

# Predictive maintenance of power industrial electronic equipment

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**Abstract** – The purpose of this article is to present the concepts and equipment which is used in achieving predictive maintenance. Two case studies are presented here. The first shows the concept of maintenance for a single phase inverter based on tree analysis technique. This technique is based on the relation between the symptoms, the causes and the defects for the inverter, but can be extrapolated to another type of electronic equipment as well. The second study presents the equipment for achieving the predictive maintenance for a combination of electrical and electronic equipment. The SIMOCOD software module has the capability to make the on-line diagnosis. The diagnosis module for a 3 phase motor asynchronous is detailed in this study, highlighting the features and advantages in use it.

**Keywords:** *maintenance; 3 phase asynchronous motor; SIMOCOD software.*

## I. INTRODUCTION

According to European norms of the international IEC or ISO, through *maintenance* means all technical measures, administrative and management undertaken during the life cycle of the electronic equipment.

Currently exist several techniques for predictive maintenance approach.

**Preventive maintenance or proactive maintenance** represents preventing damage by planned and scheduled; systematic checks and repairs are performed at predetermined intervals, even when this is clearly necessary. These activities are planned in accordance with manufacturer's instructions and managerial policy aimed at reducing the probability of failure or degradation leading to failure of the work equipment or facilities. Periodic maintenance, planned and carried out correctly is essential for maintaining the safety and reliability of equipment, machinery and working environment helping to eliminate workplace dangers and can prevent sudden and unexpected failure.

The most important types of preventive maintenance are:

**Systematic maintenance or maintenance performed** by a maintenance plan in maintenance activities, current repairs, maintenance and repairs, is constituted in "use and repair plans" [1].

### *Preventive maintenance and repair system:*

- In the form of planned repairs of such revisions (RT), repair of grade 1 (RC1), grade 2 (RC2);
- The shape of periodic checks (Vp), partial revisions (Rp) and overhaul (R);
- By groups of equipment by setting the frequency of interventions.

This type of maintenance can cause errors in planning the starting of maintenance, it does not take into account the operating hours effective work equipment with a risk that maintenance starts too early (where he worked shortly) or equipment to malfunction before the planned start time maintenance (because it was very intense use).

Predictive maintenance or maintenance performed by comparing the measured parameters with the technological limits of the items / sub-assembly work equipment or facilities, aiming to detect, analyze and correct potential problems before they occur following the interventions of maintenance to be carried out before the occurrence of the defect.

A predictive approach can be applied to any equipment problems if it can measure various parameters like vibration, temperature, pressure, voltage, current, resistance, etc. There must be a limit in terms of technology so that problems can be detected during routine checks. Also, the limit should be set low enough to detect the problem before equipment failure. Correcting the problem is the key route maintained.[1] ; [2] ; [3]

### **The predictive maintenance cycle.**

Once the equipment was placed under surveillance in terms of maintenance, it enters the predictive maintenance (PDM) cycle: set parameters to be measured periodically (weekly, biweekly or monthly). If the measurements exceed the limits, they should be monitored and analyzed further. After the source of the problem has been determined, you can choose how best to repair the defect. If engineering limit is quite low, it will be enough time to fix the problem before further damage occurs and, to this end, there must be a demand for repair. The

equipment must return periodically monitoring program [1].

## II. STUDY CASE WITH THE ANALYSIS OF THE TREE TECHNIQUE BASED ON THE SYMPTOMS, DEFECTS AND CAUSE

In this study case is presented a technique for make the maintenance predictive based on the tree analysis. To make this type of the analysis is necessary to know the defects, symptoms and causes. This study is applied particular for a single-phase inverter.

### *Description of the analysis symptoms and causes defects*

After a while which is monitored the electronic equipment, a data base with results obtained is created.

This data base represents the defects and symptoms. With these data is possible to create a tree analysis starting from the causes to the defects.

In figure 1, it is presented a tree analysis.

The defects, symptoms and causes are interconnected and help to understand the possible causes for damage and to prevent them [5]. After is make the analysis is resulted a table with a possible causes. In according with the table is created a software program in the PLC (Programmable Logic Controller). The PLC is able alone to take a decision when is detected one of the error which is declared in the soft. This error is detected with tree analysis.

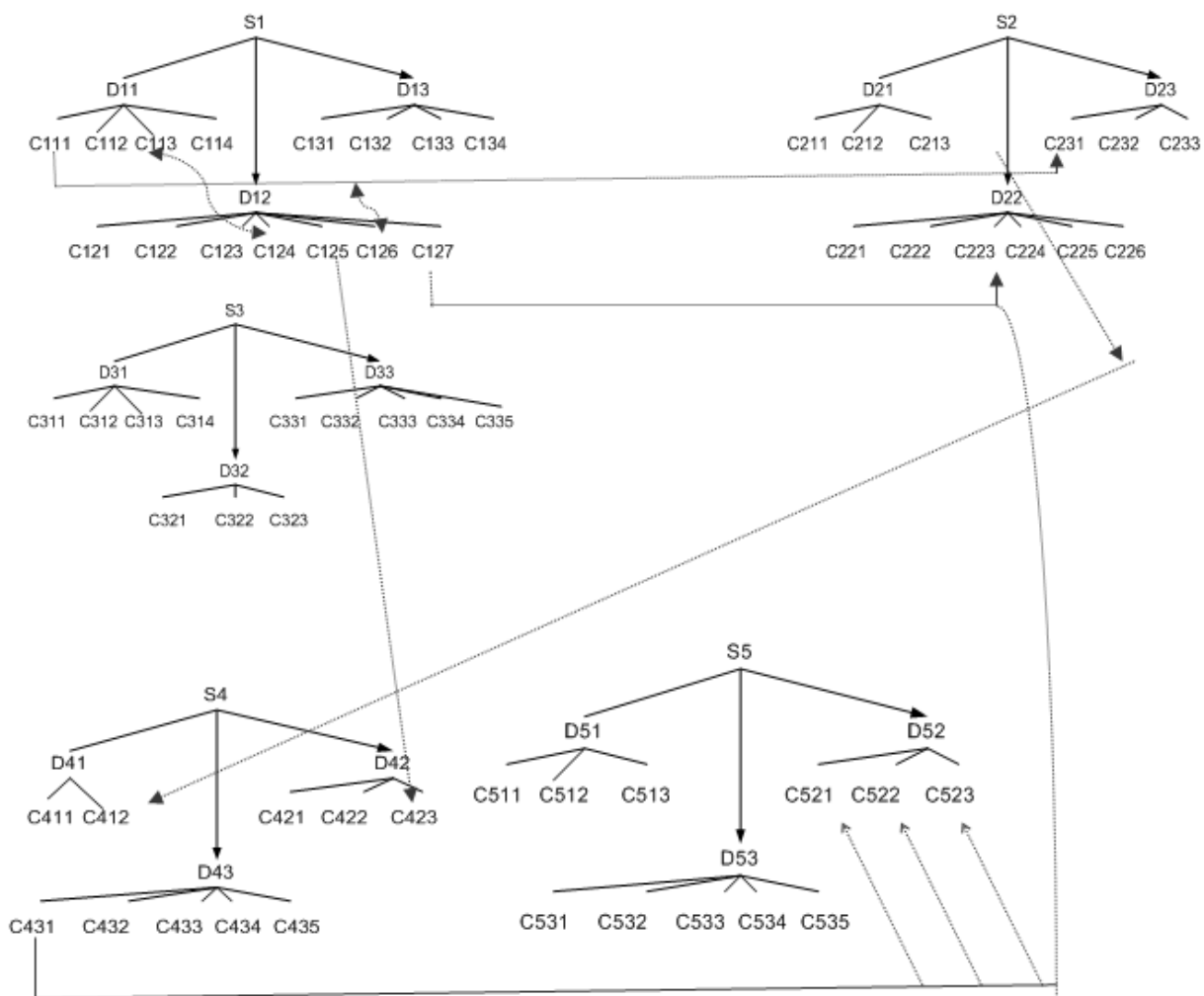


Figure 1. Diagram of the tree analysis with defects, symptoms and causes

In Table 1 it is presented an interconnection of the defects - causes in the structure of the PLC system. Also in the input of the PLC are connected the sensor who perform the check of the parameter and on the output is the message and the action who is realized after the sensor is made the checks. So, for each sensor is assigned a input on the PLC, which is interconnected with one output.

Checking is done within the limits set. These limits are set by operator after he consults the tree analysis.

The advantage to use this concept is because the operator is set a limit of the parameters after a lot off checks. These checks are done once with the tree analysis and once with the software and hardware structure of the PLC.

Nr. faulty	Causes	Type of faulty	IN	POSSIBLE CAUSES	OUT / message alarm
1.	External causes	No voltage output	I05 (voltage check)	Cable network interrupted	D01 (error display power) Q02 (warning light) Q01 (connection / disconnection inv.)
	External causes		I07 (voltage test)	Input fuses burned (faulty)	D02 (display no phase voltage) Q02 (warning light) Q01 (connection / disconnection inv.)
	External causes		I08 (frequency wrong)	Mains transformer fault	D06 (display freq. Error) Q02 (warning light)
	External causes		I05 (voltage check)	absence (Lack ) phase or null	D01 (error display power) Q02 (warning light) Q01 (connection / disconnection inv.)
	Mixed cases		I07 (voltage test)	Broken all fuses or all diodes	D02 (display no phase voltage) Q02 (warning light) Q01 (connection / disconnection inv.)
2.	External causes	low voltage level	I07 (voltage test)	Voltage oscillation	D07 (voltage display erroneous) Q02 (warning light)
	Internal causes		I07 (voltage test) I12 (thermometer)	Damage of a diode	D07 (voltage display erroneous) D09 (temperature display) Q02 (warning light)
	Internal causes		I11 (a current transmitter)	Damage fuse	D08 (current error display) Q02 (warning light)
3.	External causes	High voltage level	I05 (voltage check)	Mains voltage higher than the nominal	D01 (error display power) Q02 (warning light)
	External causes		I07 (voltage test)	The appearance of resonance voltage	D07 (voltage display erroneous) Q02 (warning light)
	External causes		I07 (voltage test)	Voltage oscillations	D07 (voltage display erroneous) Q02 (warning light)

Table 1. Structure of the tree analysis using the PLC

### III. STUDY CASE FOR PREDICTIVE MAINTENANCE BASED ON EQUIPMENT TYPE SIMOCOD WITH DIAGNOSTIC AND MONITORING MANAGEMENT INCLUDED

Using the equipment for predictive maintenance has enjoyed an increased lately, although currently the technology is too expensive, and the installation process can be lengthy.

The case study for diagnostic a motor three - phase asynchronous has been used a SIMOCOD module. The data recorded in this module is acquired using several sensors such as: sensors for temperature, inductive sensors, monitoring electrical phase.

To identify the defects it must needed to monitor a lot of parameters. The monitored parameters for a three-phase asynchronous motor are:

- Monitoring temperature of the motor;
- Partial discharge monitoring;
- Noise and vibration of the motor;
- Monitoring the speed and torque of the motor;
- Monitoring the absence of voltage at the terminal of motor;

- Monitoring the trends of the all 3 phase of the motor.

In Figure 2 is presented a block diagram of diagnostics for an electric motor using a SIMOCOD module. This scheme includes sensors for speed, torque, power and inductive with which it acquires data from motor. These data are transmitted to SIMOCOD module using the communication protocol PROFIBUS, Ethernet or IO-Link.

All these parameters are analyzed using logical blocks. Based on these logical blocks the SIMOCOD module can take a decision. To monitoring or change some data of the parameters, or limits is must need a connection to the PC, because is exist a series of interface for the SIMOCOD module. Also the diagnosis is done with these interfaces. The internal program is created in the dedicate software named PC-S7, these software is created with Function Block (FB) to understand more easy the logical scheme.

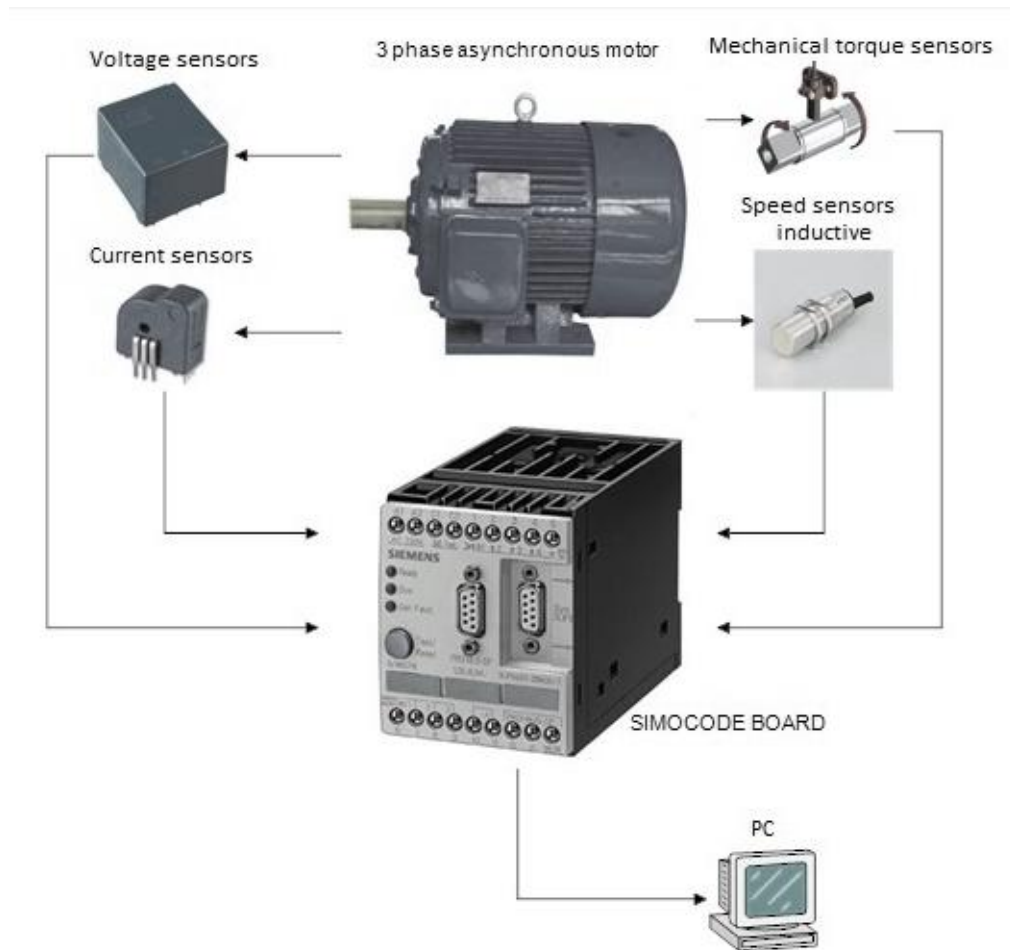


Figure 2. Diagnostic block diagram of a DC motor with permanent magnets with a module SIMOCOD

The purpose of using this application is the prevention the damages of the components by setting certain operating parameters of the electrical motor. The monitoring of the work regime of a motor three-phase can be done using the interface presented in figure 4.

The monitoring of the work regime of a motor three-phase can be done using an interface presented in figure 4. This monitoring is for all 3 phase of the motor. If exist some imbalance in amplitude are signaled immediately because has exceeded their limits. This monitoring it is realizing on-line. These techniques are monitoring the motor in time and prevent a possible fault of the motor.

To achieve prevention in the case of an electric motor, the SIMOCODE allows settings a limit for operation. These settings are set in an interface presented in figure 5.

This module has the possibility to set the following settings:

- The maximum current of the stator;
- Temperature range at which the engine to stop;
- The emergence imbalance between phases (the limit that is allowed without affecting the smooth functioning of the motor);
- The number of operating hours;
- number of starts of the motor;
- Starting the motor type - star – triangle;
- Speed of the motor and the ramp for converter.

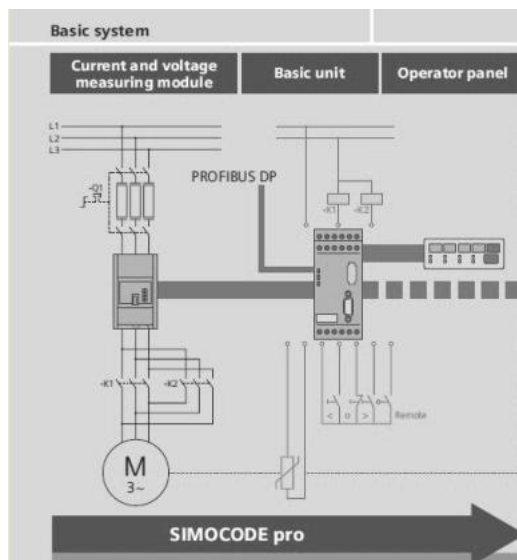


Figure 3. Basic System with a SIMOCOD module [7]

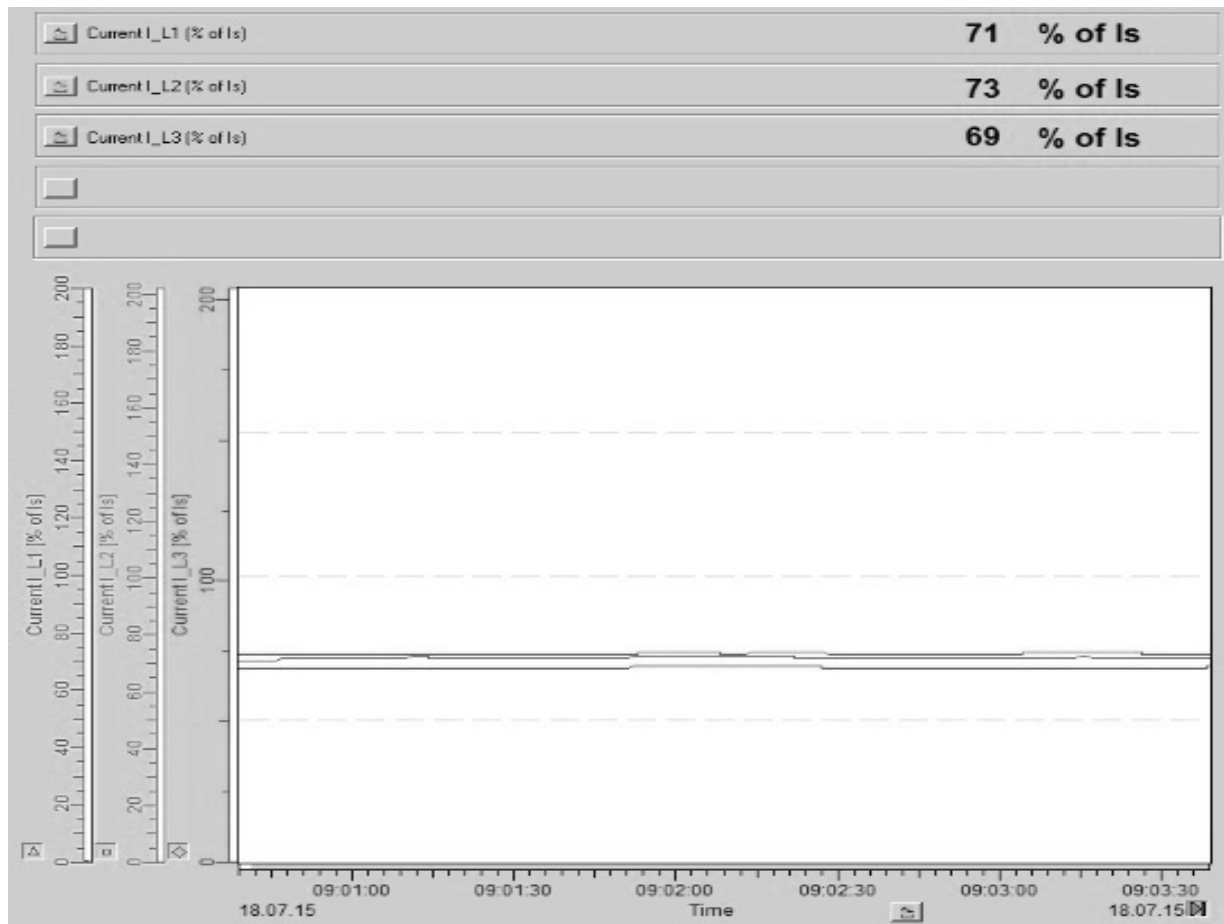


Figure 4. Interface for monitoring the amplitude of all 3 phase for a electrical motor

**Current Limits**  
(Monitoring of max. Current I<sub>max</sub>)

I > (upper limit)

Trip Level  % of Is

Response at Trip Level

Trip Delay  s

Warning Level  % of Is

Response at Warning Level

Warning Delay  s

I < (lower limit)

Trip Level  % of Is

Response at Trip Level

Trip Delay  s

Warning Level  % of Is

Response at Warning Level

Warning Delay  s

Figure 5. Interface to set the operating parameters of a three-phase motor

The software at the SIMOCOD allow create a page for monitored continuously the vital functions and parameter. These parameters and functions are introduced in maintenance page. This page for maintenance is presented in figure 6.

To prevent a possible damage for an electric motor is created a interface which established a lot of protection for the motor such as:

- Change status of the motor (ON, OFF, slow, fast);
- Set the currents limits for all 3 phase and set the maximum current;
- The maximum voltage for each phase;
- Set the operation time;
- Set the working temperature depending the motor type;
- Set the time required cooling after overheating the motor.

This page is presented in figure 7.

**Faults** | **Warnings** | **Status Information**

☐ General Fault      ☐ General Warning

Controlling	Protection	Monitoring	Miscellaneous/General
<input type="checkbox"/> Execution On-Command <input type="checkbox"/> Execution Stop-Command <input type="checkbox"/> Feedback On <input type="checkbox"/> Feedback Off <input type="checkbox"/> Test Position Feedback (TPF) <input type="checkbox"/> Power Failure (UV0)  <input type="checkbox"/> Stalled Positioner <input type="checkbox"/> Double 0 <input type="checkbox"/> Double 1 <input type="checkbox"/> End Position <input type="checkbox"/> Antivalence	<b>Overload</b> <input type="checkbox"/> Overload <input type="checkbox"/> Overload + Loss of Phase <input type="checkbox"/> Unbalance <input type="checkbox"/> Stalled Rotor  <b>Thermistor</b> <input type="checkbox"/> Thermistor Trip Level  <b>DM-F LOCAL/ DM-F PROFIsafe</b> <input type="checkbox"/> Safety-oriented tripping  <input type="checkbox"/> Wiring <input type="checkbox"/> Cross circuit	<b>Current Limit</b> <input type="checkbox"/> Trip Level I> <input type="checkbox"/> Trip Level I<  <b>Earth Fault</b> <input type="checkbox"/> Internal Earth Fault <input type="checkbox"/> External Earth Fault <input type="checkbox"/> Open Circuit <input type="checkbox"/> Short Circuit  <b>Power</b> <input type="checkbox"/> Trip Level P> <input type="checkbox"/> Trip Level P<  <b>Voltage</b> <input type="checkbox"/> Trip Level U<  <b>Power Factor</b> <input type="checkbox"/> Trip Level CosPhi<	<b>External Fault</b> <input type="checkbox"/> External Fault 1 <input type="checkbox"/> External Fault 2 <input type="checkbox"/> External Fault 3 <input type="checkbox"/> External Fault 4 <input type="checkbox"/> External Fault 5 <input type="checkbox"/> External Fault 6  <b>Watchdog (Bus / PLC/DCS)</b> <input type="checkbox"/> Bus <input type="checkbox"/> PLC/DCS  <b>Hardware</b> <input type="checkbox"/> Hardware Fault Basic Unit <input type="checkbox"/> Module Fault <input type="checkbox"/> Temporary Components <input type="checkbox"/> Configuration Fault

Figure 6. Interface for maintenance

**Overload Protection**

Set Current Is1: 15.00 A  
 Transformation ratio - active: ☐  
 Transformation ratio - primary: 0.000  
 Transformation ratio - secondary: 0

Set Current Is2: 0.00 A  
 Transformation ratio - active: ☐  
 Transformation ratio - primary: 0.000  
 Transformation ratio - secondary: 0

Class: 10  
 Response at Trip Level: tripping  
 Cooling Down Period: 300.0 s  
 Pause Time: 0.0 s  
 Type of Load: tri-phase  
 Response at Pre-Warning Level (I>115%Is): warning  
 Pre-Alarm Delay (I>115%Is): 0.5 s  
 Reset: Manual

**Unbalance Protection**

Level: 40 %  
 Response: warning  
 Delay: 0.5 s

**Stalled Rotor**

Level: 0 % of Is  
 Response: disabled  
 Delay: 0.5 s

Figure 7. Setting page for protection the electric motor

To prevent the damage to other components when the motor is damaged the SIMOCOD module have possibility to create a page for initialization. This page for initialization the motor make an interrogation

of all sensor and in function of the response received, the module decide if is right to start the motor. These page is presented in figure 8.

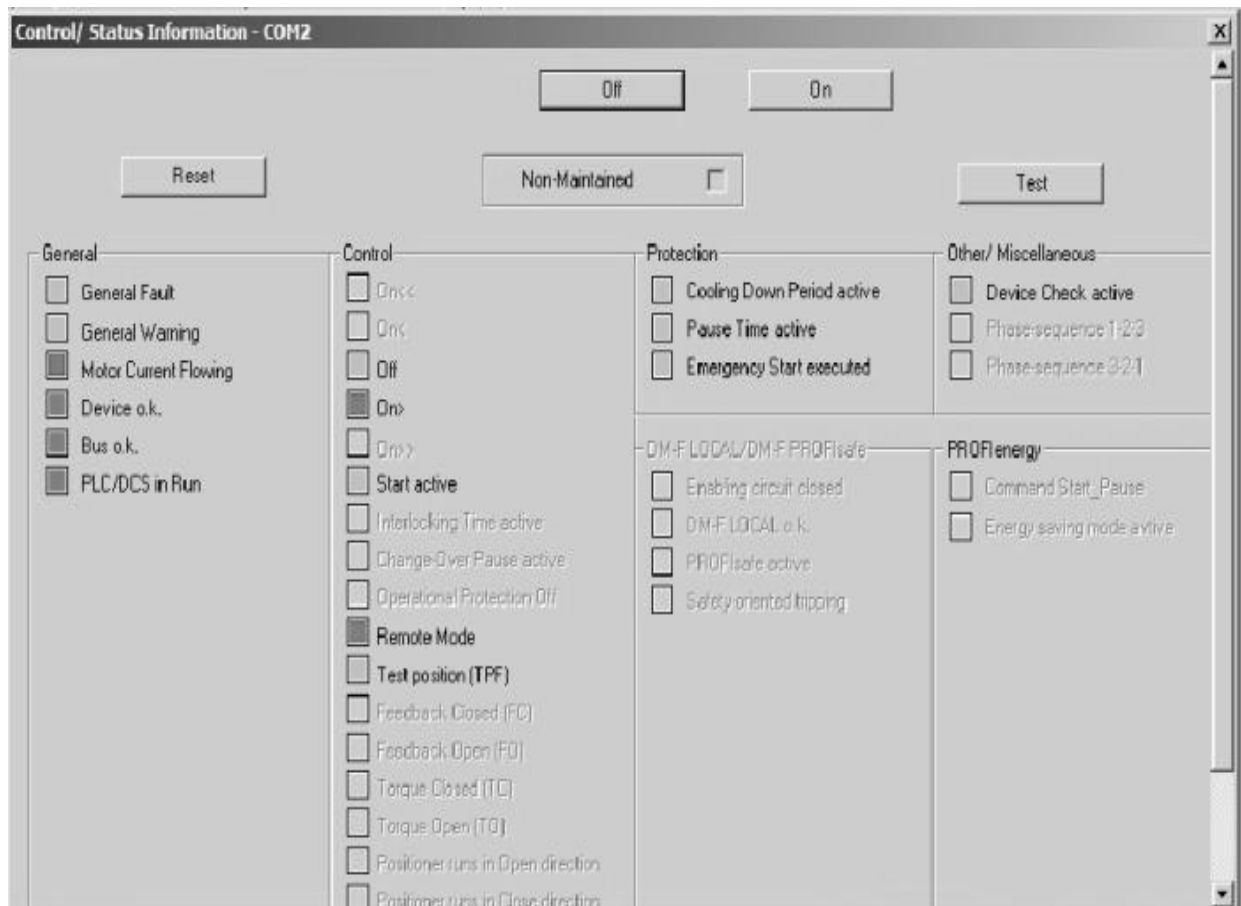


Figure 8. Page for initialization

Another advantage to use the SIMOCOD module for predictive maintenance is represented the speed process for parameterizing.

The process it is very fast because it is possible to copy and transfer in the same directory. It is possible to copy the parameters at a old motors and put the same parameters at a new motors.

The memory of the SIMOCOD is structured on the module.

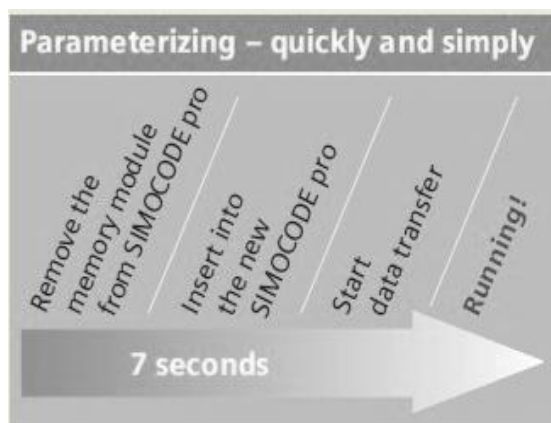


Figure 9. Parameterizing process [7]

A logical program is needed to be created when the SIMOCOD module is used in the maintenance predictive process. The schematic block language is used for an easy diagnostic.

In figure 10 is presented a diagram block for software using in process for maintenance predictive. These diagram contains blocks for command or

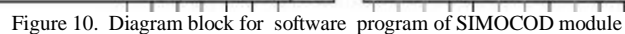
decision, in the left side is presented the input block in the center are the blocks for control, protection and in the right part is the decision block and the output blocks, communication blocks and the block for indicator lights for alarms.

In block for enhanced protection is presented the value limits for operating and also is show if this value is in range or not. In the software configuration is exist the possibility to enter a block which is connected to the control block, that can turn off the motor when one of the parameters set is out of set range, all these action for protect the electrical motor.

Also when is detects one alarm, the interconnection line between connection the input block (signal from the sensor measure of current), control block and the extended protection becomes red as is illustrated in figure 11.

At the same time on the display is showing an error message with short description of the defects. In the control block is set a parameter for stop the motor if the alarm have a high importance.

The SIMOCOD module it has the ability to decide the importance of alarms after a classifications declared by the operator.





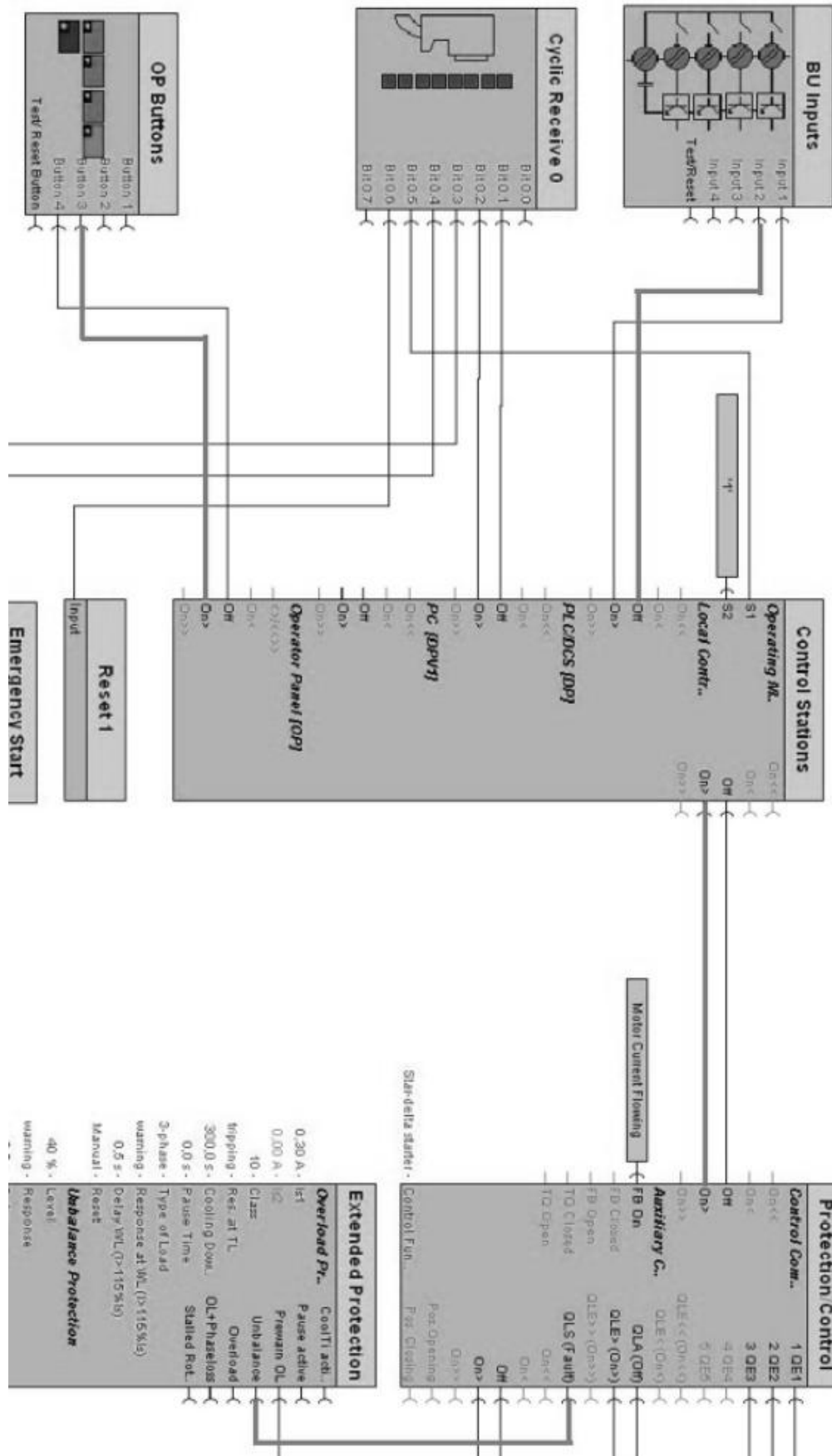


Figure 11. Indication a fault in the diagram block of the SIMOCOD module with a red line

## IV. CONCLUSION

Maintenance is a generic term for a variety of operations in different sectors, including the industry, and is applied in all kinds of environments.

The maintenance is essential to ensure the continuity of production to manufacture high quality products and maintain the company's competitiveness, the impact on health, and safety at work.

In the last years, the diagnostic techniques for monitoring the process, in order to apply the advanced predictive maintenance techniques based on electronic equipment, were moved from the traditional methods to Artificial Intelligence techniques, which use Neural Networks and Fuzzy Logic Systems.

It is increasingly recognized that most techniques based on artificial intelligence have, besides the advantages, certain drawbacks. Thus, a hybrid approach of the diagnosis is better to be used.

The main contribution of this paper is the comparative design of diagnostics interfaces into various programs dedicated (such as PC - S7 and SIMOCOD) to highlight the differences in monitoring and signaling of the faults. The user interface contains various parameters in the settings page, including the limits in on-line operation and diagnosis of the electronic equipment.

It can be noted that the both methods has clearly advantages in prolonging the service life for the electronic devices monitored, even if both use only traditional maintenance methods. A comparative analysis between traditional and advanced maintenance methods will be realized in next paper.

## A. Abbreviations and Acronyms

PLC - Programmable Logic Controller  
 FB – Function Block  
 PDM – predictive maintenance  
 RP – partial revision  
 RC1/ RC 2 – repair of grade 1 or 2  
 R – general revision - overhaul

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