Electromechanical Conversion Chain Fault Diagnostic - State of Art

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***Abstract*— In this research paper, the state of the art related to different failures found in an electromechanical conversion chain will be presented.**

In this regard, each part constituting the chain will be presented. This has a crucial role to sort out failures, their origin and conduct to good analysis and diagnosis.

We are going to focus on the main frequent defects that occur in the electromechanical conversion chain parts and their roots, with the aim to provide an analysis of the chain and its defects.

***Keywords*— Electromechanical chain, Failure, Diagnostic, Power grid, Induction machine, Rectifier, Inverter, Transformer.**

I. INTRODUCTION

In the recent years, the electromechanical conversion chain is increasingly used in industrial sector. It is a big structure that comprises electrical devices namely: the power grid, transformer, rectifier, inverter and an asynchronous motor.

Unfortunately, despite the developments of the protection tools, no industrial system is immune from failure. Electromechanical chain may know an unscheduled total or partial damage in one or more of its components, causing, thus, an outage and subsequently influence on productivity.

The protective elements can't avoid the appearance of defects affected all the constructive devises of electromechanical chain and only takes places after damage. Therefore, early fault detection is crucial to avoid unexpected and catastrophic failures.

Diagnostic online is required to establish the system by determining the source of failures through a careful monitoring which will overcome existing problems.

For this purpose, great efforts on systems monitoring and on-line fault diagnosis are nowadays bearing to reduce the maintenance costs, improve reliability of these systems and successfully allow early failures detection.

In this paper, we will present the state of the art study of different defects occurring in each part constituting the electromechanical conversion chain.

II. ELECTROMECHANICAL CONVERSION CHAIN

The electromechanical conversion chain is constituted of a transformer related to a power grid of distribution medium voltage followed by a rectifier that converts alternative voltage to the continuous one. Another static converter is also used; its as inverter which supplies alternative voltage to the asynchronous machine.

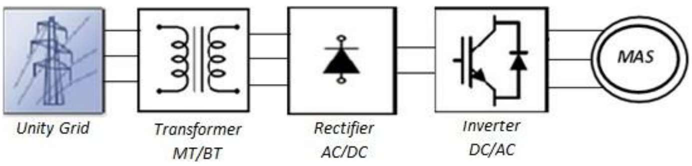

Fig 1. Chain constituting

A. Power Grid

Electrical grids are a network designed to supply or deliver electricity from generating stations to consumption points. The power lines are used for electricity transmission and distribution. At the stage of production, the transformer is located in substation to step up the electricity voltage so as to transmit it with less losses. Once it reaches the distribution lines, another voltage stepped down transformer is used.

B. Transformer

The transformer is a crucial device for electrical energy transmission and distribution by modifying the voltage and current magnitude keeping the frequency and the waveform unaffected. The transformer is used as a stepper up at high voltage or as a stepper down to obtain low voltage during the different stages from the production to the transmission until the customers distribution. The transformers are connected by the transmission lines.

C. Rectifier

The function of rectification provides the conversion, often through a transformer, from alternative current to direct current. The three phase ac to dc converters can take two forms namely: half wave circuit or full wave circuit. It is obtained by a controlled or uncontrolled rectifier. In the case of a controlled rectifier, the thyristors are used for regulating the output voltage. In the second case, the output voltage do not required to be adjusted so the diodes are used instead of thyristors.

D. Inverter

The inverter is an electrical device designed to convert direct voltage to alternative voltage. It is also used for variable frequency. The input dc is obtained from a diode bridge rectifier connected to a filter. The inverter is formed of three legs and six switches. In order to generate controllable frequency, an ac voltage magnitudes using the PWM (pulse wide modulation) strategies is used.

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E. *Asynchronous Machine*

The induction machine, especially the squirrel cage one, is considered as the most widespread electrical machine used in the industrial sector due to its robustness, reliability, stability and reducing maintenance. A squirrel cage motor contains a three phase winding stator and a rotor consisted of equally spaced bars short-circuited together by two identical end rings. It is associated to PWM inverter as a variable speed drive either with vector or scalar control.

III. The Chain Defects

All of the chain components can be attacked by different sources of defects.

A. *Power Grid Faults*

There are many faults that can affect the grid such as the over current due to a lightning sparks during the storm. This can cause a primary electrical arc in the grid and a degradation of the insulation system. Other causes of faults that can occur are broken conductor or damaged cable by civil works. All these defects can led to short-circuits that generate considerable voltage and variation of time duration. There is also the voltage dip fault which is broadly defined as a fall of 10 % of the nominal voltage[1].

B. *Transformer Faults*

The main faults occurring in a transformer might appear due to various raisons further categorized into internal and external failures such as AC power system. The Fig.1 presents the percentage of all failures sources that appears in every sensitive part in transformer[2].

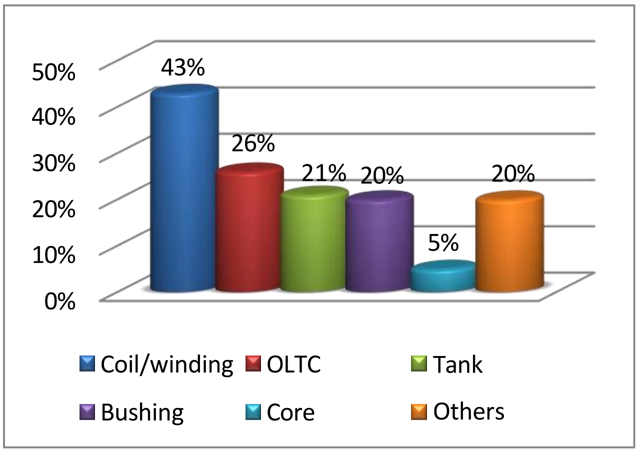

Fig.2 Type of transformer fault

The transformer winding is one of the major components that can be more affected. Moreover, bushing depicts the most fragile and weakly part of transformer.

The main causes of power transformer faults are presented in table1[3].

TABLE I
POWER TRANSFORMER FAULTS

Internal	Winding open circuit Overheating Insulation deterioration Operation of build in OLTC Winding distortion or displacement Winding turn to turn short circuit Loose connection to bushing terminals, taps leads, terminal boards Overloading Damaged shunt packs of Tank Leakage of oil comes from the pierced tank Cracks or breakage of terminals insulators
External	Lightning strikes System overload Transport conditions System switching operation Grid short circuits

C. *Rectifier Faults*

The rectifier faults can be subdivided into open circuit faults and short circuit faults[4].

1) *Open Circuit Fault:* happens for either one or many diodes that can be opened concurrently or consequently. Open circuit fault for more than one diode can appear in the same legs where the diods are connected to positive or negative terminals or in different legs where one of diodes is connected to positive terminals and other one is connected to negative terminals.

2) *Short Circuit Fault:* It can also happen in one or may diodes. In most of the cases, the short circuit affects the system behaviour causing an over current.

Fig.3 shows the rules required to detect and locate either the open circuit faults or the short circuit faults.

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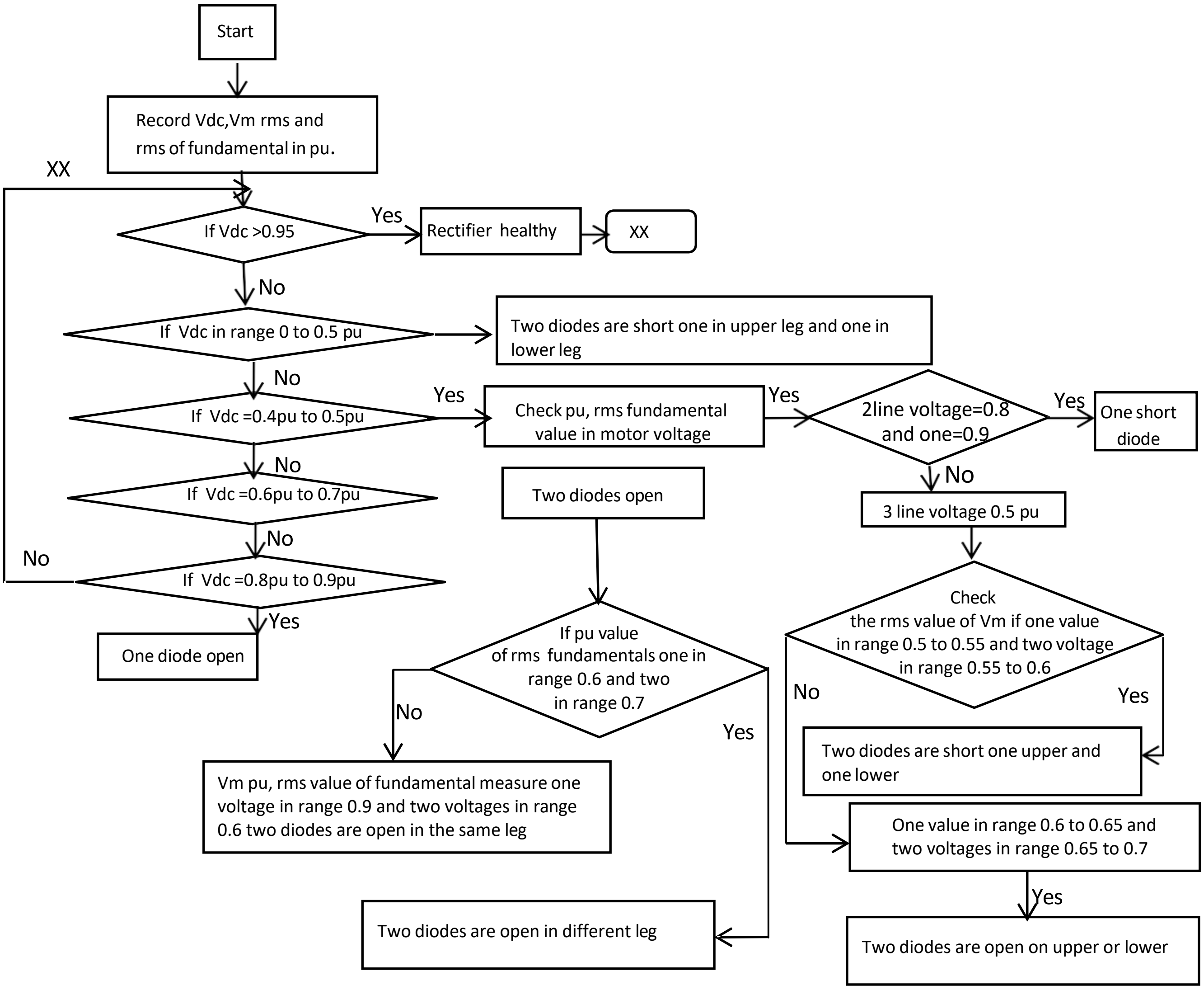

Fig. 3 Flow chart of rectifier faults

D. Inverter Faults

Inverter faults behaviours are the same as the rectifier faults[5][6].

1) *Open Circuit Fault:* These kinds of faults can occur if a switch or more than one are disconnected simultaneously. This case can happen if the defected switches are located at the same leg or in different legs connected to a positive or a negative terminal or if one of the switches is connected to a positive terminal and the other one is connected to a negative terminal.

2) *Short circuit Faults:* Short circuit faults are similar to the open circuit faults. These faults can appear in one or in many switches.

In Fig.4 the algorithm required to detect the inverter faults is presented[7].

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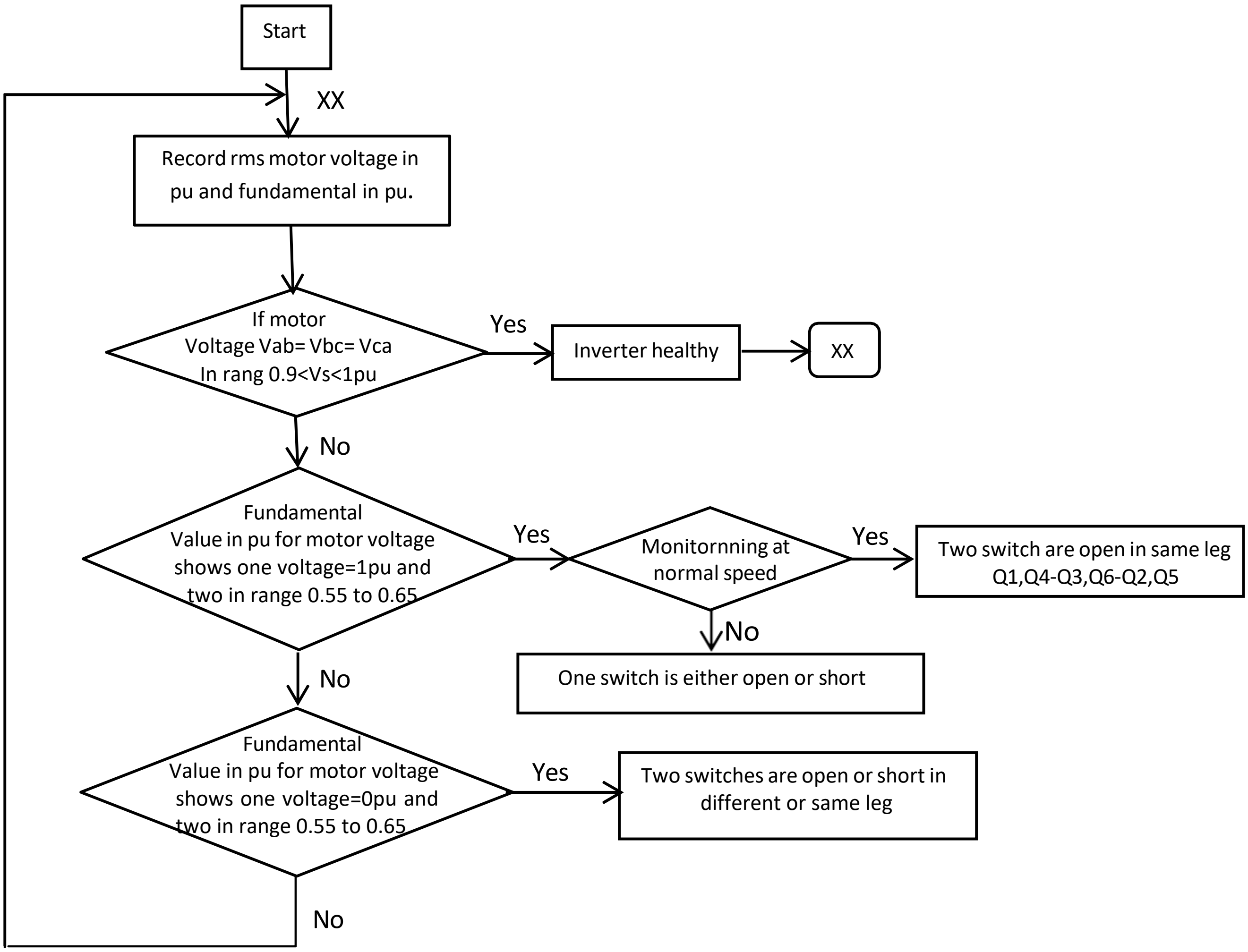

Fig. 4 Flow chart of inverter faults

E. Asynchronous Motor Faults

Induction machine failure surveys categorize the common faults according to different motor components: stator faults, rotor fault, bearing fault and others faults[8][9][10]. These failures can be also classified as mechanical and electrical faults[11].

Mechanical faults are the most occurred on an asynchronous machine. They can appear at the rollers bearing, the end shield and at the motor shaft.

The electrical failures can appear in the electrical circuit main components either in the machine stator or in its rotor.

Fig.4 show the induction machine faults during its operation[12].

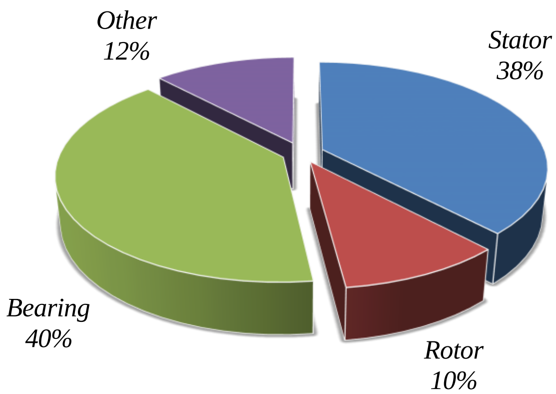

Fig. 5 Type of induction machine fault

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Bearing faults are one of the most prevalent causes of failures. They present 40 % of all faults arising in electrical machine.

1) *Roller Bearing Fault*: The winding damage or the cracked winding causes visible artifacts at the motor cylinder head during its rotation. The lubricating system that helps the motor shaft to rotate easily can also cause a big problem of eccentricity if it becomes stiffer[8][13].

2) *End shield Faults:* The wrong locating of the end shield during the machine manufacturing phase can lead to the rollers bearing misalignment, causing therefore the motor shaft eccentricity.

3) Shaft Fault: The quality of the material used in the construction of a machine shaft is critical for the fault occurrence. A lower quality can provide a crack that may lead to a steep broken motor shaft or to an eccentricity and consequently to the machine shut down.

4) *Stator Electrical Faults*: The stator faults can be produced from different sources resulting from the machine winding opening or short-circuiting. The shorted turn or turn-to turn faults emerging in the stator slots are often caused by insulation failure between two adjacent turns in a coil provided from degradation of insulators between phase and neutral or between two phases. An imbalance in the magnetic field caused by an extra heating produced by the resultant induced currents can has a result a damage in the stator insulation[11].

5) Rotor Electrical Faults: The majority of the rotor faults in the induction machine are caused by a breaking or a cracking of the rotor bars or of its end-ring. This kind of faults could be related to several reasons such as operating environment conditions, the high currents in the bars or in the end-rings caused by frequent starting, the motor overload…..

IV. Conclusions

In this paper an overview of the electromechanical conversion chain state of art was presented of electromechanical conversion chain for a better understanding of the defects characterizing the electromechanical chain different components.

The future work will focus on a detailed mathematical modeling of a non-defected electromechanical chain associated to the diagnosis method. Another work will deal about the defected chain diagnosis. The simulations will be done on MATLAB SIMULINK in order to show the efficiency of the proposed method.

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