THE ELECTRIC VEHICLE IN TERMS OF RELIABILITY

Alina Daniela Handra, *University of Petrosani, Petrosani, ROMANIA*
Dragos Pasculescu , *University of Petrosani, Petrosani, ROMANIA*
Florin Gabriel Popescu, *University of Petrosani, Petrosani, ROMANIA*

ABSTRACT: The present paper aims to analyze various aspects of the electric car reliability. Elements such as generalities and scientific research will be explored during the study, and also elements connected to the electric vehicle reliability, methods to prevent the reliability in the process of designing and producing the electric vehicles. Another important component of the paper is represented by the case study, which consists in assessing and comparing the reliability between an electric vehicle and a mechanical one. In order to elaborate this case study, I chose the following vehicles: Renault Zoe (electric) and Renault Kadjar (mechanical).

KEY WORDS: reliability, electric vehicle, mechanical vehicle.

1. INTRODUCTION

The electric vehicle is a vehicle with zero emissions, powered by an electric engine, charged from an electric source, usually an electric car battery or a super-capacitor. The vehicles operate by repeated charging of a battery, similarly to the process of recharging a mobile phone. There are also electric vehicles with mechanics explained through the conversion of the hydrogen gas into electricity. Not all the electric vehicles (or "EV") operate in the same way. The hybrid vehicles operate based on a petrol or diesel-fuelled engine and also with an electric engine: the latter is powered by a battery that can be charged by connecting it to the electric station [4,5,7].

2. THE RELIABILITY OF THE ELECTRIC VEHICLES

2.1. Generalities

Theoretically, an electric vehicle is more reliable than a hybrid one or than a vehicle that has only a combustion engine. The electric engine, through its construction and demonstrated physical principles, has a five times longer lifespan than a combustion engine. Though, the practice demonstrates differently. Elon Musk, the Tesla founder, the one who launched the first large series electric vehicle, was promising that his engines will last between a minimum of one million kilometres and a maximum of ten millions km. In real life, no owner of Tesla vehicles went beyond 300.000 kilometres without changing its engine. Renault Zoe and other electric vehicles have not managed yet to exceed the barrier of 400.000 kilometres without changing the original engine with a new one. For a regular user this would not be a problem, because maybe they do not reach this kilometres number with their own car in ten or more years. There is a big problem for those who drive it for many kilometres or do not have money for a new vehicle and buy a second one. For example, a taxi driver drives minimum 50.000 km every year, and the delivery persons or the ones from distribution sometimes go beyond 80.000 km per year [1,10,11].

2.2. Scientific research

The reliability is one of the main quality indicators of any technical device. The reliability of an electric vehicle is the property of a vehicle to meet the specified functions, keeping in time the values of the operational indicators established in the limits that are specified, adequate to the ways and conditions of use, maintenance, repair, storage and transport. The reliability is a complex property which, according to the purpose of the vehicle and to its operating conditions, can include reliability, durability, maintenance and maintainability. When the reliability is calculated, a structural diagram of the electric vehicle reliability is elaborated; the main operational factors that affect the reliability are identified and quantified. The structural diagram includes the main components of the vehicle, components that are prone to malfunctions. See the figure 1.

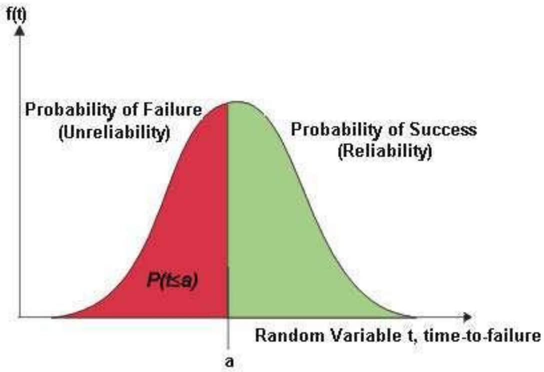

Figure 1. The structural diagram when the reliability of an electric vehicle

For example, for the asynchronous engines, such units are the winding and bearing assembly of the stator, for machineries with direct current- the windings: reinforcement, excitation, auxiliary poles, compensation, and for synchronous vehicles, these are the stator and field windings, slip rings assemblies and bearing assemblies. If the probability of no flaw operation of the individual nodes is near to the unit, these nodes are not taken into account in the structural diagram when the reliability of an electric vehicle is calculated [2,3,12,14].

The analysis of the failure causes in different types of electric vehicles provides the following information on the malfunctions distribution among the individual nodes:

Induction engines: In most of the cases (85 - 95%), the failures of the asynchronous engines, with a power higher than 5 kW, occur due to the failures of the windings and they are distribute as follows: closures between turns - 93%, the breakdown of the insulation interface - 5%. The bearing assembly represents 5-8% of the malfunctions and a small percentage is associated with reasons such as the lead heads opening, the spindle twisting, the rotor rods breaking etc.

The synchronous vehicles. The stator of these vehicles is the weakest node in terms of reliability. In the same time, the stator winding isolator represents 2,26% from the malfunctions and 3,67%, for fusing - 0,34 and 0,92%, for the deterioration of the active stator steel - 0,15 and respectively 0,64 %.

Direct current vehicles. The largest part of failures in these vehicles occur in the collector-brush and bearing assemblies. According to the operational statistics, on average, approximately 25% of the vehicle failures occur due to the collectors that malfunction. Another serious reason is the occurrence of a circular fire. The failure rate for this reason is 70% [8,13].

3. METHODS OF PREDICTING THE ELECTRIC VEHICLES RELIABILITY

Currently, in different fields of science and technology, there are numerous methods to predict the reliability indicators which differ in all the tasks to be solved and the characteristics of the mathematical apparatus that is used. Depending on the amount of information used in the prognosis, these methods can be divided in three groups:

- Experts evaluation methods used in the cases when there is no reliable information on the object and data about the changes in its condition while operating;
- Methods based on extrapolation and used in those cases when there are sufficiently complete data but the general laws of the changes in the object condition during operation are not known;
- Modelling methods, used when there is a sufficient quantity of statistic data regarding the changes of the similar object condition during operation.

Currently, the methods of the second group are mostly used in predicting the technical condition of the objects. The basis for predicting the technical condition from these methods is the analytical prognosis, in which, according to a multidimensional state vector S (s1, s2, ..., sn) or diagnostic signals X (x1, x2, ..., xm), determined or measured on the moment t1, t2, ..., ti, ..., tk, it is necessary to determine their values on the subsequent instantaneous moments tj (j = k + 1, ..., k + l). When methods for calculating the reliability of an electric vehicle are developed, one of the important steps is to create a reliability mathematical model for each node included in the structural diagram. The failures are random events, therefore, in order to build a reliability mathematical model, the probability theory and mathematical statistics are used [6].

When a mathematical model is compiled for electric vehicle reliability, the entire electric vehicle can be considered a product. In this case, the model is complex enough. Another way can be used, considering each unit as a product in the structural reliability scheme (inter-turn insulation, insulation of the casing and the interphases, bearing units etc.). Then, for each node, a mathematical model is elaborated and, based on it, a methodology to calculate the node reliability. After calculating the reliability of the main components and knowing a structural diagram on how (in parallel or sequential in terms of reliability) these components are interconnected, it is possible to calculate the reliability of an electric vehicle.

Integrating the reliability in designing and manufacturing the electric vehicles, in contrast to the radio electronics and automation devices, only in rare cases allow an increase in the reliability due to circuits design. Even if choosing the type and the scheme for the winding, the number of channels, the conductors in the groove, etc., it exercises some influence on the vehicle properties in terms of reliability and durability. However, the main way of these properties is improving the design and manufacturing quality. The design flaws are reflected firstly in the longevity, while the technological flaws are reflected in the intensity of the sudden failures and running-in malfunctions [9].

Ensuring the vehicle necessary characteristics is the main task of the design. When they are solved, a preliminary evaluation must be done for the structural reliability of the vehicle. It is advisable to be performed in three stages:

- In the first stage, the calculation and the comparison of the reliability indicators are selected, for different versions of the vehicle, and the optimal version from all points of view. In this stage, for the calculation, it is not yet necessary to know the exact values of the reliability indicators for the individual elements of the vehicles because only a comparative evaluation is performed for the options taken into consideration.
- In the second stage, an in-depth study is performed for the reliability of the selected option in order to ensure that the specified conditions are met. In this case, it is already necessary to know the

exact value of the elements reliability indicators. The modern manufacturing of the electric vehicles is mostly in series, which confers to each series a significant degree of similarity and facilitates the extrapolation of the reliability indicators to the new tests. The providers must issue reliability quantitative indicators for the components.

- The third stage of the reliability control assumes testing the prototypes and comparing the results with the calculated values. In practice, this stage is possible only for the vehicles with reduced power, because the reliability tests of the big vehicles are inacceptable for economic reasons. The results of the calculations and of the tests allow performing the adjustment adequate to designing, the materials and the winding data of the vehicle final version.

The most important means to increase the reliability of an electric vehicle is to simplify its design and to use high quality active and structural materials for manufacturing it.

In the same time, it is necessary to ensure maintaining other technical and operational indicators at an adequate level: specific consume of active and structural materials (on unit power), minimum dimensions and costs. These requirements are in contradiction with the conditions for choosing the funds for increasing the reliability. Therefore, when designing, a detailed analysis of all the measures is needed, to obtain the wanted reliability for the minimum weigh vehicle and the general performances and also the corresponding starting and operating characteristics.

In other words, in the process of designing and manufacturing an electric vehicle it is necessary to make efforts in meeting the following basic requirements:

- Maximum simplification of the vehicle designing as a whole and also its components and parts;
- Selection of the electromagnetic charges, taking into account the requirements for obtaining a given reliability, and also ensuring the minimum weight and sizes;
- Reduction of the vehicle operating temperature by applying, if necessary and possible, adequate means to cool it;
- Elimination of the vehicle vibrations in the interval of the operating rotation speed by selecting the corresponding sizes of the casing and of other pieces and the careful equilibration of the rotor;
- Using high quality active and structural materials to produce a car, especially for insulating the heat proof casing and the winding wires;
- Improving the vehicle manufacturing technology, with proper organization of the operational control for its individual parts and for the assembly process;
- Testing thoroughly the prototypes in order to comply with the technical and reliability requirements;
- Elaborating the technical conditions, the installation, repair and operating rules and instructions.

4. CASE STUDY. THE ELECTRIC VEHICLE VS THE MECHANICAL VEHICLE

What should we choose: the electric vehicle or the mechanical one? What are their advantages and the disadvantages?

The same company can produce, depending on the market requirements, both electrical and mechanical vehicles. Below, we analyze Renault Kadjar (mechanical), see figure 2 and Renault Zoe (electric) vehicles in figure 3.

Price. The electrical vehicle is friendlier with everyone's budget than a combustion vehicle, if we do not take into account the purchase price. Even if the initial price of the electric vehicle is higher, for example the price of Renault Zoe is 27000 €, and the price of Renault Kadjar is 16500 €, we must take into account that the maintenance of a vehicle on internal combustion costs a fortune, if we calculate only the money for the petrol/diesel and for the RCA (Civil Auto Liability), while the public charge for the electric cars is free for now. Another important aspect is the electric vehicles exemption from pollution taxes.

Figure 2. Renault Kadjar

Figure 3. Renault Zoe

Energy. The electric vehicles reduce to minimum the wasted energy, stopping the vehicle engine when it is no longer registered to be in motion (function stop-start) and charging the battery while braking (regenerative braking). The electric engines are also more efficient from energetic point of view than the petrol or diesel engines.

Autonomy. Fully charged, most batteries offer an autonomy ranging between 100 and 150 km, in the limits of the most population daily requirements. The increasing number of the public charging stations and recharging points from work offer a supplementary charging capacity. Renault Zoe offers 300 km autonomy, a very high one compared to other electric vehicles and a small one compared to the 965 km autonomy of Renault Kadjar.

Torque. The electric engines generate almost instantaneous torque, while the torque of the internal combustion engines increases in tandem with the engine rotation (RPM). This means that the BEVs have an extremely rapid acceleration and a sensation of an agile vehicle compared to the conventional vehicles.

Battery/engine lifespan. Depending on the battery charging/discharging, the lifespan can vary from 5-6 years up to 13 – 15 years. This value is very small, compared to the fact that a 10 year old second hand car can be a very good purchase.

Powering. Powering the electric car is totally different from powering a petrol car. Generally, it is more convenient to charge an electric vehicle – when you get home, you will spend 2-3 seconds connecting it to an electric source and in the next day you will spend another 2-3 seconds to disconnect it from the current source, when you are ready to drive again. 95% from the total charges of the electric vehicles is performed at home and there are some common ways to charge them at home.

Pollution. In what regards the impact on the environment and the CO2 and other pollutants emissions, the electric vehicle offers a better performance today than any other available alternative and it is the sole technology that offers the total elimination of the local nitric oxide (NOx) emissions and suspended powders (PM) while being used.

5. CONCLUSION

In conclusion, the advantages of the electric vehicles are numerous. They are silent and perfectly adapt to the urban environment, given the fact that the battery gets charged when braking, and the traffic from the cities gives the drivers even too many occasions to slow down. As the infrastructure of the charging stations will develop, the owners of electric vehicles will have higher and higher freedom of movement, which will allow them to cross the country without worries. The maintenance costs of an EV are smaller than those of a traditional vehicle with internal combustion. In contrast to a traditional engine, an electric engine does not have moving components, consumed during use, nor liquids which necessitate the replacement, and, therefore, it is cheaper and easier to maintain. Due to the energy recovery systems in the deceleration phase, the brake pad wear is also reduced. Moreover, considering that the battery lifespan is equal with the one of the car, this does not necessitate maintenance.

REFERENCES

[1] Buica G., Dobra R., Pasculescu D., Tătar A., Leakage Current Measurement of Protective Equipment Ingulating Materials used in Electrical Installations, IOP Conf. Series: Materials Science and Engineering, 2016.

[2] Buica G., Antonov A.E., Beiu C., Pasculescu D., Dobra R., Occupational health and safety management in construction sector – the cost of work accidents, Quality-Access to Success, Volume 18, Issue S1, pp. 35-40, 2017.

[3] Dobra R., Buica G., Pasculescu D., Leba M., Safety Management Diagnostic Method Regarding Work Cost Accidents from Electrical Power Installations, Proceedings of the 1st International Conference on Industrial and Manufacturing Technologies, 2013.

[4] Handra A.D., Ciotor N.R., Eficienta energetica, Analele Universităţii "Constantin Brâncuşi" din Târgu Jiu, Seria Inginerie 3, pag.325-330, Târgu Jiu, 2009.

[5] Marcu M., Popescu F. G., Slusariuc R., Arad S., Handra A.D., Overview of control methods for induction motor drives, Annals of University of Petrosani, Electrical Engineering, Vol. 19, pp.57-64, Petroşani, 2018.

[6] Pasculescu D., Romanescu A., Pasculescu V., Tatar A., Fotau I., Vajai Ghe., Presentation and simulation of a modern distance protection from national energy system, Proceedings of the 10 th International Conference on Environment and Electrical Engineering – EEEIC 2011, Rome, Italy, pp. 646-650, 2011.

[7] Popescu F.G., Slusariuc R., Uţu I., Maşini şi acţionări electrice -lucrări de laborator, Editura Universitas, Petroșani, 2017.

[8] Popescu F. G., Pasculescu D., Marcu M., Niculescu T., Handra A. D., The technical and economic advantages of power factor correction, Annals of University of Petrosani, Electrical Engineering, Vol. 21, Petroşani, 2019, ISSN 1454-8518, Ed. Universitas, EBSCO, pp.35-42.

[9] Stochitoiu M.D., Marcu M., Utu I., Niculescu T., Popescu F.G., Modern concepts and its application for energetically security requirements at different connected sources, 18th International multidisciplinary Scientific Geoconference SGEM 2018 Conference Proceedings, Vol. 18- Informatics, Geoinformatics and Remote sensing, Albena, Bulgaria, pp. 591-596, 2018.

[10] Stochitoiu M.D., Handra A. Intelligent solutions for sustainability of power systems, Annals of Electrical Engineering, ISSN 1454-8518, vol.XX, 2018, pg.99-103.

[11] Uţu, I., Păsculescu, D., Power Quality Study in Order to Comply with

European Norms. Publicat in Revista Calitatea, Supplement of "Quality - Access to Success" Journal, Vol.18, S1, January 2017, ISSN 1582-2559, pp. 366-371.

[12] https://www.larevueautomobile.com/Fiche-Technique-Auto/autonomie/renault_kadjar

[13] https://renault.md/cars/KADJAR_nou/Overview.html

[14] https://www.promotor.ro/masini-noi/dosar-analize/sa-intelegem-mai-bine-fiabilitatea-masinilor-12105820