Reliability Analysis through Block Diagram for Small Electric Motors

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Abstract *- This paper presents a reliability and reliability indicators analysis through block diagram concept. The analyzed device is a small electric motor. This study can be extended to all types of small and medium-sized electric motors, with or without brushes, with or without permanent magnets, in either normal or reversed position (with an outer rotor). It is important that both the system and the environment in which it operates to be known, taking into account the consequences of system failure, possibilities of repair, respectively. RBD execution method is based on a visual representation of relationships between system reliability related to its components. RBD can be regarded as a model of a system based on definitions of success or component defect, respectively.*

Keywords - Reliability, Electric Motors, Reliability Block Diagram

1. INTRODUCTION

To model reliability we resorted to Relex Reliability Studio programming environment. This programming environment can make a prediction on the reliability and maintainability of a system, can perform an evaluation of critical failure modes, and can model a complete system for analysis of the reliability and availability as well as the assessment of all parameters and indicators necessary to research reliability.

In this context, research started from:

1 Defining the system and its components;

2 Defining FMEA (Failure Mode and Effect and Analysis);

3 Defining RBD (Reliability Block Diagram);

4 Defining FTT and FTD (Fault Tree Table, Fault Tree Diagram);

5 Defining Markov structure.

Step 1 and 2 of this research, respectively were presented in previous publications [1][2]. This paper presents the analysis in terms of reliability of block diagram (Step Three).

As a reference for modelling reliability was elected MS-1 N-8811-type permanent magnet synchronous motor [4][5][6]. Initial data were obtained experimentally and those supplied by the manufacturer (requirements on operating conditions and technical parameters of motor). The presented method of calculation of reliability can be used for any small to medium-sized motor, with or without brushes, with or without permanent magnets in either normal or reversed position (with an outer rotor) [3][4]. For the calculation of reliability parameters [5][6] we must only know the environment in which the motor is running, its design parameters and requirements of the manufacturer.

2. DEFINING RBD (RELIABILITY BLOCK DIAGRAM)

By modelling the reliability of a system there is generated a mathematical image during operation in an operating mode. It is important that both the system and the environment in which it operates to be known, taking into account the consequences of system failure, possibilities of repair respectively [3][4][5][6].

With Relex programming environment [7][8] it is possible to make a prediction on the reliability and maintainability of a system, perform an evaluation of critical failure modes, and model a complete system for analysis of the reliability and availability as well as the assessment of all parameters and indicators necessary to research reliability.

RBD execution method is based on a visual representation of relationships between system reliability reported to its components. RBD can be regarded as a model of a system based on definitions of success or component defect, respectively [7][8].

If the system performs several functions or has several operating modes, it may be needed more than one RBD. When modelling a RBD all elements must be independent of each other. For small and medium–sized motors we took into account their components based on the procedure shown in Figure 1.

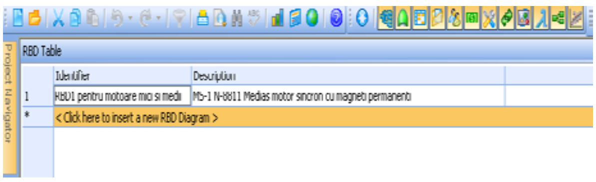

Fig. 1 Defining components for configuring the RBD

To generate a reliability model for a system, we should be aware of all the links//relations and actions that occur between the components of the system. RBD analysis allows an easy way to achieve it. Thus, in case of the MS-1 N-8811 -type motor we generated a RBD taking account its components. To these elements, brushes and mechanical couplings have been added so that the calculation algorithm can be extended to other motor models (Figure 2).

The motor has accumulated 1800 hours of test time. During this time period, we monitored the operation of a batch of 10 motors. All problems and failures occurring during that period were taken into account for the calculation of reliability indicators.

RBD technique is used to model systems with variable series parallel configuration. When system components are connected in series, all components must be operational for the system to work. By using alternative systems when designing, failure of an item shall not stop the whole system. This alternative system takes over the tasks of the defective item (redundancy).

By using redundant elements in the system, we enhance its reliability and availability.

The reliability of a complex system depends on the reliability of each of its elements and the position of these elements in the system. To any system with independent components a RBD can be attach by combining commonly used configurations.

In this context, the most common situations are:

Series Configuration.

All items must be functional for the system to be operational. The reliability of the entire system with items in series is given by the relation [3][5][6]:

$$R_{sistem} = R_1 \cdot R_2 \cdot R_3 \cdot \ldots \cdot R_N \tag{1}$$

Parallel Configuration.

All components have to fail for the system to fail. The reliability of such a system is given by the relation (2) [3][6][7].

$$R_{sistem} = 1 - \{(1-R_1)\cdot(1-R_2)\cdot(1-R_3)\cdot\ldots\cdot(1-R_N)\} \tag{2}$$

In any case when we can obtain an expression for reliability, we can also obtain an expression for MTTF (Mean Time To Failure - mean time to first failure). It is defined by the following relation [6][7]:

$$MTTF = \int_0^{\infty} R(t)dt \tag{3}$$

In the case of the analyzed synchronous motor, it was considered that failure rate is constant, thus MTTF becomes [5][6]:

$$MTTF = \frac{1}{\lambda_{sistem}} \tag{4}$$

λ_{sistem} - is total failure rate of system

Availability of a system having a constant failure rate or repair rate is calculated based on the relation

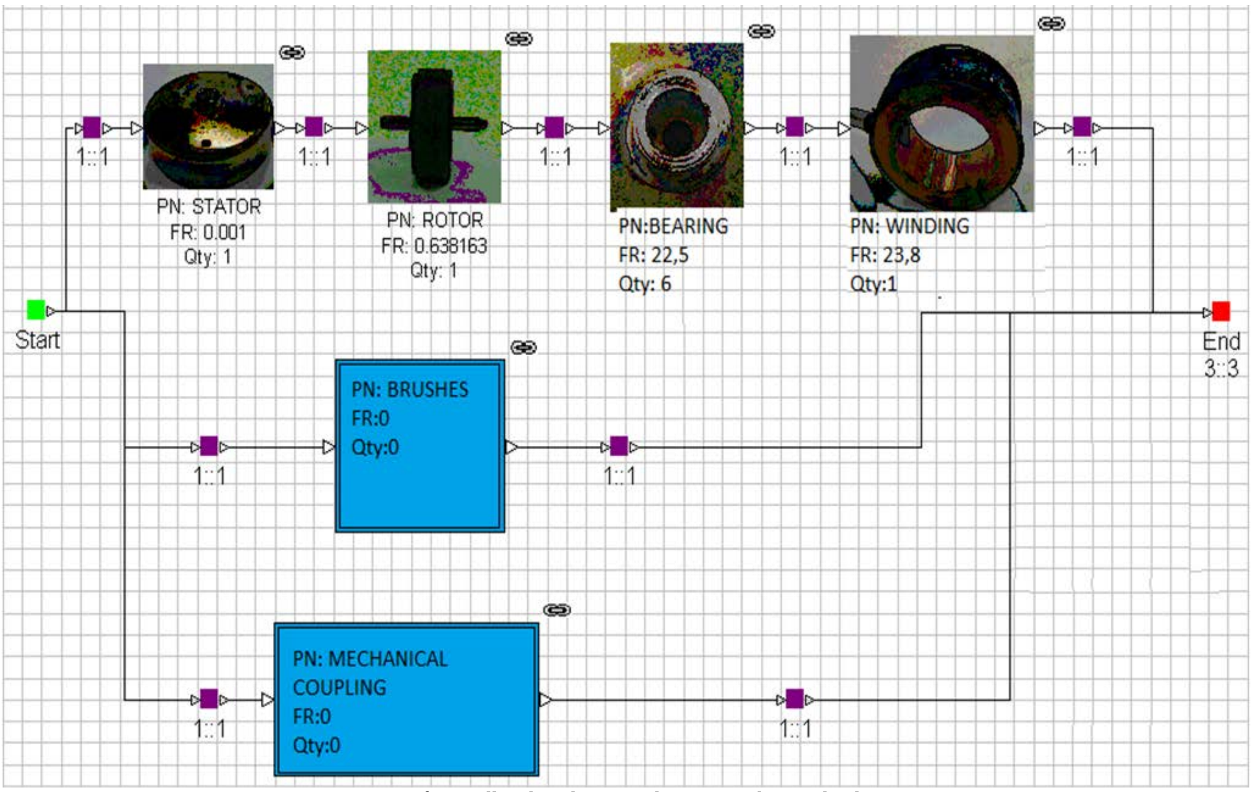

Fig. 2 RBD for small and medium-sized motors without redundant items

[4][5][6][7]:

$$A(t) = \frac{\mu}{\lambda+\mu} + \frac{\lambda}{\lambda+\mu} e^{-(\lambda+\mu)t} \quad (5)$$

where: $A(t)$ - is system availability at time t;

λ - is constant failure rate;

μ - is constant repair rate.

Relex programming environment allows complex simulations, so that failure rates, repair rates respectively be determined statistically.

Another relationship for the calculation of availability is [4][5][6][7]:

$$A = \frac{MTBF}{(MTTR + MTBF)} \quad (6)$$

where MTTR is the average time until repair is performed (Mean Time To Repair) and MTBF is Mean Time To Failure.

Calculation of the number of hours during which the system does not operate at rated parameters, TDT (Total Downtime) is given by the formula:

$$TDT(t_1,t_2) = \int_{t_1}^{t_2} U(t)dt = \int_{t_1}^{t_2} (1-A(t))dt = t_2 - t_1 - \int_{t_1}^{t_2} A(t)dt \quad (7)$$

where: $TDT(t_1,t_2)$ - is the number of hours in the interval $[t_1,t_2]$ in which the system does not work at rated parameters;

$A(t)$ - is system availability;

$U(t)$ - is system unavailability.

In order to calculate the number of failures, we can use an analytical method and a simulation. The analytical method employed uses the frequency of failures. The number of failures is given by the formula [4][5][6][7]:

$$n_f(t_1,t_2) = \int_{t_1}^{t_2} v(t)dt \quad (8)$$

where: n_f - is the total number of failures in the interval $[t_1,t_2]$;

$v(t)$ - is the frequency of failures (this results from failure rate λ).

Besides the calculation of reliability, availability, optimization and analysis of a system, RBD allows the introduction and analysis of the activities of maintenance, spare parts and information on resources for repairs. For the system shown, the MS-1 N-8811-type motor, we calculated system availability (Figure 3), the number of hours in which the system does not work at rated parameters (Figure 4) and the estimated number of failures (Figure 5).

In Figure 3, one can see that after 1800 hours of operation the system availability is around 0.8. This means that this type of permanent magnet synchronous motor has at the end of its life, 80% chances of being considered to be in good condition.

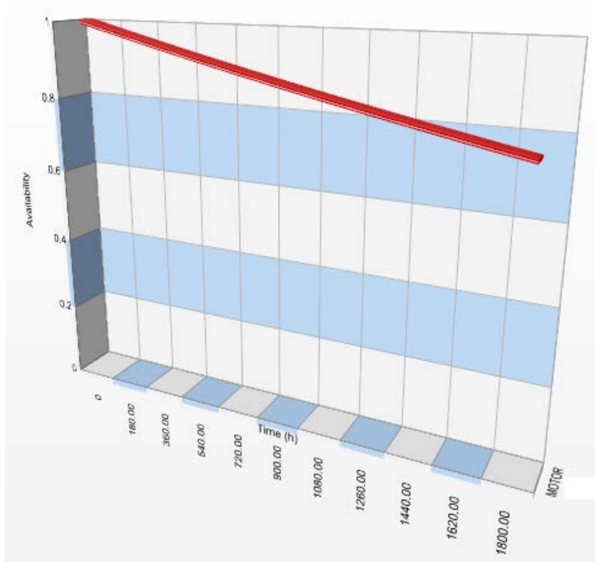

Fig. 3 System availability during 1800 hours of operation

In the figure below (Figure 4) we can note that the TDT calculation shows that during the considered life, the motor will not work at rated parameters between 200 and 250 hours. This does not mean that the motor will fail during this number of hours, but that it will not work at rated parameters as indicated in the Technical Manual of the device.

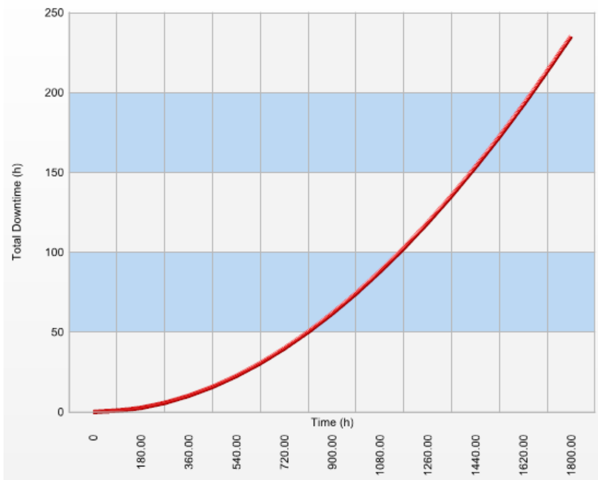

Fig. 4 Number of hours during which the system does not operate at rated parameters

Taking into account the aspects previously analyzed, in Figure 5 we can notice that during the 1800 hours of operation considered for size "Number of failures" we have a value of about 0.25. This size indicates a small probability of major failure for the motor considered.

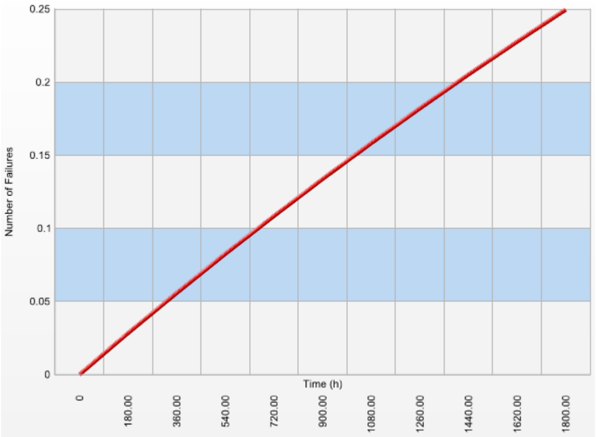

Fig. 5 Estimated number of failures during the duration of operation

3. IV. CONCLUSIONS

This article treats the reliability of permanent magnet synchronous motors. This paper is part of a larger study that aims finding all indicators of reliability of these types of motors.

Based on the results obtained for RBD calculation, we can say that the studied motor is within rated parameters and that no hidden manufacturing defects have been found. It is highly probable that the motor will be functioning during the planned period of time, meaning that there are very high chances that all economic and probabilistic indicators initially outlined will be observed (it is highly probable that the motor be functioning during its entire warranty period).

This calculation algorithm can be used by any company producing electric motors from the design of the particular motor to pilot series analysis. Thus, we obtain reliability standard characteristics and its indicators. We can determine warranty period, the terms of repair or replace, data which are important for each manufacturer.

The newly generated algorithm comes to support manufacturers of electric motors, optimizing the design and execution processes, taking into account reliability requirements imposed by the environment in which the motor operates as well as the requirements imposed by the users.

4. REFERENCES

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