International Journal of Academic Research in Computer Engineering
Print ISSN: 2476-7638 and Online ISSN: 2538-2411
Vol. 2, No. 1, Pages. 17-23, May 2018

International Journal of Academic Research in Computer Engineering
Volume 2, Number 1, Pages 17-23, May 2018
www.ijarce.org
IJARCE

Predicting Software Reliability in Design for Controlling Hybrid Vehicles

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Receive Date 2017.03.11; Accepted Date: 2017.11.18, Published Date: 2018.05.15

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Abstract
Reliability of a system is associated with its probability as well as the various risk factors. The probability of a system is defined by its operation and maintenance, over a period of time, without making any proper changes. For the control system of hybrid vehicles that works on the vibrational and magnetic environment, high reliability must meet the executive and the security requirements of the entire system. Reliability of the substrate was noted from the various stages of designing, installation, and testing. In this paper, we reviewed the proposed methods for the designing a reliability model software. The software, in turn, would offer a hybrid vehicles controller. The error rate and the average time between failures, was obtained with the stress analysis. After the software was tested, the evaluation was performed with G–O, J–M, and Musa methods, and Littlewood-Verral model. Based on the analyses, suitable results were obtained that could be further used to reduce the consumables components and the average time between failures. White box and black box testing was performed for predicting the reliability of the software. Ultimately, the results were and the results of the simulation were referred in this paper. The proposed method could assist the manufacturers in achieving a reliable system.

Keywords: Control Circuitry, Ensuring Design, Error Rate, Hybrid Vehicles, Stress Analysis, Software Evaluation, and Software Testing.

1. Introduction

The core control system of a hybrid vehicle constitutes the vehicle management computer (VMC) platform. The task of vehicle control is responsible for the aggregation functions. In addition, it is also responsible for the other tasks, such as testing the management of equipment's and the vehicle's position, and navigation. The machine control system design ensures an excellent functioning, well performance, and high reliability of the VMC platform [1–4]. Plug in techniques [5–8] has been one of the most popular methods, using VMC, to improve the reliability and the security of the control system. Also, the fault monitoring devices (FMD), such as built-in test (BIT), are widely used in computer management system redundancy (RVMCS) for error detection [9]. Without loss of generality, assuming that FMD is able to correctly detect the system errors, it can be claimed that reliability and security of RVMCS is higher than VMC. Circuitry of the hybrid vehicles control is relatively complex. It is composed of various parts, and the functioning conditions are full of powerful vibrations and magnetic field. The circuit design is the key to the requirements of reliability, maintainability, and testability. Reliability is built, based on the general reliability diagrams and mathematical models. Reliability is the key to the designing of the reliable products, not only from a qualitative point of view but also from a low point of view. Reliability should be included in the schema research and the development stages of engineering system. Methods for prediction of the reliability of the control circuits were similar to that of the parts prediction methods, the prediction methods for estimation of the active units, predict-ion methods for the kinetic energy, the conversion methods, and the stress analysis. The methods used in this paper are as (1) parts count and (2) analysis of stress.

In other words, if the design was complete, and partial data for the components were calculated, then the stress analysis was done for prediction of the reliability of the components. Along with these hardware analysis, black box testing, white box testing, and regression testing was used to analyze the reliability of the software.

The structure of this paper is as follows: In Section 3, we discussed on the origin of the problem of reliability. Section 4 is devoted to the methods of predicting reliability. Section 5 includes hybrid vehicle control system components and functions that describe the block diagram. Section 6 is devoted to the proposed method to predict reliability. Section 7 and 8, represents data analysis and software reliability, respectively. We ultimately summarized in Section 9.

2. Related Work

A reliability prediction model for electric vehicles has been presented [10]. Compared with the part count method that determines the reliability of a system only based on the types and numbers of components used in the system, the model presented in this paper not only considers the thermal and electrical stresses, but also includes the effects of load variations related to driving behaviors and road conditions on the reliability of components since the model is based on the standard driving cycles. On the basis of the accurate reliability analysis, improvement in design of the powertrain, in control methods and in energy management strategies can be realized to further enhance the performances of vehicles and to reduce the operation and maintenance cost [11].

3. The Origin of the Reliability

The origin of reliability of the United States, during the world war II, took place with an evolving special body called AGREE, to solve the problems related to the reliability of the military radar, established in 1952. After this phase, Japan and many European countries, began their studies at this area in the early 60s, until the error was detected with the statistical tests mechanisms. The models based on the data of error detection and error reasons, were completed. Many of the test environment and accelerated test methods were established; a range of technologies, reliability, software, procedures, and standards were presented. Ultimately the reliability of the electronic equipment's was converted, from qualitative to quantitative. This is at first satellite of Iran by sending data from four years ago, more seriously followed. Reliability of the analysis had already occurred during the designing of the military equipment's such as radars, missiles, and military transport units. This way the networking was established for secure exchange of data, and research centers published the standards and manuals, at the scope of the software reliability.

4. Steps and Methods for Reliability Prediction

4.1. Prediction Method of Counting Pieces

Information about the prediction method was obtained by counting pieces of the type and number of the components, grade quality parts, and place deployment of the components. Equipment error rate can be described by calculated Equation (1):

$$\lambda = \sum_{i=1}^{m} N_i \lambda_c \pi_Q \qquad (1)$$

Where, λ is the total error rate of the equipment; λ_{ci} is the normal error rate, except I; π_{Qi} is the normal quality factor, except I; N_i is any number from the components, and m is the number of species of all components. This method assumed that the reliability of the equipment was calculated at the same environment, even if the operating environment was different, and the components have a separate calculation values. Ultimately the results were integrated.

4.2. Stress Analysis of the Components

The main requirements include:

(1) Detailed list of the components in the final design stage, (2) having statistics and conditions

of stress analysis, on the reliability of each component, in the circuit described user guide, in order to obtain the error rate component, and (3) calculate the error rate and the combined results of the equipment reliable model, to calculate the reliability of the equipment's.

Because of this approach, the type of environment, quality and various stress adjustment factors were taken into consideration. Also higher reliability is considered, so it can better reflect the reliability inherent equipment.

4.3. Predicted steps in Determination of Reliability

The predicted steps in determination of reliability can be summarized as follows:

(1) Setup a model of reliability, series of diagnostics, and parallel circuits ingredients, based on the capabilities of the device.
(2) Error rates calculated by the method of the component reliability, based on the different stages of the design work.
(3) The error rate to streamline component type Calculate.
(4) The error rate of the constituent components Calculate.
(5) The total error rate based on the reliability of their equipment Calculate.
(6) Mean time between failures were calculated, based on the relationship MTBF = 1/λ.

5. Block Diagram of the Control System of Hybrid Vehicles

5.1. Block Diagram of the Operation and Structure of the Control System:

The proposed control system for a vehicle included four consoles, they are as follows:

(a) Console (1): Input and output interface; also converts analog signals to digital, and vice versa.

(b) Console (2): Core of the control system, includes four ranges; the console is the task from processing data; sends and receives feedback information from the memory and the control.

(c) Console (3): Controls the feedback information and the power and the range that includes five phase electricity.

(d) Console (4): Semi–automatic control console is responsible.

The basic block diagram of the system reliability and the performance was analyzed in the block diagram. The block diagram in Figure 1 shows the status, roles, relationships, and functions of the various subsystems.

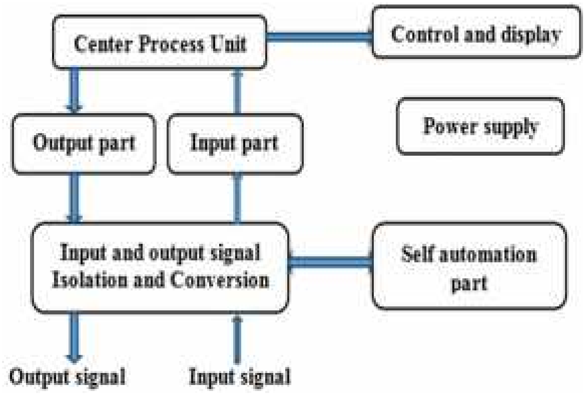

Figure 1. Block diagram of the control system operating the vehicle

5.2. The Block Diagram of the System Reliability:

The block diagram represents the logical reliable relationships (such as the reliability series of circuits, parallel, rates, reservations, etc.), between the various components of the system. The block diagram can be derived, based on the mathematical model of prediction of reliability. The proposal of the block diagram is shown in Figure 2.

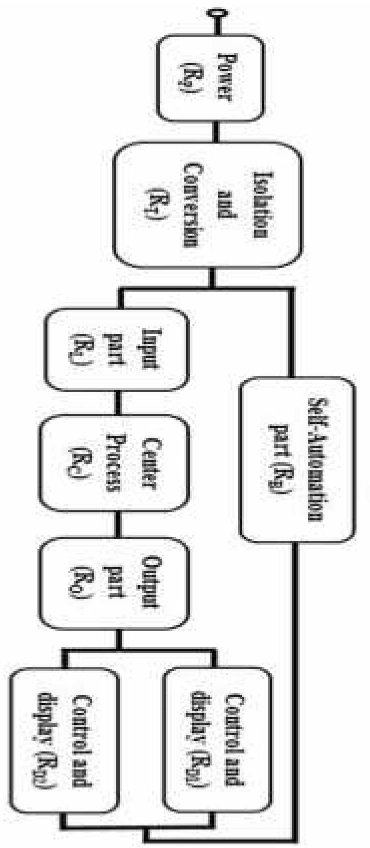

Figure 2. Block diagram of system reliability

Where, R_B is the console reliability, Rc is the mainframe reliability, R_O is the output signal reliability, R_I is the input signal reliability, R_D is the reliability of the display and the control department, R_T is the transmission reliability, R_P is the electricity source reliability, and R_S stands for the system reliability. Various probability distributions were used to model the reliability, out of which distributed Binomial, Poisson, and Gaussian methods were noted. In this study of the model of reliability, the exponential probability distribution of the electronic equipment's was calculated, and the mechanism of error was satisfied. The reliability was calculated from the equation (2).

$$R = e^{-\lambda} \quad (2)$$
$$R_E = R_{E1} + R_{E2} - R_{E1}R_{E2} \quad (3)$$
$$R_M = R_C R_I R_G R_E \quad (4)$$
$$R_S = R_P(R_M + R_B - R_M R_B)R_T \quad (5)$$

6. The Reliability of the Predicted

6.1. The Reliability Analysis of the Control Circuit:

The control circuit was installed in the vehicle with regular maintenance, against the errors, to be modified. Hybrid systems can be claimed for maintenance repair, without any change in the reliability. Based on the GJB / Z299B-98 manual [12], three types of condition applications were considered to be reliable. Analysis of stress components, the effect of factors such as electricity, heat, weather, and quality, of the parts, was considered. The stress analysis was used to analyze the reliability of the system. The stress and error rate data components from the analysis were based on the information in the hands, obtained from the manual GJB / Z299B-98. Job error rate could be calculated based on the working conditions, and the coefficients of the stress components. In fact, the total error rate was represented by PΣ λ. The different work modules listed on the error rate were calculated. In summary, discrete devices and integrated circuits (ICs), based on the differences in the error rates were calculated.

6.2. The Reliability of the Prediction based Vehicle Control System

Based on the requirements of the various projects, and with considering criteria of the reliability, maintenance, reparation, and testing can be stated as the average time between failures (MTBF) digit of 250 hours. By considering the stress analysis statistics on the system, error rate was calculated from the following equation:

$$\lambda_s = \sum_{i=1}^{n} N_i \lambda_{p} \quad (6)$$

Where, λ_s overall error rate, N_i number from pieces I And λ_{pi} error rate of component I And n is the number total components involved in the system. System reliability is calculated as follows:

$$R_s = e^{(-\lambda_s t)} \quad (7)$$

According to the above mentioned equation, six modules and the console error rate was calculated. Basing on these results, the error rate and the MTBF of the system was calculated, as per the following equation:

$\lambda_s = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 = 2509.8(10^{-6}/h)$

MTBFs = 398.4 h

Reliability of any of the department, along with the acceptable amount of error rate, on various sectors, and the relationship between equation (2) and (5), were calculated results of these calculations were as follows:

T = 200h: $R_D = 0.996$, $R_M = 0.8569$, $R_S = 0.8103$
T = 250h: $R_D = 0.994$, $R_M = 0.8233$, $R_S = 0.7685$

7. Data Analysis

7.1. The Error Rate of the Components

Error rate is dependent on the type of system components. The components must be included at the baseline test. Components with high error rates are shown in Table 1. It shows that the error rate relay and NPN transistors in the whole system is much higher. The components can greatly reduce the reliability of the system.

Table 1. Error rate components

Name	Count	Assigned module	The error rate of each component
Silicon NPN transistor	2	Console 2	24.57
Silicon NPN transistor	1	Console 2	10.733
Silicon NPN transistor	2	Console 3	7.2
Electromagnetic Relay	1	Console 3	10.733
Electromagnetic Relay	2	Console 1	32.634
Electromagnetic Relay	7	Console 1	24.476
Electromagnetic Relay	12	Console 1	16.317
Electromagnetic Relay	22	Console 2	24.476

7.2. The Reliability Systems

According to the previous calculations the control system error 2509.8 × 10-6/ h to 398.4 h, and the MTBF was found to be greater than the specified value of 250 h. The proposed system showed 62.75% reliability, at 250 h. From results of the reliability analysis, it was confirmed that the sustainability and reliability of each system component was low, and that had a greater influence on the entire system. Analysis conducted in this paper considered only the theoretical aspects, and many other conditions such as non-work stages reliability, and environmental factors, have not been considered. Therefore, the actual reliability should be calculated by the tests of reliability. Based on the analysis of the previous section, the components at the proposed system were replaced with low reliability, and a simpler design was created. So the numerical results of MTBF were obtained from 790.4 h, which was higher than 250 h, and the secure system reliability was recorded at 94.6%.

8. Software Testing and Evaluation

8.1 G-O Evolutionary Model:

Software capability model is a setup of a mathematical model, and a block diagram of the software capability, estimated the reliability. Reliability is considered as a complex system. Hence, to build such a model, the best way was to break the system into simpler subsystems that would lead to the achievement of reliability through forecasting, distribution, and estimation of more complex system. Models for the software reliability modeling systems include: J–M, Littlewood-Verral and G–O systems [12]. The J-M model assumed that the errors were independent of each other at the testing phase. The Littlewood–Overall model assumed the total software error at one level. The Musa model assumed that the software errors were independent, the average occurrence of software errors was fixed, and the time of occurrence of the error obeyed the exponential probability distribution function. The use of G–O model was preferred because it was assumed that the cumulative number of errors were non homogeneous, and the component Poisson processes were similar to real processes. The clear baseline assumptions of the model are listed in order of G–O:

- The software runs under the same conditions as expected by the operating environment.
- The numbers of errors detected were independent at each time series t0 <t1 ... <tm, which consisted of the time intervals (t0, t1), (t1, t2)..., (tm-1, tm).
- The severity of the probability of error detection was almost the same.
- Cumulative number errors detected [N (t), t ≥ 0] one incremental process, independent at the specified time. N (t) was related to the Poisson distribution function m (t), at the various time intervals (t, t + Δt). The numbers of errors found in the expected timeframe posed the residual error at (t) time.
- The expected function m (t) monotonically increased the function of the number errors, satisfied with the condition m (0) = 0 and lim m (t) = a. A fixed total number of expected errors were eventually diagnosed.

The Vehicles control system was independent from the main operating modules, and also from the several other modules. According to research conducted on the software reliability models, two types of errors have been proposed. Software reliability models of m types are as follows:

$$m_i(t) = p_i N_0(1 - e^{-b_i t}),\ i = 1, 2, \dots, m \quad (8)$$

$$\sum_{i=1}^{m} p_i = 1 \quad (9)$$

$$p_r\{N(t) = n\} = \frac{[m(t)]^n}{n!}\exp[m(t)] \quad (10)$$

$$m(t) = N_0 \sum_{i=1}^{m} p_i(1 - e^{-b_i t}) \quad (11)$$

The reliability of the intervals (s, s + x) to:

$$R(x|s) = \exp[-N_0 \sum_{i=1}^{m} p_i(e^{-b_i s} - e^{-b_i(s+x)})] \quad (12)$$

Based on the test results and the evaluation, the two types of G–O and evaluation of the reliability led to development of the A and the B model. These models are displayed in the 13 and the 14 equations:

$$R(x|T_n = s) = \exp[-a(e^{-b\ \ } - e^{-b(s+x)})] = \exp[-216.6111(e^{-0.0\ \ s} - e^{-0.0\ \ (s+x)})] \quad (13)$$

$$R(x|T_n = s) = \exp[-a(e^{-b} - e^{-b(s+x)})] = \exp[-38.2595(e^{-0.0\quad s} - e^{-0.0\quad (s+x)})] \quad (14)$$

It has been assumed that the reliability weights p1 = 0.6 and p2 = 0.4 were considered, for obtaining the A and the B models as shown in equation 15:

$$R(x|s) = \exp[-N_0 \sum_{i=1}^{m} p_i(e^{-b_i s} - e^{-b_i(s+x)})] = \exp[-254.8706(0.6(e^{-0.0\quad s} - e^{-0.0\quad (s+x)}) + 0.4(e^{-0.0\quad s} - e^{-0.0\quad (s+x)}))] \quad (15)$$

These two types of assumptions were displayed as the cumulative test time, and the time keeping software for s = 220, x = 60. For the reliability models A and B, R0 = 79.37% and RB = 79.04%, respectively, and the overall reliability was equal to R = 45.38%.

8.2. Testing Software

Software testing was done, to improve the reliability of the software. These tests were based on the specifications phase of the software development process, and the internal structure of the program were selected so that the process discovered the error events. The goal of software testing was to detect the potential errors software with minimal use of time and manpower. The results from this phase were implemented in building of the foundation of the reliability of the software. Software testing methods normal included the dynamic testing, the static testing, and the white box and the black box testing. Access to the test data, test cases, and the work implementation by working on the main menu of modules, and also module development assistance, was possible due to such testing methods. Exams included documentation software testing, black box testing, system testing, and regression testing. Based on the results of the test, software errors were eliminated, and the software reliability was improved.

8.3. Evaluation Results of the Improved System with Test Software

Based on the test results and the G–O models, the evaluation, and the reliability results were obtained from the A and the B models.

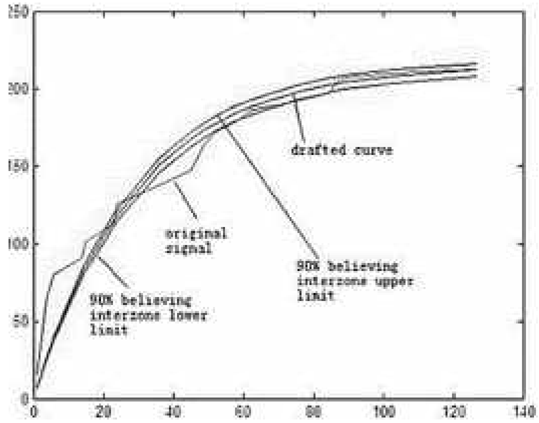

Figure 3. Results of G–O model estimation on the A model system.

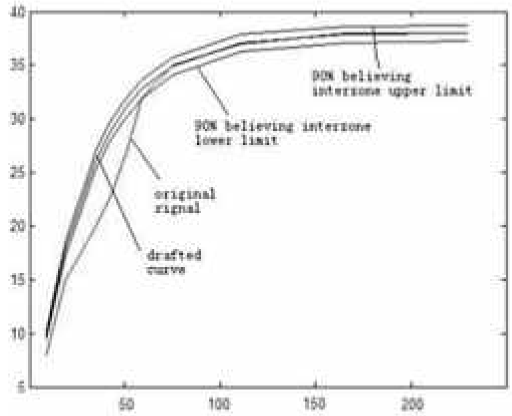

Figure 4. Results of G–O model estimation on the B.

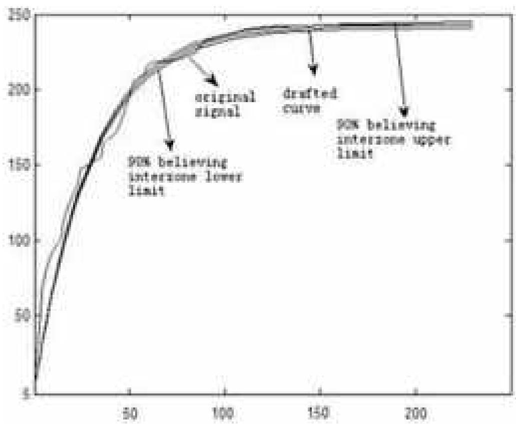

Figure 5. Results of G–O model estimation on the A and B models.

Figure 3 and 4 shows the evaluated results obtained from models A and B, based on the assessment testing errors, in a hybrid vehicle control system. Figure 5 also shows the assessment test data error on the total model A and B.

9. Conclusion

Control system for hybrid vehicles that works in vibration and magnetic environment, must have high reliability and security of the entire system in order to meet operational requirements .In this work, the analysis was Vehicles ride out with low reliability of the system components, which were replaced for improvements. The system was designed in such a way that it made it easier to increase the operational efficiency, and the power assisted system. The design of simpler functions department, followed by the functions and design of hardware modules were broken. Mean time between failures was recorded at 790.4 h, which was significantly higher than the standard 250 h. Normal system reliability was recorded as 94.6%, at 250 h time, which we proposed along with the reliability testing. Also testing various software's, including the white box and black box testing, and regression testing was performed. The results showed the evidence from the implementation of the results of assessment criteria, with that of the proposed system. Ultimately the results of the simulation were evaluated, with the mentioned criterion in the paper. It can be said that the proposed method can help creators to achieve a reliable system for the hybrid vehicles designing.

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