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Speed/position sensor fault tolerant control in adjustable speed drives – A review

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ABSTRACT

The position sensor is one of the most used devices in Adjustable Speed Drives (ASDs). Its use is mandatory in electric machines vector control. In this paper, an interest was addressed to this field. Indeed, a bibliographical review, about Fault Detection and Isolation (FDI) and Fault Tolerant Control (FTC) in ASDs, is presented. Thus, the paper deals with position sensor FDI and sensorless control-based FTC in ASDs. Moreover, this issue is mainly addressed to position sensor faults in ASDs. This paper is based on a wide literature review referring to scientific papers and manufacturer's technical documents. In total, 186 references in the open literature, dating back to 1981, have been investigated in order to perform this study.

1. Introduction

The automation development in industrial processes has created a demand for different machine types which are characterized by precision and rapidness. Furthermore, automation is based on servo control systems which include control loops principles. These control loops allow smoothly rotation especially at very low speeds. However, this can be done only when the motor speed and position are measured with a maximum resolution and accuracy. These measurements are obtained using a speed/position sensor mounted on the machine shaft. These sensors are basic components in Adjustable Speed Drives (ASDs); they give information that can be used to perform speed, position or torque control. Indeed, motor control is based on two control loops, one for speed or position and one for torque. The choice of the sensor depends on the application requirements. The common used speed/position sensors in ASDs are resolvers, incremental encoders and absolute encoders. For example, resolvers are used in robotic applications because of their robustness. Encoders are mainly used on machine tools which require high accuracy. These sensors are also used in direct drive in order to give an accurate position for the control loops (Fig. 1).

In fact, speed/position sensors are largely used, for electric machines control, in a wide range of applications:

- Military equipments,
- Land transports (road and rail, industrial vehicles, etc.),
- Maritime transports (ship transport, marine propulsion systems, etc.),
- Avionics (aircraft propulsion systems, etc.),
- Wind turbines,
- Solar panels,
- Medical equipments,
- Robotic systems,
- Textile machinery,
- Tire making equipments,
- Test stands,
- Construction equipments,
- Servo motors,
- Packaging machines,
- Machine tools,
- Conveyors,
- Elevators,
- Sheet and web offset presses,
- Food handling equipments,
- Valves/flow metering,

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- Overhead cranes,
- Process monitoring Equipments,
- Steel making/foundry equipments,
- Etc.

The ASDs service continuity, incorporating several sensor types, depends intimately on measurements availability. Indeed, the control of these systems depends largely on the measured variables using sensors. In the case of sensor faults occurrence, these sensors cannot perform measurements in a good way. This may affect the ASD normal operating. Indeed, in order to evaluate sensors ability to satisfy the application requirements, a preliminary study is required. This study must be based on resolution, accuracy, linearity, position measurement type (absolute or relative), response time, sensitivity to electrical noise, temperature range, sensitivity to mechanical shocks and vibrations, as well as the required connection number.

In this context, this survey presents methods that are used for Faults Detection and Isolation (FDI) and Fault Tolerant Control (FTC) in ASDs, namely in the case of speed/position sensors. After that, some past and recent researches in FTC and FDI are presented in order to highlight the contributions and the emerged works in this field. Thus, a classification of applications–based speed/position sensors has been performed.

Moreover, the main objective of this paper is to present a literature review about faults that may affect position sensors in ASDs. This study deals with the types of these faults, their causes and sources, and their occurrence mechanisms. In fact, position sensor faults are highly detailed comparing to the existing works. Therefore, this study consists in a knowledge basis that may be helpful when studying and analyzing the impact of the position sensor faults on ASDs.

2. Statistics about speed/position sensors

Today, the existing electrical systems such as AGVs (Automotrice à Grande Vitesse), TGVs (Train à Grande Vitesse), airplanes and robots are based on ASD principle. Certainly, most of electrical systems are based on open and closed-loop operating, which requires the use of speed/position sensors such as linear displacement sensors, rotary sensors and airspeed sensors. In fact, these sensors carry out important information for open and closed-loop operating. Table 1 summarizes the different types of speed/position sensors which may be divided into three categories; the linear displacement sensors, the proximity sensors and the rotary sensors [1,2].

According to [1], in 2007 and in 2011, proximity sensors have occupied the largest markets in North America. Thus, the smallest markets were for linear displacement sensors. However, the

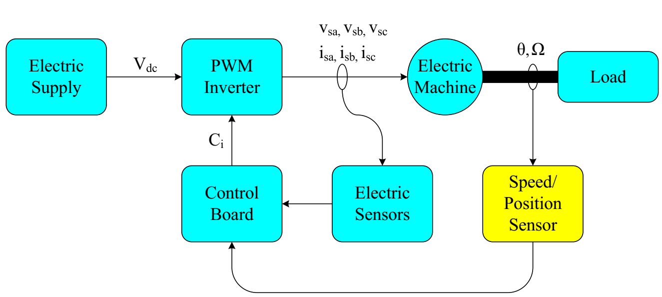

Fig. 1. Speed/position sensor-based servo control system.

Table 1
Speed/position sensors types.

Linear displacement	Proximity	Rotary
Capacitive	Capacitive	Contact
Inductive encoders	Inductive	Inductosyn
Laser systems	Magnetic	Magnetic encoders
LVDTs	Magnetic actuated	Optical encoders
Magnetic encoders	Photoelectric	Potentiometric
Magnetostrictive	Photointerrupter	Resolvers
Optical encoders	Ultrasonic	RVDTs
Potentiometric		Synchros
Ultrasonic		

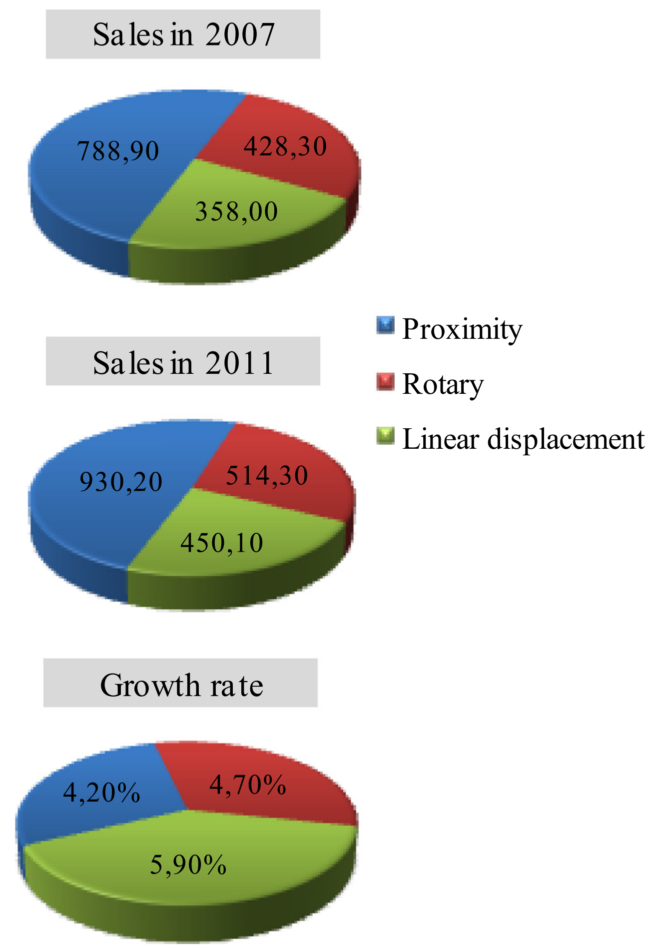

Fig. 2. North American position sensor markets in millions of dollars.

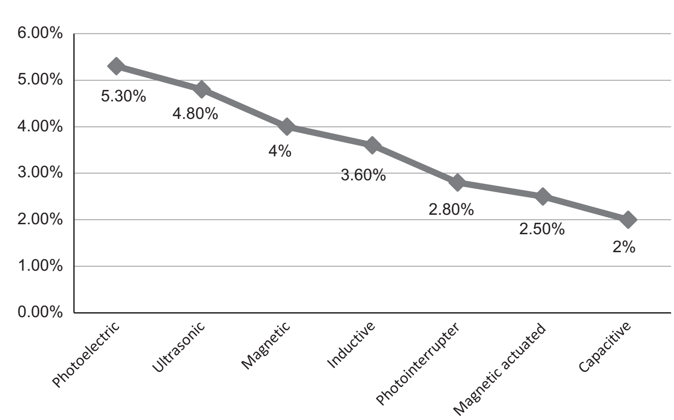

Fig. 3. Forecast North American market growth rates for proximity sensors (from 2007 to 2011).

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