MAINTENANCE OF HYBRID VEHICLES

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Abstract: This paper at the begining presents the basic concepts of the different conceptual solutions for hybrid and electric vehicles, primarily in terms of their transmissions. From now on, there are certain observations concerning the reliability of these vehicles, taking into account that this area has not been explored to the extent as it is the case with conventional vehicles (with IC engine).

With the development of modern diagnostic methods, a special place takes telediagnostic, as an area that offers huge advantages in quality and timely diagnosis of all processes on hybrid and electric vehicles and provides excellent input parameters to optimize the maintenance system.

Finally, a serious approach to the optimization of the maintenance system of modern hybrid and electric vehicles could not be imagined without the combination of "soft" computing, i.e. fuzzy logic, classical reliability theory vehicles and newly developed diagnostic methods.

This approach of the system of maintenance increases the quality of the exploitation, increases availability and reduces the overall lifecycle costs of hybrid and electric vehicles.

Keywords: hybrid and electric vehicles, maintenance, transmission, reliability, diagnosis, fuzzy logic.

1. INTRODUCTION

Hybrid vehicles fall into vehicles with low emission (Low Emission Vehicles). They have been based on two sources of energy - aggregate energy conversion (combustion engine or fuel cell) and the aggregate accumulation of energy produced (batteries or ultracapacitors). Complete drive system comprises: engine with internal combustion, electric generator, electric motor, power converter and the battery pack [1].

There are two basic configurations of hybrid vehicles: serial and parallel. In addition there is a serial - parallel configuration of a hybrid vehicle, resulting from efforts to consolidate good characteristics and serial and parallel configurations of hybrid vehicles.

From the very complexity of the structure of different concepts for hybrid vehicles arises the need to consider the reliability of these types of vehicles, both in terms of organization and in terms of maintenance technologies.

A prerequisite for a quality review of the maintenance of any technical systems, particularly hybrid vehicles as a very complex technical system, the understanding and study of the reliability of individual components, aggregates and systems for hybrid vehicles, and the vehicles themselves as a whole.

Using fuzzy logic gives a special dimension to the consideration of the maintenance of hybrid vehicles given its advantages: ease of understanding, flexibility, tolerance of imprecise data, the possibility of modeling nonlinear functions, the ability to describe and expert basing on natural language [2], [3].

In examining the reliability of hybrid vehicles, as well as special, but also an inseparable segment, there is a diagnostics and hybrid vehicles, especially bearing in mind all the sophisticated diagnostic methods and new concepts for their application, with even remote sensing certain parameters, using the expert insight of the technical condition of the hybrid vehicle in telediagnostic centers [3].

2. RELIABILITY OF HYBRID VEHICLES

The most of the scientific and popular articles and studies based on hybrid and electric vehicles have been focused on the control of electric drives applied and components of the hybrid and electric vehicles.

However, very little has been written about the issue of the overall reliability of hybrid and electric vehicles as a transport system. This question is not trivial, and overall acceptability and availability of these vehicles in the long term, will significantly depend on the issue despite the

present fuel consumption and additional costs, that are not present on conventional vehicles. In studying the same reliability of hybrid and electric vehicles, it must be emphasized the fact that these vehicles are not just a combination of many types of machinery and systems for management and control, in order to provide better fuel economy, but there are a lot of things that must be considered in all its complexity.

For a discussion of the reliability of hybrid and electric vehicles is necessary to recall the definition of reliability as the probability that the component, subsystem and system functional, that is, to perform its dedicated function at the end of a certain period of time, without any changes or probability of performing maintenance activities in a given time period. Thus, the reliability associated with both the probability and the time span. In addition, it is necessary to define the notion of availability, that has been taken hypothetical system with reliability equal to 1 (the highest possible reliability). For such a system can be said to be "fully" available.
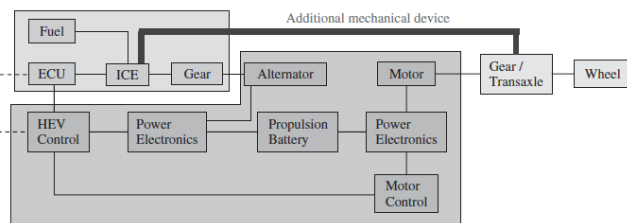
Studying the overall reliability can best be accomplished display of individual operating modes using block diagrams, just as shown in Figure 1 [4].
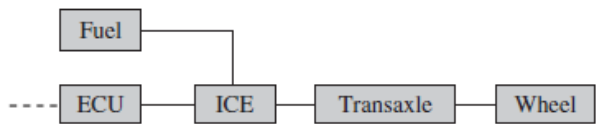
a) conventional vehicle with internal combustion engine
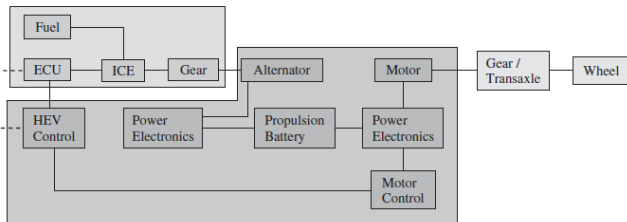
b) hybrid vehicle with a serial drive

c) hybrid vehicle with a parallel drive

*ECU – Electronic Control Unit
 ICE – Internal Combustion Engine
 HEV – Hybrid Electric Vehicles

Figure 1 - The system block diagram for a) conventional vehicle with internal combustion engine, b) hybrid vehicle with a serial drive and c) hybrid vehicle with a parallel drive

By reviewing diagrams can come to certain conclusions. For example, if the electric motor in a parallel hybrid vehicle is defective, it can still operate the vehicle engine at a specified engine and continue driving along the lower operating performance.

If there is a failure of internal combustion engine, hybrid vehicle with a parallel drive can run an electric actuator, but only as long as it enables the battery to power the electric motor. Then only has been needed to connect the battery hybrid vehicle batteries or make correction subsystem vehicles with internal combustion engine in order to provide additional battery charging while driving. Here in particular must take into account the fact that it may not allow the level of the battery voltage falls below the permissible value in order to prevent damage to the battery [4], [5].

A similar analysis can be carried out for a hybrid vehicle with standard drive, with the final analysis of the observed outcomes can be summarized by the chart shown in Figure 2.
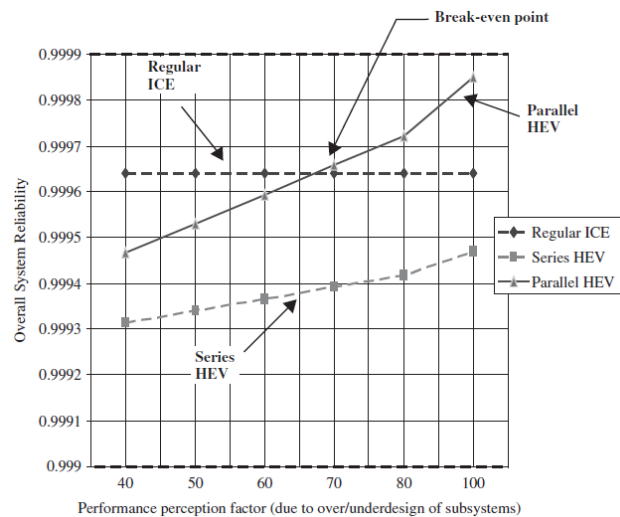

Figure 2 - Diagram for determining the reliability of vehicles from the available factors of performance, expressed as a percentage of the individual concepts of classical (only with internal combustion engine) and hybrid drive vehicles (parallel and serial) [5].

The graph in Figure 2, as well as from earlier considerations, it is clear that the overall reliability of mass-produced hybrid vehicle is much lower than the overall reliability of a parallel hybrid vehicle. On the other hand reliability to serial, and parallel hybrid vehicle in most of the observed range lower than the reliability provided by the vehicle with conventional drive, i.e. exclusive internal combustion engine. This is conditioned by the fact that conventional vehicle with internal combustion engine has fewer components and therefore initially it has the advantage in terms of reliability [5].

The basic idea of the design of a parallel hybrid vehicle that is how the engine combustion, and electric drive dimensioned with lower installed power and torque respectively, than it takes to drive a hybrid vehicle as a whole, because it takes the assumption that both the maximum, so and the optimal vehicle performance

achieved in simultaneous operation and combustion engines and electric drive. Hence when an engine malfunctions or electric drive occurs loss of performance of the hybrid vehicle. If the designer or the user requires better performance of hybrid vehicles and in particular the cancellation of one or the other of the drive system, the design must go to a certain degree with oversize engine combustion or electric drive.

3. DIAGNOSIS OF HYBRID VEHICLES

Each vehicle, whether conventional, hybrid or purely electric vehicle should possess some sort of diagnostics (system or individual components to find the cause of the problem that has already emerged in the vehicle) and to provide adequate forecasts (finds problems that can possibly happen in the future), given the current state of the vehicle based on the monitoring of different information on it [6].

With this in mind, we have a modern vehicle diagnostic functions on the dashboard, where you can read the individual parameters of diagnosis, but not provide forecasts. The diagnostics may be on several levels. One is at the level of the vehicle within the vehicle, and provides information to the driver or service on what would happen to the vehicle. The second level of the diagnosis can be at a somewhat higher level of maintenance when the vehicle can be broken down into different sub-systems in the service, with the identification of problems and the eventual replacement of the defective part (assembly). Third level diagnostics can be on level of car dealer or possibly a vehicle manufacturer, to determine the reasons why part (circuit) is not performed its function. Finally, the diagnosis can be at the level of components or subcomponents when along with the more microscopic analysis of components can be determined a deficiency in the production, design, or other defects, if any. On the second level of maintenance is usually the replacement / repair of part or subsystem, without necessarily finding the cause of the malfunction. The third and last level of diagnostics can analyze the underlying cause malfunction due to design or manufacturing defects. Sometimes it can be due to the failure of individual components of the structure or inadequate materials and components, or due to misuse, or improper use of the device by the user. In these cases, in addition to the latter, modifications or changes to the system or subsystem will have to make the vehicle manufacturer [6].

Telediagnostic (remote diagnostics) is part of the technical diagnostics, i.e. its most advanced segment, which applies information and communication technologies for remote monitoring of technical systems with a certain accuracy at a given time. It deals with all aspects of technical communication between spatially distant technical systems and refers to the technique of transferring data at a distance [7].
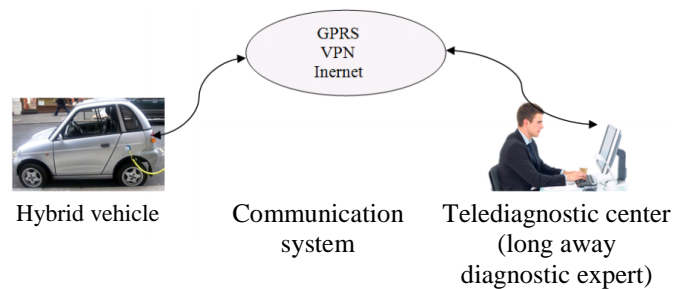
The need to develop a model telediagnostics hybrid vehicles were due to the current repair of vehicles have more experience with the maintenance of hybrid vehicles primarily drive system (batteries, electric motors, etc.).

This method of diagnosis contributed to significant increase in the level of reliability of hybrid vehicles and facilitate the maintenance of obtaining accurate data on the stock of vehicles, which would be achieved by continuous monitoring of the status of hybrid vehicles.

This would be some maintenance activities hybrid vehicles decreased (to perform repairs only the damaged parts of the vehicle) and able to plan ahead. Then reduce the likelihood of accidents on the vehicle, which could cause overheating batteries and the like. So to speak, manufacturers of hybrid vehicles could spot the parts that are subject to layoffs and improve their structure. Telediagnostic would be particularly suited to vehicles that annually realized a large number of kilometers [8].

Model telediagnostics hybrid vehicles based on the measurement and analysis of multiple diagnostic size, whose general concepts shown in Figure 3, would consist of three parts:

• remote hybrid vehicle (whose status wants to remotely monitor) with built-in sensors and measuring systems,

• communication system,

• two telediagnostic centers (centralized location where data is stored and analyzed), one would be at an authorized service of such vehicles, and the other with the manufacturer of hybrid vehicles.

Hybrid vehicle   Communication   Telediagnostic center
                              system   (long away
                                                    diagnostic expert)

*GPRS - General Packet Radio Service

VPN - Virtual Private Network

Figure 3 – General concept of model telediagnostics hybrid vehicles [7]

Hybrid vehicles would be connected with servers telediagnostic centers through mobile wireless Internet. The telediagnostics process (remote monitoring diagnostic parameters) hybrid vehicles would consist of several phases, such as:

▪ the continuous remote monitoring (monitoring) and the constituents of the diagnostic parameter vital vehicle components,

▪ the analysis of data to identify trends (trending),

▪ the comparison of the parameters of the known or anticipated parameters,

▪ the early warning of the possible occurrence of failure, after detecting declining performance, predicting the moment of cancellation by extrapolation,

- the identification of failures and

- the maintenance plan, when it is really necessary, timed to prevent the cancellation or delay.

Telediagnostics system (remote condition monitoring) hybrid vehicles would have to meet the following criteria:

- transparency (to provide a complete picture of the state of the vehicle and delivers timely information on the current state of the vehicle),

- the openness of the (possibility of integration into other systems, i.e. the ability to exchange information with systems that work on other protocols) and

- the scalability (the ability to upgrade with minimal cost, and that the functionality of the system at the same time preserve).

Tasks of continuous telediagnosis (remote monitoring of the situation in real time) would be:

- the detection of failures in the initial phase of development (creation), in order to rise to their level of confidence,

- the classification of development cancellation,

- the modeling and monitoring of degradation by modeling reliability,

- prediction of the remaining useful life of the hybrid vehicle with a high degree of security,

- the prediction of system failure:

  - the failure of which may be the street to the safety of people and vehicles,

  - the failure of which could lead to failure of the vehicle,

  - the failure of which may affect on the level of the reliability,

  - cancellation can reduce the degree of functionality of the vehicle,

  - those reliability is not enough time tested in real conditions of exploitation,

  - those are extremely expensive (eg. Battery),

  - those service life is relatively short.

The practical application of this model telediagnostics would allow insight into the state of hybrid vehicles in real-time monitoring and analysis of the results by:

- diagnostic expert in telediagnostic authorized service center for hybrid vehicles,

- diagnostic experts in tele diagnostic center manufacturers of hybrid vehicles.

Thus, the practical application of this model teledagnostics allow an increase in the level of reliability and availability of hybrid vehicles, reducing maintenance costs and extending their lifespan. Preventive maintenance activities to be carried out depending on the state of the hybrid vehicle [7].

The benefits of these models diagnostics would have had only the owners, but also manufacturers of hybrid vehicles, because they could determine the causes of the failure of batteries and their relatively short working life. That could contribute to the improvement of production technology batteries, which would extend their service life, improved features and to reduce the price. This would contribute to wider use of hybrid vehicles and thus reduce the consumption of fossil fuels and emissions of greenhouse gases.

4. OPTIMIZATION OF THE MAINTENANCE SYSTEM

Maintenance of technical systems can be implemented in several variants, according to several strategies, with greater or lesser differences in the basic characteristics of individual solutions. As soon as there are multiple versions, the question is which to choose, or which is the best. The answer to this question, in principle, is not easy, so when choosing maintenance strategies should take account of the following two major reasons:

• each variant maintenance strategy causes certain effects, some certainty, costs and other characteristics of the system maintenance, so therefore the output characteristics of the system for each variant must be expressed clearly and quantitatively;

• comparison of different variants of the strategy is a multicriteria problem (certainty, cost, etc.), Who successfully solved only if they are clearly identified all the important requirements and constraints, and the objective function that is observed.

Selection of the optimum defined criteria and defined limits of the direct task of optimization. It is not enough to determine the optimal strategy, it is necessary to explain which criteria and what limitations it is the best solution on the basis of which the estimate is made [9].

Optimization system maintenance can be done in different ways. It is optimizes the model of the simplified scheme of the process, and not the physical essence of maintenance, as the stochastic processes. Analysis and optimization of system maintenance can be carried out using:

- mathematical models,

- empirical - heuristic model.

Analysis and optimization of the maintenance system by using the mathematical model provides the following [10]:

• provides opportunities to observe the technical system as a whole, as an entity, and simulation and other techniques to define the impact of variable parameters,

• allows comparison of several possible variants,

• facilitates the detection of links between certain influential parameters not previously observed or that can be set up verbal and experiential methods,

• indicates the information to be provided in order to carry out the necessary analyzes,

• facilitates the prediction of future conditions or events, with the risk assessment or confidence limits.

On the other hand, empirical - heuristic model provides the following [10]:

• include the factors that can not be included in the mathematical model, which can not be analytically unambiguously linked to other factors,

• allow analysis of subjective and other factors which can not be described analytically.

A special form of hybrid vehicle maintenance optimization is achieved by using fuzzy logic. According to Professor of Computer Science at the University of California at Berkeley, Lotfi Zadeh (founder of fuzzy logic), fuzzy logic can have two different meanings in a broader sense, fuzzy logic is synonymous with the theory of fuzzy sets, which refers to objects with unclear borders whose affiliation extent certain degree, while in the narrow sense, fuzzy logic is a logical system that is an extension of classical logic. The essence of fuzzy logic is very different from the so-called traditional logic [2].

Fuzzy logic uses the principle of incompatibility, which means the effort to increase the vagueness of the statement takes on its relevance. Fuzzy logic is logic that allows multivaluable medium defined between traditional attitudes: true - false, yes - no, black - white, etc. Fuzzy logic uses the experience of experts in the form of linguistic if - then rules, a mechanism of approximate reasoning (Figure 4) is used as a control for the specific case. A key aspect of the application of fuzzy logic is to develop a theory which formalizes everyday informal opinion that it could be, as such, is used to program a computer.
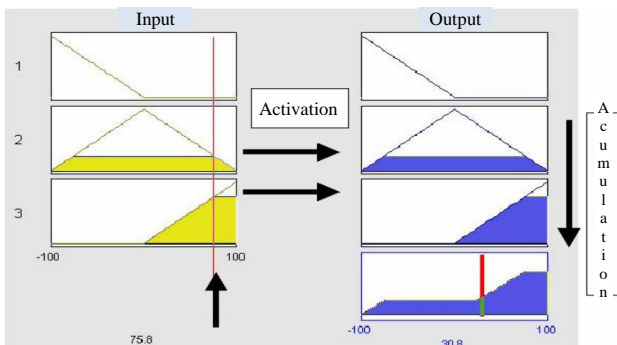

Figure 4 - Graphic process approximate reasoning [2]

Fuzzy controller is a central part of the operating hybrid vehicles. Phase controller can be implemented using a program that is running on a personal computer and is connected with the process in the usual way, as in the case of classical management. In this case, the phase controller is used for intelligent management, so that the knowledge of experts - the operator benefits in the management process. Of course, when necessary, the fuzzy controller can be incorporated in the form of the microprocessor in the small devices [11].

Possibilities of application of fuzzy logic are great. Some examples of fuzzy controller on motor vehicles in Japan and Korea, countries that are leading in practical applications of the technology phase [11]:

- fuzzy brakes (Nissan): manages breaks in dangerous situations based on the speed and acceleration of the vehicle and based on the speed and acceleration of the wheels,

- engine vehicles (NOK, Nissan): manages the fuel injection and ignition depending on the condition of the valve for supplying fuel flow (volume) of oxygen, temperature of cooling water, the number of revolutions per minute, the volume of fuel, the angle of the crankshaft, engine vibration and pressure in suction part of engine;

- the transmission system in the vehicle (Honda, Nissan, Subaru): select gear depending on engine load, driving style and road conditions;

- managing the movement of vehicles (Isuzu, Nissan, Mitsubishi): adjusts the valve status of fuel supply based on the speed and acceleration of the vehicle.

7. CONCLUSION

General observations that can be deduced by examining maintenance, diagnostics and reliability of hybrid and electric vehicles to hybrid vehicles compared to conventional vehicles provide much greater opportunities for the application of advanced methods and technologies to diagnose the condition. In addition, the reliability in terms of providing the basic functions of the vehicle higher in hybrid vehicles, because they have the possibility of transferring from one species to another drive in case of a malfunction, while the other side in terms of ensuring full safety of all system elements and hybrid vehicles are less reliable, primarily due to the complexity of transmission and application of a wide range of electronic components.

Due to the large number of possible architectures for hybrid and electric vehicles, the development of the next generation of vehicles will require increasingly advanced and innovative simulation which models must include the maintenance and servicing of vehicles. Whereby it must on mind that the complexity of the model does not mean at the same time the quality of the model, but the key feature of the model applied in addition to its quality and flexibility should be simplicity, which is sometimes crucial in terms of the model user, or whoever deals with preventive and corrective maintenance.

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