Strategy for Implementation and Use of Monitoring Systems for Gear-Motors

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Abstract: *The article describes the strategy of implementation and use of a monitoring system that specifically targets the moto reducer assemblies used in many equipment and machinery in various fields. The article presents the architecture of a monitoring system and how to achieve the system. The testing of the system on a firewood-breaking equipment made within a project developed by the company together with INOE 2000-IHP is also presented.*

Keywords: *System monitoring, moto reducer, maintenance*

1. Introduction

In recent years, the increase in the technical and technological level has had a strong impact on all branches of industry. At the same time, mass production imposed the maximum reduction of the operating costs of machinery, production lines. This is how the phrase "Maintenance free" appeared more and more frequently without maintenance, or "Low Maintenance", with low maintenance, in the marketing plan of the products. This phrase is based on the consideration of a normal period of life of a product, strict operating conditions. Real life shows us, however, that the equipment is used far beyond the normal period declared by the manufacturer and the operating conditions often exceed the limits imposed by the manufacturer and designer. This brings to the fore the maintenance of the equipment, which, however, must be done in the conditions of limiting the operating costs. It has been shown that the "fault intervention" strategy, reactive maintenance, is a particularly expensive one, especially given by the costs of equipment downtime, loss of production.

The widely used maintenance strategies are periodic, corrective maintenance and predictive maintenance. Periodic maintenance is based on maintenance schedules given by the manufacturer with periodical revisions, changes of parts and consumables. Periodic maintenance imposes important operating costs given by the downtime, the change of some subassemblies and consumables before reaching the necessary wear due to the operating conditions, or the failure of the equipment between the revision periods due to the exceeding of some technological limits in operation [1].

2. Predictive maintenance

Predictive maintenance is based especially on adapting the schedules of maintenance actions based on the real operating conditions and the real condition of the equipment in order to prevent failure and reduce both maintenance costs and costs imposed by repairing after defect of an equipment.

In order to have an efficient predictive maintenance, the essential condition is the correct monitoring of the equipment, the target both in terms of operating conditions and in terms of the state of real wear and probability of failure.

Monitoring in operation by non-invasive means is essential to obtain the statistical data necessary for a correct evaluation necessary for planning predictive maintenance.

Monitoring in operation requires the reading of some operating and operating parameters continuously with an acquisition rate that is relevant for the tracking wear phenomena.

3. Monitoring a moto reducer

The monitoring of a moto reducer is done throughout its life in order to verify the operating conditions, to estimate the usages and the life span, to replace the worn elements, in order to preserve the characteristics necessary for the good functioning. After mounting the moto reducer in the installation, the alignment of the axes, noise and vibration of the system are checked. Both before and after the run-in (where necessary), the most important parameters are checked in the void and in the load, namely the working temperature and the absorbed currents that correspond to a certain moment necessary for the application. These measured initial parameters allow us to report the values measured later to the initial values and to detect wear and tear of certain components, aging or oil leakage, decommissioning of auxiliary equipment such as forced ventilation, cooling installations, accidental loads, etc. [1].
The reducers contain gears that undergo wear over time; wearing and tearing are influenced by the number of cycles, speed, and operating temperature, type of lubricant, the number of starts-stops and the number of changes in direction. If the wear of the cemented gears is hardly noticeable, at the molten gears the wear is more pronounced and can be checked by checking the clearance.
The gears are mounted in the housing together with their axes on the bearings. Bearings also suffer wear and tear that are depending on the number of cycles, speed, applied forces, their position relative to the oil bath, the lubricant used, and the lubrication mode of the bearing.
Lubrication of gears and bearings is made depending on the type of gear, gauge and shape of the reducer, mounting position. The oil is also subject to wear and is influenced primarily by the working temperature and the maximum working temperature [2].
Periodic checking of the seals is then required. Seals on moving axles are the most exposed to wear and depend on the spindle speed at the contact points, the type of lubrication and the quality of the lubricant, the temperature and working conditions (dust, aggressive environments, sun).
It is checked the mounting of the motor on the reducer, the correct tightening of the screws, the wear of the input shaft and the wedges, the absence of abnormal vibrations and noises, the output shaft from the reducer and the alignment with the driven machine.
In the motor, the absorbed current is measured on each phase and checked with the one listed on the engine label but also with the one initially measured when the empty and load tests were made and the operating temperature is measured and checked compared to the initially measured temperature.
Two parameters are those that monitor the moto reducer behavior very well: the effective power and the working temperature. Sharp changes in them are signs of wear and tear of the engine. Parallel interpretation of the power and temperature measured over a long period of time can create a model for determining the type of wear existing in the gear motor.
Classic monitoring is done (visual – monthly), oil change (if applicable) between 3000 and 10000 hours of operation. Next, we propose a monitoring system with the recording of the electrical parameters for the motor and the temperature at several points of the reducing motor assembly.

4. Architecture of the monitoring system

The monitoring systems in operation are based on an architecture with distinct layers of data acquisition and processing taken from the target equipment. The system uses a set of sensors that take information from the system in operation, archive the acquire data in a database from where it is read and processed in order to obtain high-level data useful in maintenance and production management.
The arch must be open, scalable, and capable of being expanded with new sensors, new recorded sizes and new processing modes for finding top-level data relevant to the state of operation and use of the system under control. The architecture is structured on several functional levels that cover specific functionalities within the monitoring system.
The architecture of the system has three main levels:

1. Sensor system
2. Communication network
3. Data processing module

5. Levels

5. 1 Sensor system

The sensors transform the monitored specific sizes into electrical signals that can be taken further for monitoring.
The sensors used in this application are sensors with WiFi communication produced by Shelly Cloud Bulgaria. The sensors used are intelligent sensors based on SoC microcontrollers, system on a chip, from express if's ESP8266 family. These sensors run an application that allows them to have a WEB interface for configuration and monitoring. ESP8266 systems have also implemented a TCP/IP stack and hardware needed to connect to a Wifi network in the 2.4 GHz band [3], [4]. At this level of system development, two types of electrical and temperature sensors are used.

1. Electrical sensors

The electrical sensor is Shelly 3EM that allows measuring the voltage in the three-phase supply network of the motor as well as the current consumed by each phase. For reading the current, current transformers are used transducers capable of correct measurement up to 120 A.

The sensor acquires all six of these vector sizes with a cadence of two measurements per minute. All the sensor makes the necessary calculations to indicate the power consumed on each phase and the power factor. It is also possible an accumulation to indicate an energy used over a certain period of time.

2. Thermal sensors

The thermal sensor is Shelly 1 with temperature measuring mode that allows the acquisition of three temperatures, in three points with semiconductor sensors of type 18S20 in cases with IP67 degree of protection. Temperatures are read with a cadence of one measurement per minute.

3. Other types of sensors

The system is open and can take signals from other types of sensors as long as they can communicate in the WiFi network with an open API or on one other of the protocols supported in the system.

5. 2 Communication network

The communication network used in the application is a local WiFi network, used only by the application components.
Communication is done in TCP/IP network protocol. Over the TCP/IP protocol, the sensors communicate with the upper level through the MQTT open protocol. MQTT is a publish/subscribe protocol in which a data source, a sensor in our case publishes information to an MQTT Broker. The MQTT broker is a software that records all data sources, receives the information sent by the data sources and publishes it to all destinations that have subscribed to a particular topic. The MQTT protocol is in agnostic protocol to the content, thus being able to transmit various types of information organized only on data topics. All components of the monitoring system connect to a local network that ensures communication between them.
The local LAN network is controlled by the microtik Hap Lite RB941 Access Point router that ensures the management of network functions:

1. Authentication of clients in the WiFi network
2. Automatic allocation of addresses in the local network through DHCP protocol
3. Network Address Translation function to be able to connect the local network to the internet
4. Firewall function to protect the internal network from attacks from the Internet
5. Port forwarding function to make available resources from the local network to the Internet to allow access to data collected and processed by the system from the Internet

All sensors connect to the WiFi network and automatically receive IP addresses from the Microtik router [5].

5. 3 Data processing module

The data processing module is implemented with a SoB, raspberry pi 4 on board system with 4GB of RAM that provides all the necessary functions for the application:

1. Data collection
2. Storage
3. Data processing.

On the Raspberry Pi runs the Raspbian operating system along with the applications necessary to ensure the above functions. In order to ensure easy replication of the system, a solution was chosen to use docker containers with the necessary applications. Under these conditions, only a compose file for the Docker Compose applications required to replicate the application. The compose file that was written specifically for this application has the YAML format. It allows downloading from the internet the necessary Docker containers and linking them to ensure the operation of the application.
The management of the installed containers can be done through the web interface of the Portainer-CE application.
The use of containers for the various applications necessary for the monitoring system was made in the idea of an easier replication process of such systems and the generation of systems adapted in more detail to the requirements of various applications of the end users.

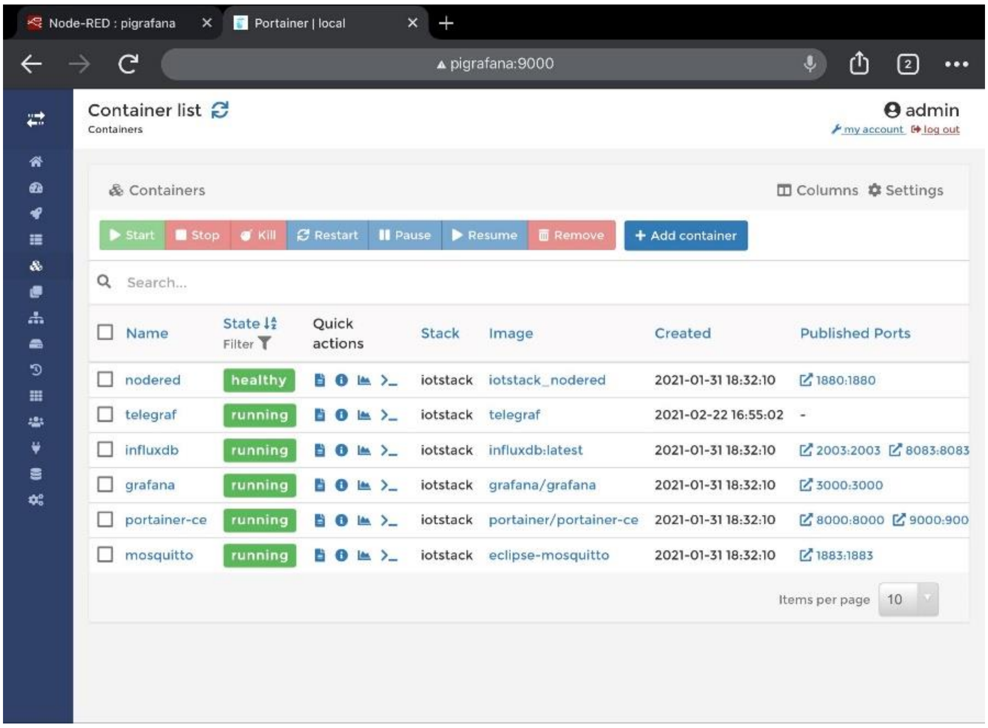

Fig. 1. Application with web interface for container management Portainer CE

5.3.1 Data collection operation

The data collection function allows retrieving data from sensors with the cadence of one measurement per minute. Each sensor is programmed to transmit once a minute the data measured by MQTT protocol.
In order to use the MQTT protocol, it is necessary to use a Broker that takes the data published by the sensors and transmits it to the applications that have subscribed for receiving the data in question. The MQTT broker is provided by the open source Mosquitto application that runs in a Docker container [6].

Within the data collection function is also the node-red opensource application that allows the graphic realization and running of NodeJS applications. The function of the Node Red module is to connect to the MQTT Broker and process the primary data received from the sensors in order to be stored in a database in a unitary way.

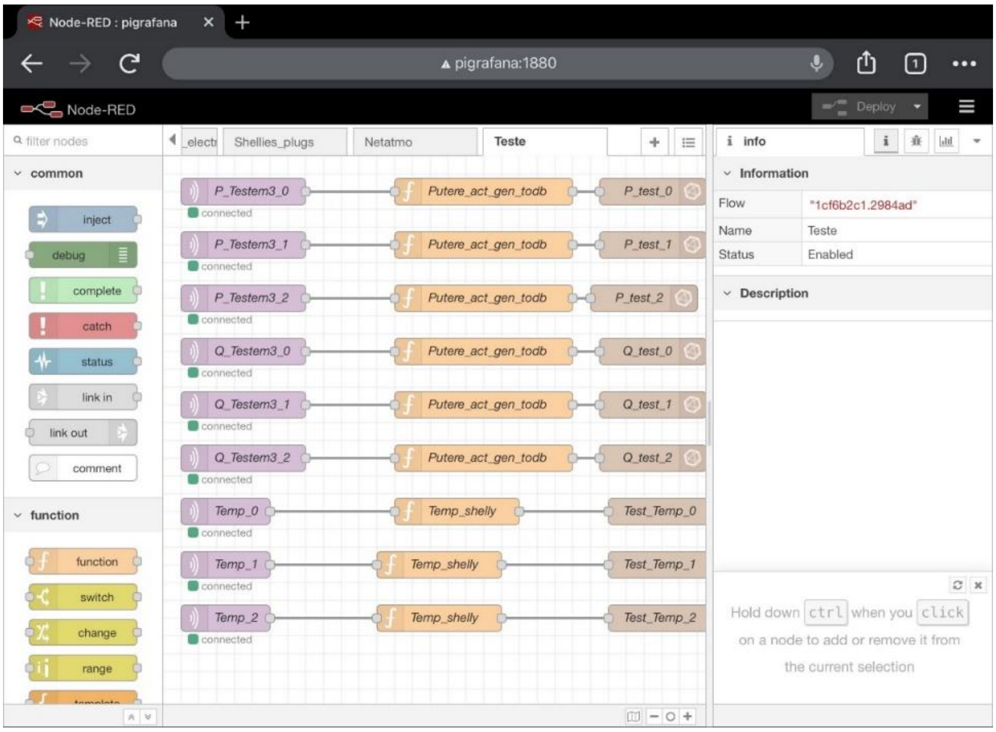

Fig. 2. Node-Red graphics application

5.3.2. Storage function

The storage function is provided by a temporal database of type InfluxDB that retrieves the data processed primary by the Node-Red module to apply it a timestamp and stores it. InfluxDB also runs in a Docker container and stores the data on the 64GB SD card in the Raspberry Pi. The InfluxDB database is of the opensource type with a high similarity with SQL databases.

5.3.3. Data processing function

Most of the data processing function is provided by the opensource Grafana application. Grafana is connected to the InfluxDB database, retrieves the data and displays it based on "dashboard" programmed specifically for this application in public web pages. The Grafana app can be programmed to give warnings and alarms when exceeding certain thresholds specified for the measured data.

The data in the InfluxDB database can be processed through specific mediation functions, maximum memorization.

Grafana was scheduled in this case to determine certain abnormal cases such as:

1. Exceeding the phase current absorbed by the motor
2. Uneven current consumption in motor phases
3. Uneven voltages applied to the engine
4. Exceeding normal operating temperatures at various points of the main motor assembly.

The values of the alarm thresholds can be easily modified depending on the specific requirements of the use of the motor [7], [8].

The alarms are stored by Grafana and are sent in various ways to a user designated to evaluate the system's operation. In our case, notifications are sent by e-mail and through the Telegram instant messaging system using a so-called BOT, a message transmission robot. These alarms, alerts can be received on any portable device running a Telegram client or email.

6. System realization

The monitoring system is made in two separate boxes with a sufficient degree of protection for placement within the monitored application.

6.1 Monitoring module

The monitoring module is placed near the monitored conductive motor assembly, and the connection of the motor is made through it to take over the current voltage electric parts necessary for the analysis.

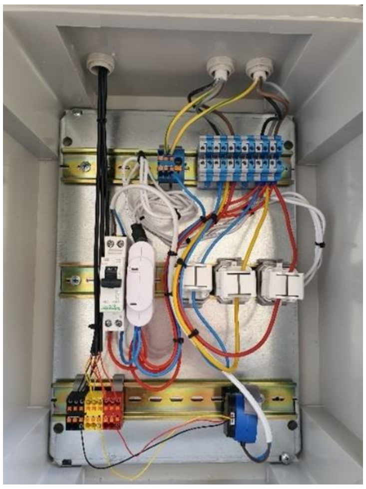

Fig. 3. Monitoring module

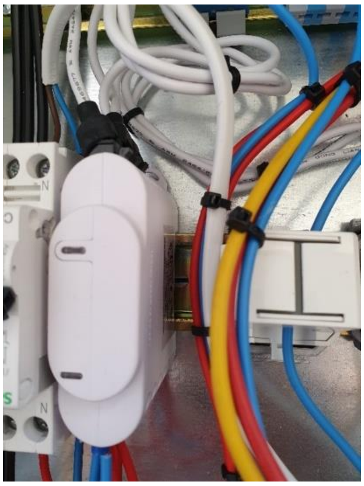

Fig. 4. Electrical size transducer

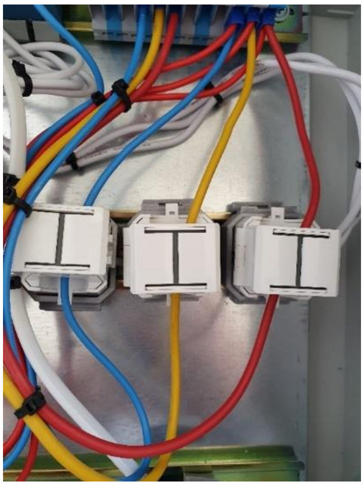

Fig. 5. Current transformers 120A

For the acquisition of temperatures, a device is used that reads OneWire sensors and transmits the readings also read via WiFi to the control module.

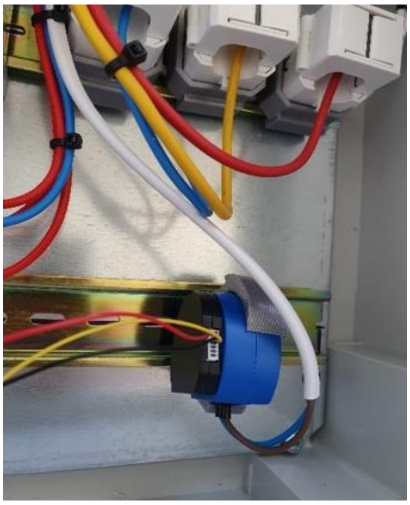

Fig. 6. Temperature transducer

Fig. 7. OneWire IP67 temperature sensor

6.2 Control module

In the control module take place the recording, processing, primary analysis of the data measured and stored in the database.

Fig. 8. Control module

Fig. 9. The Processing Computer Raspbarry Pi 4

The continuous control module the router that ensures Wifi communication with the rest of the monitoring modules and the Single Board Computer of Raspberry Pi 4 type that stores the data and processes it according to the processing levels described above.

7. System testing

The testing was done in this case on a moto reducer assembly with a 2.5 Kw motor and a molten reducer. The electrical sizes and temperatures at various engine charges were read. The data was acquired in the control module and was displayed in the panels generated by Grafana [9].

Fig. 10*.* Tested system

Fig. 11. Tests and measurements

Fig. 12. Measurements of current, voltage, powers, power factor

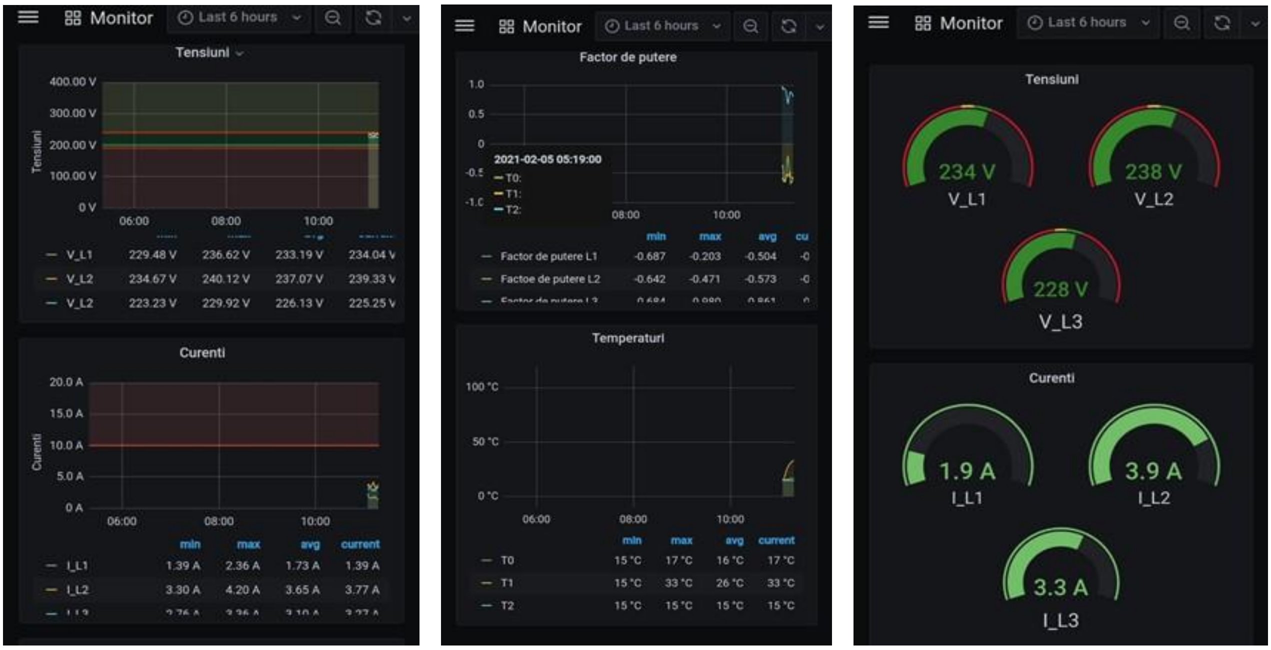

Fig. 13. Various data display panels

8. Conclusions

The monitoring system allows the acquisition and recording of the main electrical parameters and temperatures from a main motor assembly, their storage in a temporal database and their graphic display at the same time with the alarm of exceeding some predetermined values.

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