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Detection of Induction Drive Fault Based on Identification Model

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***Abstract*—parameters of induction motor due to nonlinearity of magnetic circuit causes difficulties in their identification, therefore difference in experimental and simulation results is observed. In this study, demand of motor diagnostic is described, fault costs are analysed. Adaptive simulation model including comparison of simulated and experimental results is developed and presented.**

***Index Terms*—Induction drive, simulation, adaptive model, online diagnostic of induction drive.**

I. INTRODUCTION

An electrical drive is one of the most important and responsible elements [1] widely used in the industry. They are mainly used in the some production lines; in the fire extinguishing systems (for ex. automated valves) and the other equipment where the controlled motion is required. In many cases these inexpensive drives can be used and their break down is not so important, but in some critical cases it can impact all processes or other people life and health. Similar important places and mechanisms like a “bottle neck” in technology need very reliable drives to save money and reduce production costs. Therefore diagnostic online remains the main aim in exploiting of these drives [2], [3].

Rinkevicienė and et.all discussed that problem of discovering has changed in the drive as soon as possible by means of identification of electric drive [4]. As it is possible to identify an operating drive, for example, controlled by frequency converter, then it is possible to develop programmable model and afterwards, when drive is in use, measure and compare currents, voltages and speed transients of real drive with those got from the model and in this way obtain proper information about mismatching torque and rotational speed in real drive and model. Obtained parameters can identify some problems with bearings, vibrations, bandages, short-circuited windings and caused overheating or other problems. Secondly, this information is very important in diagnostics of electrical drives. From diagnostic history results engineers can get a lot of data for generation severe solutions about fault problem of the drive and prepare to repair it when is possible or manipulate with an operating drive (for example, to change speed, to go away from resonance frequencies) and to avoid the consequences of the failure. This can save a lot of money for companies in maintenance and availability of their production lines.

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In this study, detection of induction drive fault based on identification model has been investigated.

II. DRIVE DIAGNOSTIC DEMAND

One of the identified mechatronic systems applications is pre-diagnosis of a system or mechanism, when the slightest deviation from rated parameters is monitored and diagnosed. That way needs to have a real mechatronic system model capable to calculate internal parameter or its change. Then the real system parameters are compared with the simulation results and give acceptable or unacceptable errors. Acceptable errors can be eliminated and only those system parameter variations that may indicate some kind of parameters change in respect of the initial state given to the model, remains in the matrix. This can be a mechanism external load influence, or result from the expected or current malfunction sign, leading to a complete drive stop or fail.

If there is an opportunity to plan the failure it allows increasing the reliability of the equipment and saving a significant amount of investments. If the parameters of the most popular induction drive is installed in an industrial production line are identified, or this drive provides power unit or boiler viability (e.g. fan, main water pump or otherwise), the unexpected failure, unplanned faults, stop the whole production line and create of huge losses for the company. These consequences could be avoided having possibility to predict, plan such mechanisms failures, sometimes to prevent the stops, eliminating the primary causes. These types of important mechanisms like "Bottle neck” maintenance costs a lot, nevertheless just some parameters can be measured and monitored in the operating drive. In automatic control systems mathematical model of adaptive identified drive provides the opportunity directly compare the predicted system output with the actual measured one and identify the nonessential deviations in the transient processes.

Slightly improving frequency converters currently often used for the control of such type drives, will serve for identification systems installation in the critical mechanisms. The system should be provided with additional coprocessor or with the processor of higher productivity, which ensures fast data processing and computing performance in the event of additional algorithms. Similar small investments such as additional measuring points installation are inexpensive. As an example, for induction drive can be optical speed sensor installed. With greater number of installed measurement sensors provide more accurate diagnostics. In the drive case, the shaft torsional torque meter, which gives a second output parameter for system diagnostic, can be added. The major change made in the form of software code significantly reduces the installation cost.

Sometimes use of adaptive identification and diagnostic tools with high-performance processors allow monitoring the drive in almost real time and to apply adaptive identification and diagnostic methods of drive protection, especially in those cases when the drive cost (the cost of repair) or the consequences of failure are higher than the production line cut-off. Application of the mixed protection code allows users and operators to be warned when parameters get undesirable values, and if these values reach the critical value, disconnect the drive from the additional virtual measurement points. Nowadays one of the developing sectors in industry is application of virtual measurement points, and it is called as sensorless control.

III. Failure Costs

In the production line (for example paper or microchip) there are some places where all products pass like a bottle neck. The system is usually automated and run by drives. Induction drives are used mostly in the industries or in other places. In most cases unplanned stops or failure of mentioned production line lost a whole of products that have been produced at that time and company immediately receive significant losses. This is only the initial losses associated with failure, because later starts downtime and repairing of damages. These losses associated with unproduced output during the repair period, employee salaries, paid for the repair time and drive repair or replacement cost (1)–(4). In the most of the cases there are large losses. In order to avoid or at least minimize such failure dynamic drive diagnostics requires and prediction of possible failures. Economically it is not purposefully to provide all drives with similar systems, but only those whose computation failure costs of stopping are higher than the cost of installation of the prediction diagnostic system.

The delivered cost of the company production line stop often costs more than the company thinking. Therefore, in most cases, the system can predict fault pays off and allows saving at least part of these costs and the other part to cut-off costs:

$$Costs = \begin{cases} +damaged\ production, \\ +unproduced\ production, \\ +repair\ staff\ salaries, \\ +line\ operating\ costs, \\ +repair\ parts\ /new\ drive, \\ +start-up\ costs, \end{cases} \quad (1)$$

$$damaged\ production =$$
$$= \begin{cases} +staff\ salaries, \\ +raw\ batch\ for\ production, \\ +loss\ of\ profit, \\ +electricity\ consumption\ for\ batch\ production, \end{cases} \quad (2)$$

$$unproduced\ production =$$
$$= \begin{cases} +staff\ salaries, \\ +loss\ of\ profit, \\ +ordered\ power\ balancing\ loss, \\ +sanctions\ for\ non-produced\ products, \end{cases} \quad (3)$$

$$line\ operating\ costs =$$
$$= \begin{cases} +lighting, \\ +building\ heating\ /cooling, \\ +other\ general\ expenses. \end{cases} \quad (4)$$

It is not always the fault may be expressed and evaluated only in terms of money, sometimes drives used for people safety or work with people where the raw “material” loss is not allowed. It’s lifting gear, safety valves, wheel drives in electro cars, mechanized various security mechanisms and so on.

IV. Fault Classification

It is possible to classify induction motor faults in few factors. Drive failure may occur on both, the internal and external influence, in this case it can be classified according to these factors. Faults can appear in one of the drive parts: its stator or rotor or it can be caused by other factor. Some of the most common faults found in induction drive are presented in the following charts (Fig. 1 and Fig. 2).

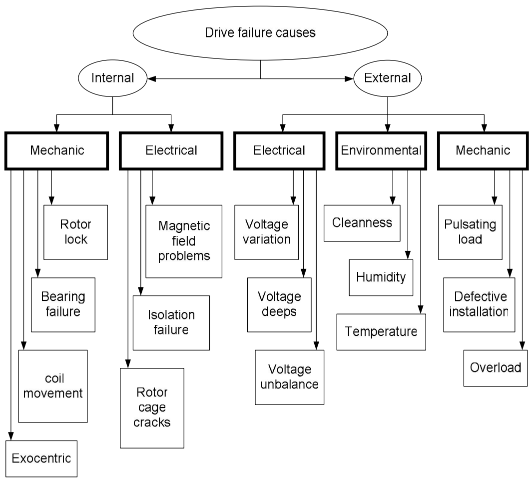

Fig. 1. Classification of drive failure causes based on internal and external reasons.

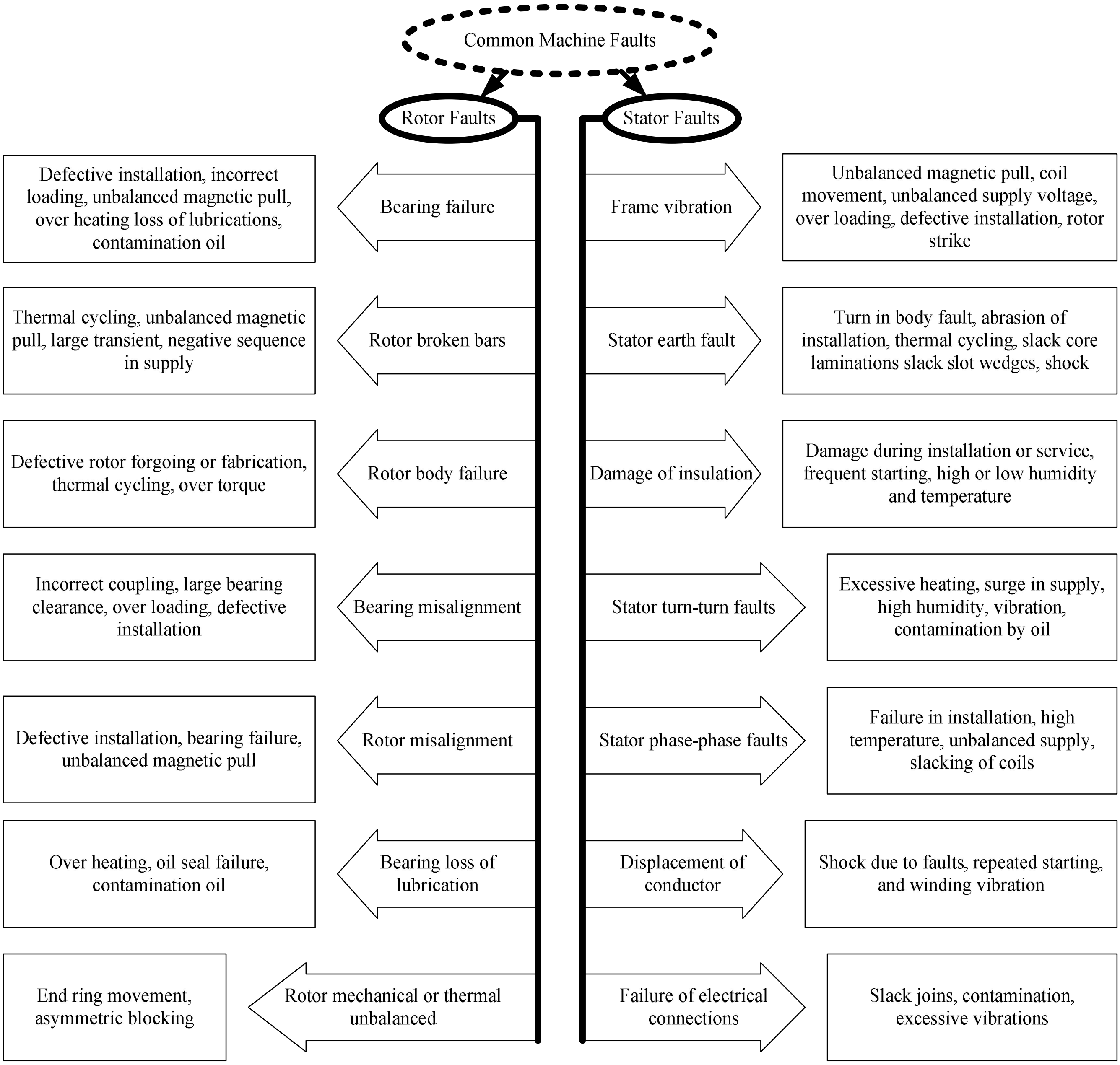

Fig. 2. Classification of common drive faults based on failure source.

V. EXPERIMENTAL RESEARCH

Two induction motors coupled with one shaft like shown into Fig. 3 were tested experimentally. Parameters of only one of those motors were measured; and other drive was not connected at all, it's like a passive load. For current and speed measurements the power analyser was used and for speed and torque measurements digital oscilloscope was used. All gathered data were transferred to Matlab. Matlab standard model of induction drive was used to simulate a mathematical model [5]. Simulation results indicate clearly seen speed error between real model and the simulated one [6]. Therefore similar model with adaptive identification algorithm can be used in the diagnostic and monitoring of processes [3], [7].

Main drive is powered through autotransformers and that gives possibility to control and change per phase voltages. In this way voltage drop was imitated in one of the phases and one phase fault. Comparison of motor running at nominal speed and running on shaft of nominal speed was made.

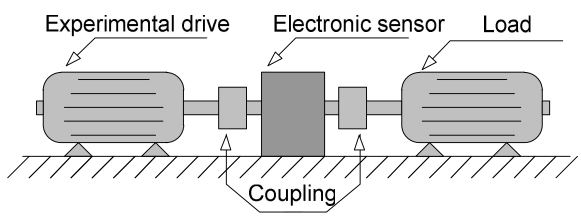

Fig. 3. System block diagram.

The existing curves shown in Fig. 4 indicate that the reduced voltage significantly affects the settling time, but at the same time it produces soft start and reduction of starting torque and reduces speed overshoot.

At the running drive, one of the phases break dawn does not stop it, but significantly increases the vibrations of the drive and mechanism connected to it.

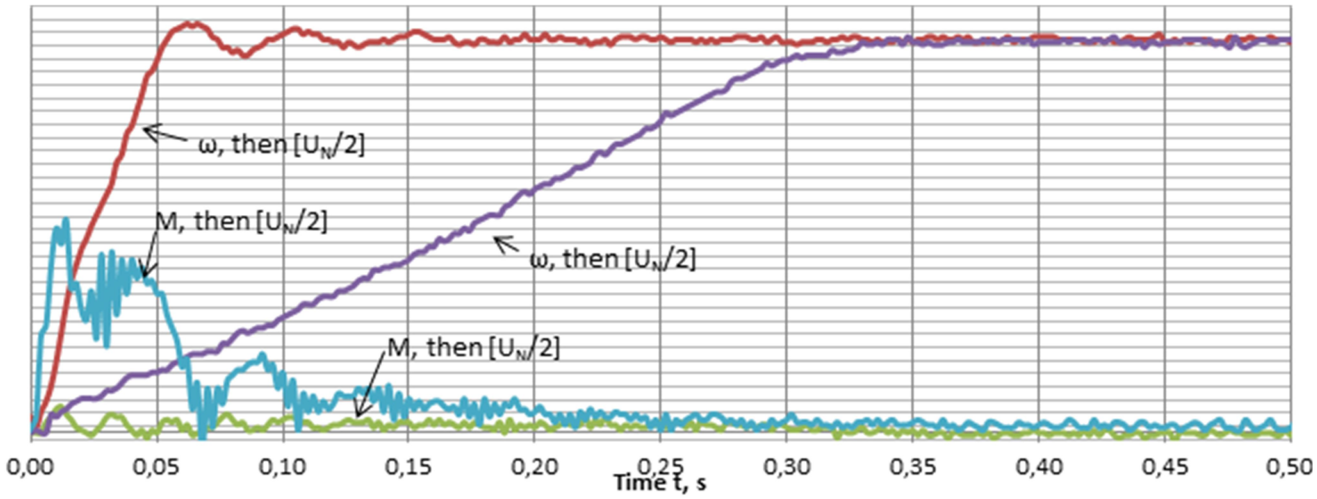

Fig. 4. Drive speed and torque start transients on different voltages.

It is not enough only measurement of voltages because it is difficult to detect phase fault, and therefore measurement of the speed or the most appropriate in this case the current measurement is required. Then failure of one of the phases increases current in other phases (Fig. 5).

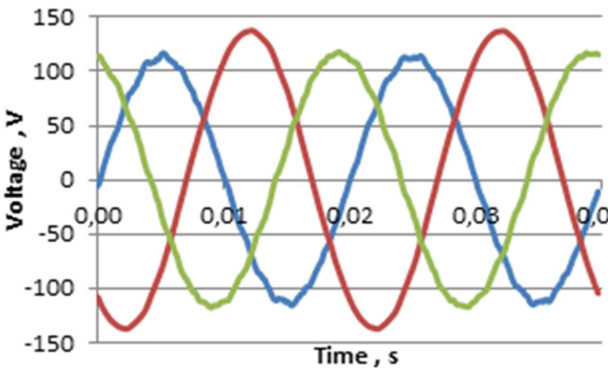

Fig. 5. Running drive voltages at disconnected one of the phases.

Currents asymmetry occurred in heavy duty mode or when difference between phase currents is more than 25 %, can cause damages except the starting torque or significant speed change.

Periodical speed oscillations depending on the rotation speed appears from the bearings (one of the rigidly connected to the shaft) deformations or wear. There may also be affected by the shaft bend. The additionally installed bearing temperature measurement which would allow heating, overloaded bearing to be identified. That can reduce the motor load torque and improve drive performance and save power consumption, which in all cases is treated as cash. The same situation occurs in the cases when the shaft is uncentered, because it pushes the bearings and increases the friction.

VI. Conclusions

The following results have been obtained as:

- Fault one of the phases (or voltage drop in one of phases) does not stop the drive but increase vibrations;
- Drive bearings are very important element for the drive life time, therefore it is important temperature and virtual measurement points of them;
- If real drive speed transients are slower than simulated one or torque amplitude reduces, its mean that drive have voltage losses in feeding line;
- Speed oscillations develop all mechanism vibrations and influences work of all system. If oscillations are periodical they come from mechanical part, if they are multiple of network frequency they come from electrical part;
- Diagnostic systems in many cases are cheaper than mechanism brake;
- Usually companies do not take in account all costs of the mechanism break down;
- Voltage asymmetry indicates one of the phase voltage drop or break dawn, these reasons also increases drive vibration and impact speed fluctuations;
- Bearing failure consequences can be seen from the rising power and increased drive torque pulsations.

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