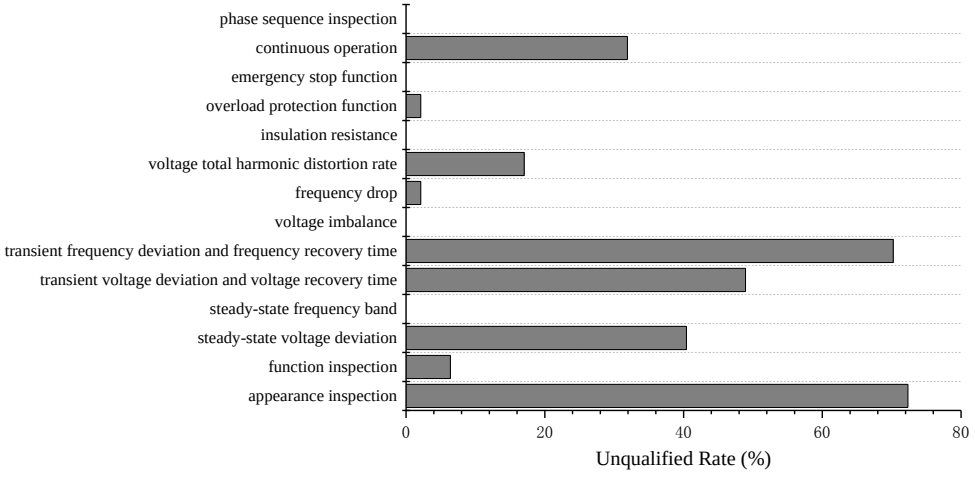

Figure 1. Unqualified rate of diesel power supply vehicle test items.

From Fig. 1, it can be found that the operation performance of diesel engine power supply vehicles that have been in service for several years has the following characteristics:

(1) The steady-state frequency band, voltage imbalance, insulation resistance, frequency drop, function inspection, emergency stop function and overload protection function of 47 inspected power supply vehicles have good performance stability, only sporadic faults exist, and the performance deterioration is not obvious with the passage of service time.

(2) The unqualified rate of appearance inspection items of 47 inspected power vehicles was 72.34%. There are 34 power supply vehicles with varying degrees of problems such as paint falling off, lock catch jamming, lighting device failure, serious cable wear, fire extinguishing agent not replaced beyond the effective period, etc., and routine maintenance is insufficient.

(3) Of the 47 tested power supply vehicles, 8 failed in the total harmonic distortion rate of voltage, 19 failed in the steady-state voltage deviation and 15 failed in the continuous operation capacity. The failure rates of the tested items were 17.02%, 40.43% and 31.91% respectively. It can be seen that the total harmonic distortion of voltage, steady-state voltage deviation and stability of continuous operation capability of diesel engine power supply vehicle are poor. With the passage of service time, the steady-state output performance obviously deteriorates, the output voltage quality deteriorates, and the continuous operation time decreases. Among them, the shortage of continuous operation capacity has a particularly serious impact on the reliability of diesel engine power supply vehicles, and most of the power supply vehicles with insufficient continuous operation time are triggered by overheating of cooling water during full-load operation, resulting in insufficient heat dissipation performance.

(4) Of the 47 tested power supply vehicles, 23 failed in transient voltage deviation and voltage recovery time, and 33 failed in transient frequency deviation and frequency recovery time. The failure rates of tested items were 48.94% and 70.21% respectively. It can be seen that the stability of transient voltage deviation, voltage recovery time, transient frequency deviation and frequency recovery time of diesel power supply vehicle is poor, and the transient performance deterioration is the most obvious during the service of power supply vehicle.

Results and Analysis of State Assessment

The state assessment results of 47 sample diesel power supply vehicles are shown in Fig. 2. Of the 47 power supply vehicles, 18 power supply vehicles are in normal state, 8 power supply vehicles are in attention state, 13 power supply vehicles are in abnormal state, and 8 power supply vehicles are in serious state. In order to understand the influence of rated capacity and production time of diesel engine power supply vehicle on the state of power supply vehicle, the power supply vehicle is statistically analyzed according to the above factors.

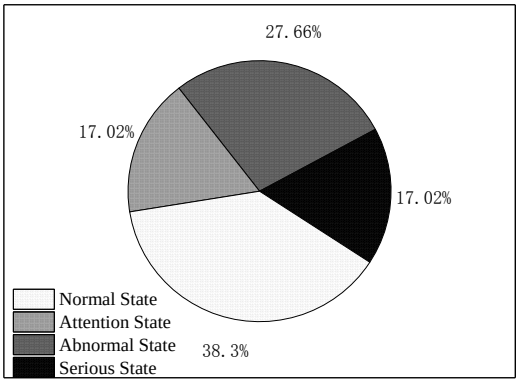

Figure 2. State distribution of diesel power supply vehicles.

Influence of Different Rated Capacity. The 47 diesel engine power supply vehicles tested this time include four rated capacity grades, 3 power supply vehicles with rated output power of 100kW or

less, 22 power supply vehicles with rated output power of 200kW, 8 power supply vehicles with rated output power of 400kW and 14 power supply vehicles with rated output power of 500kW.

As shown in Fig. 3, the state grades of diesel engine power supply vehicles with different rated capacities account for four vertical bars respectively representing different rated capacities, and the proportion of different colors in the vertical bars represents the proportion of four state grades in the same capacity. As can be seen from the figure, the state grade of large-capacity power supply vehicles is relatively excellent, and none of the power supply vehicles with 400kW or above are in serious state. The proportion of normal power supply vehicles in 400kW power supply vehicles is the highest, reaching 62%. Although the proportion of normal state of 500kW power supply vehicles is lower than that of 400kW power supply vehicles, the total proportion of normal state and attention state is the highest, with only 14% of power supply vehicles in abnormal state. The state level of 200kW and below power supply vehicles is relatively poor. Only 36% of 200kW power supply vehicles are in normal or attention state, 36% are in abnormal state, and the remaining 27% are in serious state. Of the three power supply vehicles below 200kW, two are in serious state and one is in normal state.

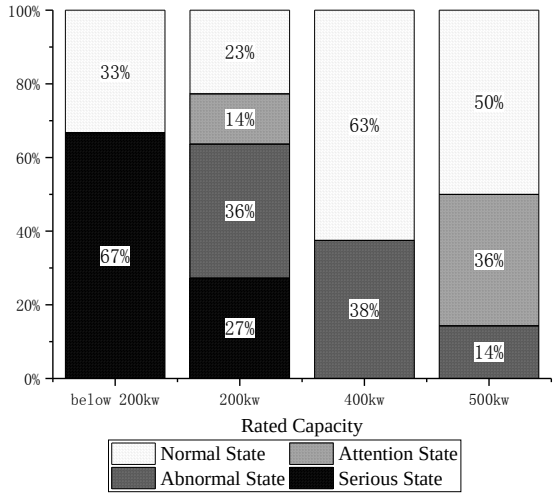

Figure 3. State grade ratio of power supply vehicles of different rated output power.

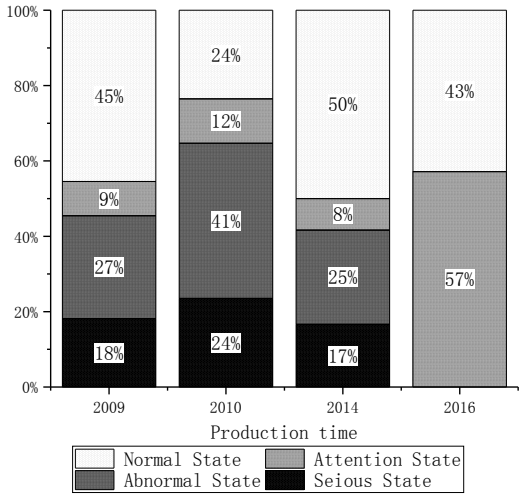

Figure 4. State grade ratio of power supply vehicles of different production data.

Influence of Different Production Time. According to the different production time of diesel power supply vehicles, diesel power supply vehicles are divided into four grades in 2009, 2010, 2014 and 2016. The 2009 grade includes 10 power supply vehicles produced in 2009 and 1 power supply vehicle produced in 2001, totaling 11 units. The 2010 grade includes 17 power vehicles produced in 2010. The 2014 grade includes 11 power supply vehicles produced in 2014 and 1 power supply vehicle produced in 2012, totaling 12 units. The 2016 grade includes 5 power vehicles produced in 2016 and 2 power vehicles produced in 2015, totaling 7.

As shown in Fig. 4, the state grades of diesel engine power supply vehicles with different production times account for four vertical bars representing different production times respectively, and the proportion of different colors in the vertical bars represents the proportion of four state grades in the power supply vehicles with the same production time. As can be seen from the figure, generally speaking, the power supply vehicles with lower production time are in better condition, and all the power supply vehicles produced in 2016 are in normal state and attention state. The proportion of the four states of the power supply vehicle in 2014 is basically the same as that of the power supply vehicle in 2009, which is about 50% in normal state, 10% in attention state, 25% in abnormal state and 15% in serious state. In 2010, the overall condition deterioration of power supply vehicles was the most serious, with the highest proportion of serious condition and abnormal condition, accounting for 23.5% and 41.2% respectively.

Conclusion

This paper presents a state assessment method of electric emergency diesel engine power supply vehicle. The method is based on the performance test results of the power supply vehicle, and points are scored according to the importance and deterioration degree of each state quantity. Through the scoring results, the state of the power supply vehicle is evaluated and the maintenance of the power supply vehicle is guided.

This method is used to evaluate the state of 47 power supply vehicles, and the following conclusions and suggestions are obtained:

(1) Diesel engine power supply vehicles with short production time and short service time are usually better than those with earlier production time, and the power supply vehicles with normal state or attention state account for a relatively large proportion;

(2) Diesel engine power supply vehicles with higher rated capacity, such as 400kW ~ 500kW power supply vehicles, are usually better than power supply vehicles with lower rated capacity, and there are fewer serious states;

(3) With the increase of service time, the transient performance of diesel-powered vehicles deteriorates most significantly, and the continuous operation performance and steady-state performance also deteriorate significantly.

(4) According to the results of performance testing and state assessment, there are many poor states of the existing diesel engine power supply vehicles, and the testing and maintenance efforts should be strengthened. In particular, attention should be paid to the power supply vehicles with long service time and small rated capacity, so as to slow down the deterioration speed of the power supply vehicles with service time and improve the stability of the performance of the power supply vehicles.

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