MODERN MONITORING AND CONTROL SYSTEMS FOR HYDRAULIC POWER UNITS

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ABSTRACT
The modern hydraulic power unit is not just the tank, pump, drive motor, the basic armature and components for ensuring the cleanliness level of the media and security as well. They need to be equipped with multiple sensors that provide not only safe operation of the power unit, but also help reduce operating and maintenance costs, extend the life of the entire hydraulic system and provide the full control over the operation.
Sensors themselves, like pressure sensors, temperature and liquid level, filter blockage,... unfortunately are not sufficient enough for reliable operation of the hydraulic system. Available signals from the sensors need to be reasonably used in the context of an appropriate control and supervisory of the power unit and measured parameters should appear on a suitable interface for visualization (HMI). As an upgrade of the system it is also desirable to the record signals and accesses their history via the Internet with a wired or wireless connection. This type of interaction with appropriate number of modern sensors and designed control system is the only way to provide reliable operation of complete hydraulic power unit and control system. The implementation of such system, including the condition monitoring of the built-in hydraulic fluid is addressing this paper.

Keywords: hydraulic power unit, monitoring and control system, visualisation

1. INTRODUCTION
There are many hydraulic systems and each of these systems contains a hydraulic power unit (hydraulic aggregate). The functioning of the power unit is essential for the proper functioning of the entire machine or machinery. In order to achieve complete control of a hydraulic power unit, we need a modern control system and an on-line condition monitoring system.
Nowadays the modern hydraulic power unit is not just a set of parts consisting of a tank, pump, drive motor, the armature, and other basic building blocks for ensuring the cleanliness of the media and basic security, but it is equipped with multiple sensors that provide not only safe operation of the power unit but also help in reducing operating and maintenance costs and extends the life of the entire hydraulic system.
Sensors themselves, such as pressure sensors, temperature and liquid level, filter blockage ... are unfortunately insufficient for reliable operation of the hydraulic system. Available signals from the sensors must be used reasonably within the context of an appropriate control and supervision of the power unit and measured parameters should appear on a suitable interface for visualisation (HMI). As an upgrade of the system it is also desirable to record signals and access their histories via the Internet with a wired or wireless connection. This type of

interaction with an appropriate number of modern sensors and designed control system is the only way to provide reliable operation of a complete hydraulic power unit and control system. In most cases, today's hydraulic power units control systems are equipped with simple monitoring and control systems that are based on low-performance programmable logic controllers and a small (usually two line) LCD display, if any. Such-like equipment, as shown in Figure 1, is suitable only for basic controlling and monitoring functions of the power unit.

Figure 1. Typical examples of hydraulic aggregates' control units

In order to achieve complete control over a hydraulic power unit, it is necessary to upgrade it with a more powerful control unit in combination with an appropriate HMI, and also to implement a system for on-line condition monitoring of all important parameters, including the condition of built-in hydraulic fluid (in most cases mineral-based hydraulic oil). These two additions to the system should also be covered when upgrading the entire control and monitoring system.

2. POWER UNIT STRUCTURE

An industrial power unit consists of mechanical and sensor/electrical parts. The mechanical part consists of components which are used for energy conversion and the conditioning of hydraulic fluid: hydraulic pump, electric motor, components of a cooling-filtration system, heater, filters and a hydraulic tank. All these elements need to act together to ensure a stable, safe and flawlessly operation of the hydraulic power unit and the whole hydraulic system. This is especially true for special designs of power units, running under special conditions or 24/mode.

Here discussed hydraulic power unit has a dual motor pump drive train, each with power of a 15 kW. A simpler drive train is a combination of an induction electric motor with a constant rotational speed in combination with a constant pump, while a second drive train is a combination of speed-controlled electric motor and a variable axial piston pump. The latter drive combination allows, due to its configuration, the use of the most efficient energy saving hydraulic supply system: the so-called maximum efficiency supply concept [1]. In this case both components are controlled; electric motor by a frequency converter and the variable pump by a powerful microcontroller system with numerous additional functions fitted. For this reason the components of the pump-control-system are placed in their own control cabinet (Figure 2).

Figure 2. Supply and control system with a 2x15 kW power train

Due to its structure and mode of operation, the power unit requires an appropriate cooling-filtration system and the monitoring of all important operating parameters. To ensure the cleanliness of the media there several filters are installed. A 10 µm filter on the return line as basic filter has the task of filtering larger particles (the continuous functioning mode) and the 3 µm filter on the cooling filtering unit is a bypass filtering function (switched on when necessary). Both filters are equipped with an integrated filter-clogging indicator/switch. High-pressure filter can be installed on the hydraulic power unit optionally and is particularly needed in cases of those exceptional cleanliness levels required (servohydraulic). In this case, when designing the control-monitoring system is this possibility necessary to equip: an available free place to connect the high-pressure filter sensor and incorporate its signal into the control system program.

2.1 Sensors on the hydraulic power unit

In addition to the sensors installed on the filters, there are more sensors installed on the tank, that allow insight into the condition and operation (operating conditions status) of the entire supply system as well the status of the actuators. These are sensors for pressure (suction and load pressure: EDS 3000), fluid temperature/switch (ETS 3000), fluid level sensor with four switching points with additional warning signal and temperature signal (ENS 3000), ... and as aggregate's actuators, by which we influence the state of the system: a cooling fan drive, the by-pass filter circulation pump, heater, on/off of constant pump or variable pump, selection of the control mode ... These sensors are mounted directly on or into the tank, as shown in Figure 3.

A prerequisite for proper functioning of the sensors or. obtaining the real-time data, is their installation at appropriate places of the tank - in the fluid-active zones. This is closely connected with the proper forms and designing the interior of the tank. For this purpose it is reasonable to use the modern, powerful CDF simulation software tools that allow the insight in fluid flow inside the tank and identify the other phenomena in the tank [2].

A temperature sensor and a sensor for the fluid level, in combination with the fluid temperature allow, besides the temperature signal redundancy, also the implementation of the switching strategy by a heater in combination with the recirculation conditioning (preheating) of the fluid, carried out by the robust constant pump.

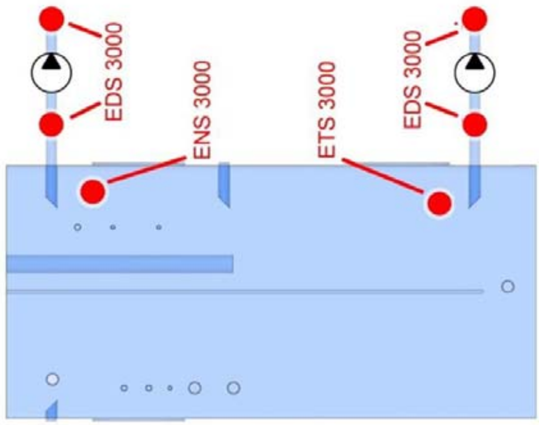

Figure 3. Mounting positions of the sensors on the hydraulic tank

A set and selection of mentioned sensors, (here solely as an example), must be carried out on the basis of economic/functional aspect: to cover as many signals/values as possible in order to obtain a better overview of the state of the power unit by taking into account the cost aspect including the safety (redundancy of important signals).
Only an appropriate set of sensors and their location on the power unit or tank, the reasonable use of the available signal in combination with a proper tank design, provides a useful implementation of the CM system operating parameters and status of the entire power unit [3, 4, 5].

2.2 Sensors for on-line Condition Monitoring of hydraulic oil

The biggest advantage when on-line condition monitoring (OCM) of lubricants, is their continuous measuring and reliable detection of sudden and unforeseeable events, when the fault is detected, so to speak, in real-time. Another advantage is the trend recording, considering the data from on-line sensors are usually acquired by automated systems that can store the history of the measurement results [6].
In order to achieve adequate quality of results from an on-line monitoring system, there are several key factors to consider whilst designing and implementing the OCM system:

- selection of suitable on-line sensors,
- proper installations of the sensors,
- determination of appropriate mounting locations for the sensors (representation of the sample must be ensured),
- adequate data acquisition unit for gathering and processing data from the sensors,
- additional measures and procedures for improving the accuracy and credibility of the measurements.

Most of the common parameters measured by today's on-line monitoring systems for lubricants are for the temperature, relative humidity, viscosity, dielectric constant, electrical conductivity, and lubricant cleanliness class.

The mentioned sensors can be divided into two main groups: sensors that detect the physical-chemical properties of the lubricant and sensors that measure the cleanliness class of the lubricant, e.g. particle counters.
Before taking actions for improving sensor measurements, special attention should be paid to the installations and locations of the sensors, as the sensors' locations alone (the locations where the lubricants are measured) can have significant influences on the measurements' results (for more information regarding the accuracy of sensors please find in [7], [8])
On-line sensors for oil condition monitoring can be, in generally, mounted at four main locations of the hydraulic system:

- on a hydraulic tank,
- on the main hydraulic return line,
- on the main hydraulic pressurised line and
- on a hydraulic bypass line.

By using a small volume pump, which transports the fluid through the sensor system, a bypass hydraulic system can be designed for condition monitoring - as in our case - Figure 4. Although such a design is the more expensive one, it provides the best and the most constant flow conditions for on-line sensors, which is especially important when an on-line particle counter is being used.
Suction and return line locations within the hydraulic tank must be placed carefully when designing a condition monitoring bypass system. Pumping and measuring oil from "dead-zones" of a hydraulic tank (where fluid does not circulate) could lead to substantial errors during condition monitoring.

Figure 4. OCM unit

The implementation of an oil on-line condition monitoring – OCM within a hydraulic power unit has many advantages over so-called 'off-line' monitoring (traditional laboratory analysis). With a properly designed OCM system we can discover timely changes of fluid and thus significantly extend the lifespan of the hydraulic power unit and its individual components. Therefore such a system should be an essential part of each modern power unit. The OCM system is a set of sensors and a bypass pump which is located directly on the power unit, and the electronic, located in the electrical control cabinet. The OCM system uses the same PLC and HMI as the power unit's control system. The sensors (in our case CS1000, AS1000, IVS01, LubCos H2Oplus II and LubCos Vis+) measure oil parameters (temperature, viscosity, dielectric constant, electric conductivity, relative humidity and contamination). By continuously following these parameters, we can spot changes in their trends and by that we can notice for example a change of oil, mixing of oils with different viscosity grades or an invasion of water into the system, and thus we can react in time to save the situation [4].

For designing of an OCM system for the hydraulic oil built into hydraulic power unit, there have been available five different on-line sensors, from three different manufacturers. All of them are multi-sensors, as they are measuring at the same time a number of different physic-chemical values. Values, which can be measured by the individual sensor, are presented in Table 1.

Table 1. A set of OCM sensors

Sensor	Manufacturer	Physics – chemical values	Nr. of values
AS1000	Hydac	Temperature, relative humidity	2
CS1000	Hydac	Temperature, cleanliness level	2
IVS 01	Internormen	Temperature, dielectric constant, viscosity	3
LubCos H2Oplus II	Argo-Hytos	Temperature, relative humidity, electrical conductivity, dielectric constant	4
LubCos Vis+	Argo-Hytos	Temperature, dielectric constant, viscosity	3

3. ELECTRICALLY CONTROLLED PART WITH THE OCM UNIT

Besides the mentioned sensors, the power unit's control system includes the following components, representing the electrical part of the power unit:

- appropriate PLC controller with the necessary modules for managing all the signals (in this case Siemens S7-1200),
- HMI display for graphically displaying the data and the system status as well as other demanding tasks,
- wiring, not only for the control-monitoring system but also in connection with control and power component and
- button for the management of basic functions,

with the possibility of monitoring all the signal from a remote location.

Nowadays it is possible to observe many different systems and monitored via the Internet. This is a significant advantage because you can observe the overall system status and, if necessary, take action and/or modify the system settings from a remote location. In case of system failure, you are immediately alerted via mobile devices or work computer in the office. So we can very quickly start to eliminate the fault from any location.
For all the systems that are controlled by e.g. Siemens S7-1200 controller, you can monitor and control via the Internet using three different options:

- The first option is the controller-hosted website. This means that it is necessary to manually write an entire website and its links in HTML / JavaScript.
- Alternatively (in the case of using the Siemens Comfort panel) is to publish on the internet a direct image display via the IP address or DNS address. This allows us to to use WinCC SM @ RT SERVER, which is already built into the software environment of TIA Portal V13.

- The third option is to use the WebNavigator-ROM an upgrade of the software environment of TIA Portal V13. This upgrade is possible for the entire SCADA control systems.

The second option represents the more optimal solution, as it offers great value for ease of use and functional capabilities.

An important part of the control cabinet is a large touch-screen HMI display (e.g. Siemens Comfort Panel TP-700). The panel is installed on the electric cabinet's door and its large screen allows us to display a large number of measured parameters in various ways (see Figure 5).

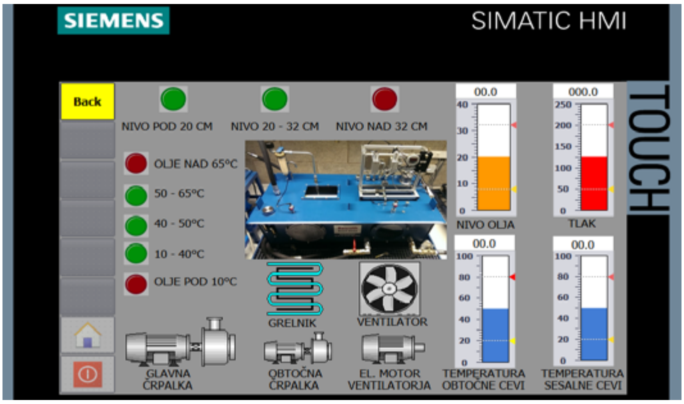

Figure 5. Visualisation of monitoring-control system

Furthermore, the HMI panel is connected to the Internet via an Ethernet or a wireless network to display the control screen with measured parameters and operating history. Thus, the entire system can be monitored and even controlled on a remote computer or smart phone.
The neat feature of this HMI is also that it can store the entire program and WinCC system on its memory card. In case the panel suffered hardware malfunctions it could be replaced without reprogramming the whole system. The user only swaps the memory card to the new HMI panel and the entire program, WinCC visualization and parameter history is transferred to the new panel. In the user interface we can choose between condition monitoring and the control system menu.

4. CONCLUSION

The proper functioning of the entire hydraulic supply-power unit is very important for reliable operation of the entire hydraulic system and the whole machine. So we have the possibility of indirectly to reducing the maintenance costs and energy consumption. In order to achieve a sufficient reliability of operations it is recommended upgrading the hydraulic system with suitable sensors, PLC and the HMI screen, which enables and controls the more important functions of the hydraulic power unit.
Due to the often outdated sensor system and signal generator control system it often fails to provide even basic monitoring of the more important parameters, not to mention complete control of all operating parameters and monitor history signal changes. The modern control system offer us many advantages, such as visualisation of the hydraulic power unit's parameters, storage of measured quantities on the memory card ... as well implementing the on-line condition monitoring of hydraulic fluid, and remote management control functions via the web.

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