VOL. 12, NO. 19, OCTOBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

DESIGN AND IMPLEMENTATION OF A PROTOTYPE TO AVOID WATER CONTAMINATION BY AUTOMATIC SWITCHING OF A HEAT EXCHANGER

Diego F. Sendoya-Losada[1], Frank Gutierrez[2] and Ricardo Avila[2]
[1]Department of Electronic Engineering, Faculty of Engineering, Surcolombiana University, Neiva, Huila, Colombia
[2]School of Basic Sciences, Technology and Engineering, National Open and Distance University, Bogotá, Colombia
E-Mail: diego.sendoya@usco.edu.co

ABSTRACT

In the present paper the solution to a problem found in the process of electric power generation is presented. Failure in the main heat exchanger causes contamination of the river because large volumes of water mixed with the lubricating oil are evacuated. The solution proposed uses water and level sensors as well as hardware and software provided by the National Instruments company to automate the switching process for the heat exchanger and thus avoid water contamination and forced shutdown of the generating unit.

Keywords: data acquisition, emulsion, heat exchanger, hydraulic generator, motorized valve.

1. INTRODUCTION

In the electricity generation industry, facilities to convert some kind of energy (chemical, mechanical, thermal, etc.) into electrical energy are called power plants. In a hydroelectric power plant, the potential energy of a natural channel of water is used to move a hydraulic turbine, which transmits the energy to a generator where it is transformed into electrical energy.

The almost permanent rotational movement of the machines necessitates the use of oil that allows the lubrication of the same. During its operation, the oil raises its temperature and it is necessary to use a cooling system to keep it at a normal operating temperature so that it can function efficiently.

The cooling system consists of heat exchangers, which need a lot of water for cooling the oil. This water comes from the same hydroelectric. One of the contaminating risks is the lubricating oil, because in case of a contingency, these are directly discharged to the waters of the river and by their composition are highly harmful. Therefore it is necessary to start working on the care of the water that returns to its channel once it is used.
When there are water leaks that are mixed with the oil an emulsion is generated, which is the heterogeneous liquid mixture of two or more liquids that do not dissolve with each other in a high degree of turbulence, modifying the surface tension of the drops to prevent the coalescence (union of two materials in a single body). Water pollution with oil in large proportion causes environmental damage due to contamination of river water. In addition, economic losses are generated in the plant because the generating unit becomes unavailable.

The present work shows how hardware and software tools provided by both National Instruments and other industrial instrumentation suppliers can be used to automate the process of switching the heat exchanger, avoiding water contamination and forced shutdown of the generating unit. This proposal is friendly with the environment and with this the interest to take care of it is ratified, with the design of an eco-efficient process.

2. MATERIALS AND METHODS

In this proposal the process is analyzed with a hydraulic generator of vertical axis, asynchronous of 180 Megawatts of generation. The water of a reservoir that is carried by the tunnel of conduction with fall for the rotational movement of the turbine with constant speed, the total of turbine flow with the unit in maximum power is of 293 m3 / sec. The water used in this process is returned downstream again. In the upper part of the turbine is located an electric generator in which the winding of the inductor is excited with continuous electric voltage and in the winding of the armature an alternating electric voltage is generated product of the electromagnetic field. This energy is conducted through a bus bar duct to the main transformers, sent to the substation to the autotransformers and distributed in the different electric transmission lines.

The hydraulic generator of electric energy consists of three bearings submerged in oil whose function is to maintain in vertical form the axis of the generating unit that rotates at a constant speed, additionally to withstand the forces that are originated in the axis. The three bearings are referred to as: upper shaft guide bearing thrust bearing and lower shaft guide bearing as shown in Figure-1.

The lubricant used is the Texaco Regal Oil R & O68, its viscosity is 5.5°Engels. Since the oil is subjected to pressures, it needs to have a normal operating temperature (36 °C-44 °C) to function efficiently. The amount of oil in each of the three bearing shells is: 730 liters in the upper shaft guide bearing, 900 liters in the lower shaft guide bearing and 13.000 liters in the thrust bearing. In order to maintain the optimum service temperature of the lubricant, it is withdrawn from the tank and circulated through a piping system to a heat exchanger - one per bearing system - and finally returned to the tank by a service pump.

VOL. 12, NO. 19, OCTOBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

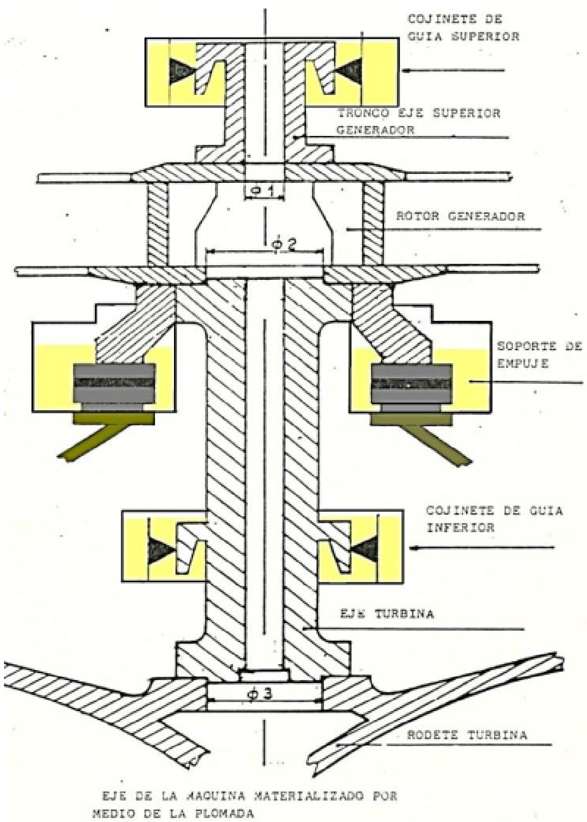

Figure-1. Alignment of the generator shaft with three guide bearings.

The oil cooling system consists of a main heat exchanger in service and a reserve heat exchanger available for each of the bearing systems. Each heat exchanger (see Figure-2) has manual valves for: Aspiration and discharge of cooling water, and Aspiration and discharge of lubricating oil.

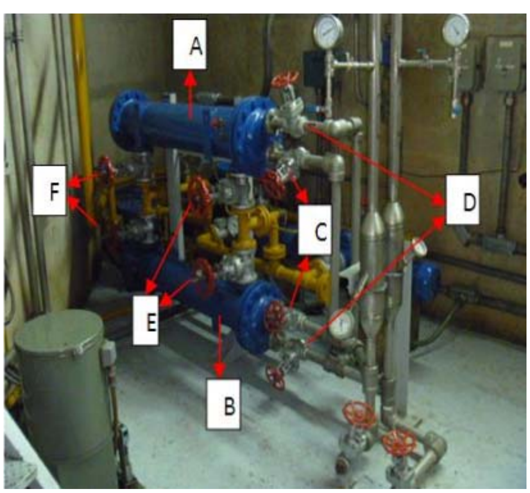

Figure-2. A. Main heat exchanger. B. Reserve heat exchanger. C. Manual valves for suctioning of cooling water. D. Manual valves for the discharge of cooling water. E. Manual valves for suctioning of lubricating oil. F. Manual valves for the discharge of lubricating oil.

In each oil tank there is a level indicator (see Figure-3), which once reaches the maximum threshold, due to water leaks in the main exchanger, activates an alarm in the control panel informing the operator of the contamination of the water/oil. This gives no time to manually switch heat exchangers.

Figure-3. Level indicator on guide bearing tank.

During the cooling process of the oil in the main heat exchanger, leaks can occur in the water ducts in its internal part, thus generating water/oil contamination. This leads to a subsequent decrease in the viscosity of the lubricating fluid due to the damage of the same exchanger.

If there is damage or malfunction of the level sensor, so that the maximum threshold is not detected, then the water/oil contamination will be visually detected by the operator during the equipment supervision round due to the creamy color of the emulsion of the fluid in the tank and the increase of temperature in the local instrumentation. In this situation, there is a greater contamination of the water and an irreparable damage of the affected bearing system, due to the increase of the temperature of the metals in friction.

When the water/oil contamination occurs in large proportion, the generating unit is declared unavailable and maintenance personnel intervene for the total extraction of the emulsion of the two liquids, cleaning of waste in the tank, purification of the oil in the treatment plant of oil, where the water/oil separation and solid waste will be carried out. In addition, the tank is filled with the treated oil, this corrective maintenance is carried out in a time span of 120 hours and the revenue that the plant no longer receives is between US$2000 and US$5000 in one hour, depending on the time of year, of the water inputs to the reservoir, reservoir level and Megawatt-Hour price. Additionally, the environmental damage caused by water-oil contamination occurring downstream of the river is considerable.

ARPN Journal of Engineering and Applied Sciences

3. RESULTS AND DISCUSSIONS

3.1 Hardware design

In Figure-4, the proposed changes to the cooling system are shown in red color. These changes consist of the inclusion of eight motorized valves for suction and discharge of water/oil for the two heat exchangers. In addition, a water presence sensor to the oil outlet and a level sensor in the tank are added.

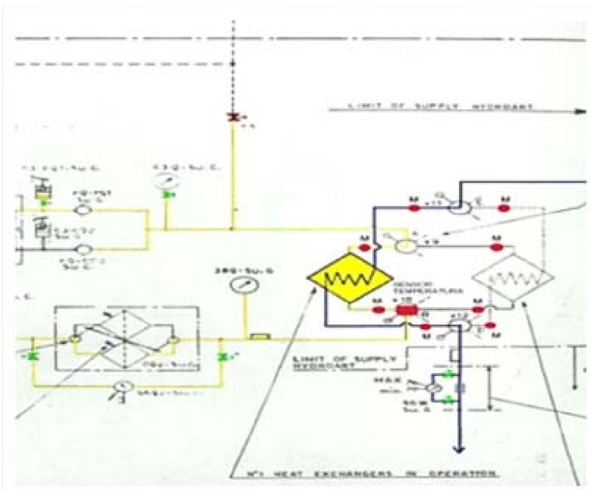

Figure-4. Hardware changes in the circuit diagram.

For each cooling system, it is proposed to install motorized valves to suction the cooling water (2 valves), discharge the cooling water (2 valves), suction the lubricating oil (2 valves), and discharge the lubricating oil (2 valves). In total, eight motorized valves [1] are required which will respond to the commands of the control system through the electric motors opening or closing the shutter.

A water saturation percentage sensor WS10 [2] (see Figure-5) is also used, which detects the level of water diluted in the oil in a percentage from 0 to 100%, also measures the temperature of the oil in a range 0 to 100°C. Its two outputs (% saturation and temperature) are 4 to 20 mA linear in ascending ramp, which are connected to a voltage-current converter board in order to obtain a range of 2 to 10 V for further processing.

An ultrasonic level sensor model UB800-18GM40A [3] must be installed in the oil tank. Its input range is from 5 to 70 cm and its output is from 0 to 10 V linear in ascending ramp. Another important element is the NI USB 6008 data acquisition card [4], which receives the linear voltages of the current-voltage converter board and the tank level sensor. The output of the DAQ must handle discrete signals for the control of the motorized valves, the generator and the luminous and audible indicators. This card is connected to the PC located in the control room for the visualization and control of the system through the USB port. Finally, it is also installed a neon bulb of 110 VAC for the visual alarm and a horn that works at 110 VAC for the sound alarm in the local instrumentation unit.

Figure-5. Water sensor pall WS10.

Figure-6 shows the exact location of the motorized valves and the water sensor in the heat exchangers.

Figure-6. Location of motorized valves and water sensor.

3.2 Software design

The software for developing the automation is LabVIEW [5], which has the user interface (HMI) and supervisory control functions via its front panel (see Figure-7). In addition it has a programming interface with block diagrams, shown in Figure-8, which allows implementing the control algorithm realized in G language.

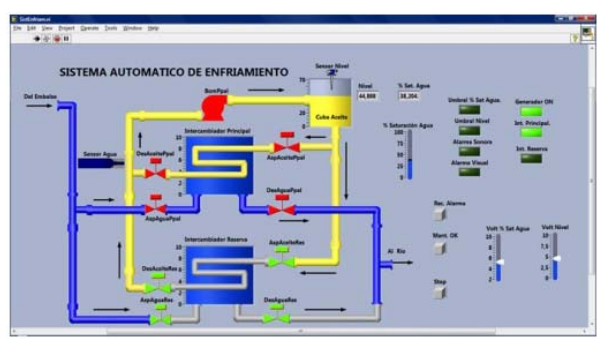

Figure-7. HMI designed in LabVIEW

VOL. 12, NO. 19, OCTOBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

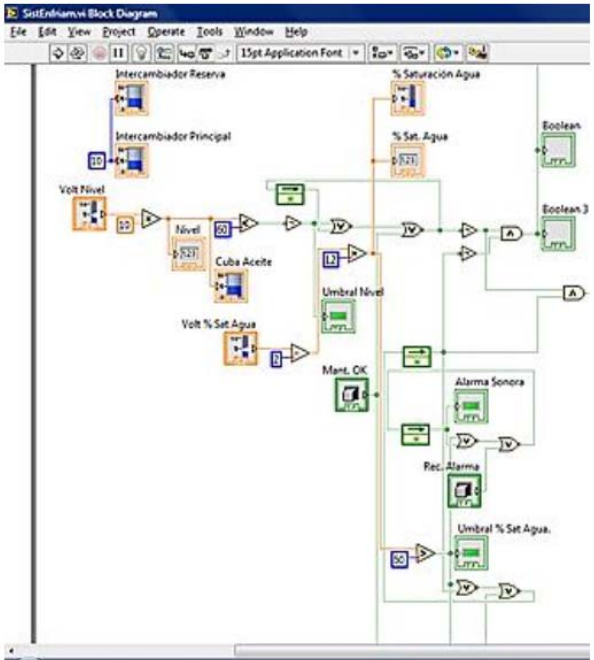

Figure-8. Block diagram for automation.

In addition, a driver for the data acquisition board (DAQ), which is NIDAQmx9.3.0 also from National Instruments [5], must be used. This is the interface between the DAQ and LabVIEW [6-8] to display the water and level saturation percent signals from their respective sensors and to export the control signals to the valves, generator and alarm indicators.

3.3 Operation of the proposed system

First a description of the hardware operation is performed. A description of the software is then made.

Explanation is best understood if Figure-9 is observed. The automatic system is responsible for monitoring the optimum operating conditions of the two heat exchangers [9, 10] and each bearing system by the presence of water and oil level sensors. In this way the automatic start-up operation of the main heat exchanger is generated, giving the opening order to the four motorized valves located in the outlets for suction and discharge of water/oil, allowing the generating unit to turn freely. The other spare heat exchanger has its four motorized valves closed in the outlets for suction and discharge of water/oil. Its water and oil systems are completely full on the inside, being available to replace the first in case of failure, and thus providing the reliability of the generating unit.

With the use of the sensor WS10, the amount of water in the discharge oil is measured, thus allowing the circulation of the fluid with quality in its viscosity and preventing possible contamination with the cooling water. When the threshold of the percentage of water saturation (50%) caused by water leaks is detected, anomaly is present in the control panel by activating the "Sound Alarm" and the "Visual Alarm" on the control panel. control.

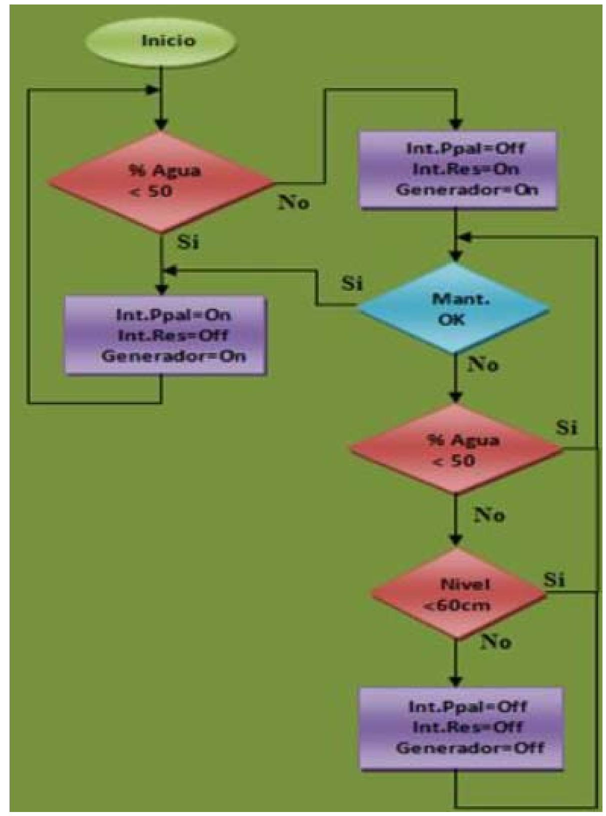

Figure-9. Flow diagram for designed system.

Simultaneously the program gives the closing order to the four motorized valves of the main exchanger to exclude it totally, at the same moment the order of opening of the four motorized valves of the reserve heat exchanger is generated being in service. Immediately the water-in-oil content measured in the discharge returns to its normal value and the "Rec Alarm" button (on the front panel of LabVIEW) can be pressed to turn off the audible alert (turn off the horn on the local control board and the respective indicator from the LabVIEW front panel).

During this process of change of service of the heat exchangers could contaminate a minimum amount of water, which when it reaches the tank and have contact with the metal of the bearing and the shaft, changes its state from liquid to gaseous by the high temperatures that are handled there. The steam is evacuated by a smoke extractor located at the top of the tank and sent to the water-oil purification process.

The main heat exchanger contaminated with water-oil is excluded from the system and its service is blocked by the system. It can then be safely operated by the maintenance personnel for removal and repair. Once the leakage has been repaired, this exchanger is installed in place with its internal water-oil circuits. Once the operator has evaluated that the main heat exchanger has the optimum conditions to put it back into service, install it and then press the "Mant OK" button on the front panel, clearing the visual alarm (turning off the neon light bulb in the local control board, and the LED on the LabVIEW front panel). Then the main heat exchanger is returned to service and the reserve heat exchanger is available.

If during the corrective maintenance of the main heat exchanger there is a failure of the reserve heat exchanger then the alarm is reactivated, but in this case it cannot be switched to another exchanger, which causes a considerable increase in the water-oil level of the tank which is detected by the level sensor. When the level exceeds the threshold (> 60 cm), the motorized valves of the reserve exchanger are closed and the generating unit is deactivated by the activation of the master relay 86M. This prevents the cooling water from being contaminated to a large extent by mixing with the oil circulating in the faulty bearing tank. Additionally taking care of the metal parts of possible damage by metal-to-metal friction of the bearing with the shaft because of the decrease of the viscosity of the lubricant used.

When both exchangers are repaired and the oil is properly filtered then the operator presses the "Mant OK" button and everything returns to normal operation, i.e. the main exchanger is in service and the reserve exchanger is available.

In order to understand the operation of the system software, Figures 7, 8 and 9 can be observed. The inputs to the program are the percentage of water and the level of the respective sensors and transducers. This is done using DAQ wizards that allow this data to be acquired for processing in the program.

Then these voltage levels are converted to values equivalent to the process variables through simple mathematical calculations, which are presented graphically and numerically through indicators on the front panel (HMI) [11, 12] of Figure-7. These data are compared to their respective thresholds via "greater than" and "less than" operations, to make the decision as scheduled. Once a threshold is reached, this state is retained with an SR latch (set on activation or Set), consisting of two NOR gates, which is deleted when a positive pulse enters its Reset input through the "Mant OK "and" Rec Alarm". To export the outputs of the program is also done with DAQ assistants for the valves of the two heat exchangers and the master relay of the generator, as well as a sound alarm and a visual alarm to control the entire process.

It also has LED indicators on the front panel to inform at all times the operating status of each of the outputs. Finally, there is a push button to stop the entire system (Stop) and two pushbuttons, one to turn off the alarm sound "Rec Alarm" and another to turn off the visual alarm "Mant OK".

The program starts by sensing the water-in-oil content in the main exchanger, in order to compare it with the previously established threshold. If the conditions are normal then the motorized valves of the main exchanger are activated and informs the starter system PLC that it has the optimum conditions of oil cooling. If at any point in the operation the water saturation touches the threshold then a latch is activated and with this the program deactivates the motorized valves of the main exchanger and activates the motorized valves of the reserve exchanger. When thesaturation percentage of water returns to normal, the operator presses the "Rec Alarm"to turn off the audible alarm.

Maintenance personnel should then check and repair the main exchanger. Once the heat exchanger has been completely repaired and installed, the operator presses the "Mant. OK", which deactivates the previous latch, turns off the visual alarm and the program responds by opening the motorized valves of the main exchanger and closing the motorized valves of the reserve exchanger. In the unlikely event that the reserve exchanger is malfunctioning (the main exchanger is out of service at the moment), or in the event of a subsequent failure, the first latch is activated, in addition to the level of the tank of oil rises outside its normal range which activates another latch, this is when the program deactivates the reserve exchanger and sends the activation to the master relay 86M and reports that abnormality to the supervisory PLC of the unit, forcibly removing the generating unit of the generation system.

In this case, the technician repair both exchangers change the contaminated oil and when normal conditions are reached, the operator presses the "Rec Alarm" and "Mant OK" buttons, which deactivates both latches to return to normal operation of the plant.

4. CONCLUSIONS

With the proposed automation solution in each of the hydraulic generator shaft guide bearing systems, the environmental damage produced by waste oils that are normally discharged when one of the heat exchangers fails is reduced.

It is possible to reduce the costs of operation and corrective maintenance of the generator by avoiding in a great percentage the damage in this one and in addition to the losses that also causes the stop for several days the generating unit.

The National Instruments products used for the implementation of the solution are based on the LabVIEW software and DAQ hardware. The implementation costs are much lower than the millionaire economic losses that the hydroelectric plant can have, due to the forced stop of the generating unit.

Undoubtedly one of the most benefited is the river and its entire ecosystem where the contaminated water is currently dumped. In addition to the people near the river who will have cleaner water for their life cycle and economic activities.

REFERENCES

[1] Frigo Pack. 2011. Válvulas Motorizadas de Bola. [en línea]. Disponible en: http://www.frigopack.com/Seccion~x~Valvulasmotorizadas-3-vias~IDSeccionArticulo~128~OrdenSeccion~090010060~Pagina~2.html.

ARPN Journal of Engineering and Applied Sciences

[2] Pall Corporation. 2010, febrero. Sensor de agua Pall WS10 Series. [en línea]. Disponible en:http://site.pall.com/pdf/IMWS10ES.pdf.

[3] CONRAD. Conrad Electronic - Europe´s leading electronics and technology online especiali. [en línea]. Disponible en: http://www1.conraduk.com/scripts/wgate/zcop_uk/~flN0YXRlPTMwMzU0NjM5NTU=?~template=PCAT_AREA_S_BROWSE&glb_user_js=Y&shop=UK&zhmmh_lfo=&zhmmh_area_kz=&product_show_id=156141&gvlon=&p_init_ipc=X&p_page_to_display=fromoutside&~cookies=1&gclid=&cookie_n[1]=u.

[4] National Instruments. 2011. Low-Cost, Bus-Powered Multifunction DAQ for USB - Data Sheet - National Instruments. [en línea]. Disponible en: http://sine.ni.com/ds/app/doc/p/id/ds-218/lang/es.

[5] National Instruments. 2011. Sistema de Desarrollo Completo de LabVIEW para Windows - National Instruments. [en línea]. Disponible en: http://sine.ni.com/nips/cds/view/modelpopup/p/pcat/845/lang/es.

[6] M. Hong and Z. Chenguang. 2008. Data acquisition system based on LabVIEW. Electron. Meas. Technol.

[7] C. Elliott, V. Vijayakumar, and W. Zink. 2007. National instruments LabVIEW: a programming environment for laboratory automation and measurement. J. Assoc.

[8] C. Kalkman. 1995. LabVIEW: a software system for data acquisition, data analysis, and instrument control. J. Clin. Monit.

[9] O. Jaramillo. 2007. Intercambiadores de calor. Cent. Investig. en Energ.

[10] V. Isachenko, V. Sukomel, A. Ganzo and N. Angel. 1979. Transmisión del calor.

[11] D. Martinez, J. Poveda, and A. Guáqueta. 2013. Electric vehicle instrumentation by using HMIs. Power Qual.

[12] F. J. Espín and S. S. Santamaría. 2013. Construcción de un sistema de lavado de arena con capacidad aproximada de ciento sesenta toneladas por día e implementación de un HMI para la Compañía.