Indian Journal of Science and Technology, *Vol 9(48), DOI: 10.17485/ijst/2016/v9i48/104355, December 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Reliability Analysis in an Electrical Drive System

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Abstract

Electric drives are one of the most significant part of the industrial applications, which are used in the conversion of electric power into mechanical power. Today, the drives are being integrated more and more into the system and hence, the reliability of the electric drives has become a major problem. A common electric drive system consists of many number of components such as an electric machine, power converters, controllers, sensors as well as other communication devices. So the major focus in the modern era has been to increase the reliability of the electric drive system as a whole.

Keywords: Electrical Drive, Faults, FMEA, FTA, RBD, Reliability

I. Introduction

Electric drive is an electromechanical system used to drive mechanical loads. They consist of an electric motor, a transfer system, an electrical energy converter, and a control system. The control system consists of a micro-controller, data channels, sensors and actuators. A basic structure of the electric drive is shown in Figure 1.

II. Faults in an Electric Drive System

The major faults that can be associated with an electric drive system occur in the following subsystem of an electric drive:-

- Electric machine
- Inverter
- Speed encoder
- Current sensor
- Control platform
- Estimation Platforms
- Wires and connectors

Some of the failures are more common compared to the rest. Hence, from the point of view of reliability, calculating those failures or weakest links in the system are essential if the reliability of the complete system has to be improved. An integrated multi disciplinary approach is hence necessary to meet the reliability challenges faced by the electric drive system[2, 3, 6, 7].

III. Fault Detection

When we consider the safety and reliability of a drive, the fault detection and conditional monitoring of the drive gets prime importance[9]. Hence it becomes easy to limit or avoid extra costs from random failures or repair. Conditional monitoring can be classified based on several conditions:

- Conditional monitoring method involving data from the devices which are stored in the memory. Based on this data, a maintenance action can be performed if triggered by an operator.
- Another class of classification, involves setting of certain threshold limits to operate the device below dangerous values. For instance, the temperature of windings of a rotor can be set to certain threshold value so that it operates below it.
- Protection based monitoring method involves the use of alarms for giving signal to disconnect the drive system from the supply.

Physical classification involves measured signal approach which can be elaborated as:

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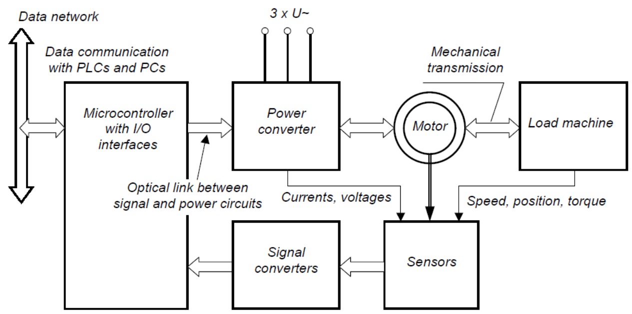

Figure 1. Generalized structure of an electric drive.

- One of the most common ways of monitoring is evaluation using electrical parameters like current, voltage, etc which can be then termed as Electrical Monitoring of the devices. Here, the electrical parameters are used to determine the threshold limit of the systems.
- The use of measurement coils in the stator of the system involves the evaluation of magnetic parameters and this classification is known as the Magnetic monitoring of the devices.
- Another classification deals with the use of mechanical signals or vibrations and this known as the Vibration monitoring technique.
- The use of temperature parameters to classify monitoring gives another group known as the Thermal monitoring of the devices.

For the monitoring based on the noise emitted by the devices, acoustic approach is used and it is termed as Acoustic monitoring.

IV. Structure of Monitoring Methods

The structure of monitoring methods is shown in Figure 2[4]. It can be seen that the parameters are first measured using signal measurement devices like current and voltage transducers, encoders or any such measuring devices which is based on the monitoring being used[1].

The next process in the block is the signal processing which determines the phase voltage or current in the case of electrical monitoring or some other values again based on the monitoring technique. In the case of a voltage or current waveform,

$$\underline{v}_s = \frac{2}{3}\left(v_1 + e^{j2\pi/3}v_2 + e^{-j2\pi/3}v_3\right) \quad (1)$$

$$\underline{i}_s = \frac{2}{3}\left(i_1 + e^{j2\pi/3}i_2 + e^{-j2\pi/3}i_3\right) \quad (2)$$

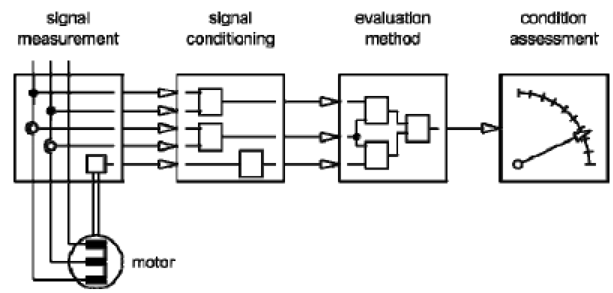

Figure 2. Block diagram of methods for the detection of machine conditions and faults.

phase voltages v_1, v_2, v_3 and phase currents i_1, i_2, i_3 determines the voltage and current phasors. The evaluation technique helps the user to know the internal features of the system. The fault associated with the system can be easily known and procedures can be initiated to counter act the fault immediately if there is an unusual transient or fluctuation in the parameter under evaluation.

V. FMEA Analysis

Failure Mode and Effects Analysis (FMEA) determines the faults associated with the design of a system or a process. The ways or methods through which a system can fail is termed as Failure modes. When these failures tends to harm the customer in any significant way, these are known as the end Effects. Failure Mode and Effects Analysis helps in identifying, prioritizing and limiting these modes of failures. Hence they identify, assess the risk, prioritize and then take corrective measures[11, 14].

Hence, in a general sense the following data should be known for carrying out an FMEA:

- Item
- Function
- Failure
- Effect of Failure
- Cause of Failure
- Immediate control
- Corrective measure and action

For most of the analysis, two main methods are used to assess the risk associated with various items in a system:

- Risk Priority Numbers
- Criticality Analysis

A. Basic Analysis Procedures

The basic steps for performing an Failure Mode and Effects Analysis include the following:

- Assembling the best possible team with relevant knowledge
- Establishing the basic rules for the analysis
- Surveying and collecting relevant data
- Identifying the item or process
- Identifying the function, failure, effect, cause, control
- Evaluating the risk associated with the item or process
- Prioritizing and assigning corrective action
- Performing corrective actions
- Revaluating risk
- Update the analysis if required

B. Risk Evaluation Methods

The team which analyses risk, should rate the following to use the risk priority numbers:

- Rating the severity of the failure
- Rating the likelihood of occurrence of the failure
- Rating the detection before it reaches the customers

Risk Priority Number = Severity x Occurrence x Detection.

C. FMEA Standards and Guidelines

The format used for FMEA analysis has been laid down based on some strict standards and guidelines. The main published being used in the world today are:

- SAE J1739
- AIAG FMEA-4
- MIL-STD-1629A.

There are also a large number of industries which follows their own procedures for the detection of faults and performing FMEA on their products or processes. As an example, Figure 3 shows a sample FMEA done on an Electric Drive system[17].

http://www.qimacros.com/lean-six-sigma-articles/fmea/

Potential
Failure Mode and Effects Analysis
(Design FMEA)

System:	Name/number of system
Subsystem	Name/number of subsystem
Component	Name/number of component
Model:	model years/programs
Core Team:	Team members
Design Responsibility:	Reliable
Key Date:	15-07-2008

Item/Function Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Class	Potential Cause(s) / Mechanism(s) of Failure	Occurrence	Current Design Controls Prevention	Current Design Controls Detection	Detection	R. P. N.*
Speed sensor	Sensor is disconnected	Motor will collaps or shaft thrown out	10	Critical	Dangers speed/Broken rotor bar	7	reduce motor speed/ switch off the supply	Visual monitoring	10	700
Supply	1-phase failure	Production/Hr is less	9	Critical	Phase to ground	8	reduce current	CT	6	432
Supply	2-phase failure	Potential safty hazard[Operater can injured	10	Critical	no rotation of motor	7	Switch off the supply	CT	6	420
Motor	Temp. rise in motor	over load	10	Critical	winding failure	8	Switch off the supply	Thermistor	3	240
Inverter	Power electronic device	connection failure	2	normal	problem in estimation	3	check for connectivity	nil	5	30

Figure 3. FMEA on an Induction Motor Drive.

Hence, depending on the RPN values, the most dangerous faults associated with the system can be identified and measures can be taken to reduce the RPN associated with the fault.

VI. Conclusion

The Failure Modes, Effects and Analysis procedure has been widely used as a tool in wide variety of processes and products for reducing the occurrence of the faults associated with the system and hence improving the standards of productivity in industries. It helps in achieving higher standards in productivity and processes, thereby increasing customer safety and satisfaction with the help of highly reliable products. This piece of work focuses on the process that has to be followed to develop highly reliable electrical drive systems which can be extended to other domains also. Further research can be carried out in other drive topologies which are currently ruled out because of their lack of fault tolerance and for improving these drawbacks associated with these systems. The use of a fixed failure rate can be said as a drawback of the FMEA analysis which can be worked upon in the future researches for improving the formats associated with the FMEA analysis.

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