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EFFECTIVE OVERSIGHT AND MANAGEMENT OF STEAM TURBINE LUBRICATION SYSTEM USING SMART SENSORS

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ABSTRACT

The 210 MW HP, IP, and LP Turbine Rotor are mounted in the log bearings that are lubricated to prevent friction. You should not have direct contact with each other with the rotor shaft and bearings. Direct contact is avoided by developing an oil film layer between the shaft and the bearing [1]. To allow the oil film to be formed, the lube oil header pressure should be maintained at 2.8 ksc. The separate lube oil scheme provides the bearings with continuous lubrication. The header pressure monitoring, main oil tank level, redundancy scheme, and the lube oil coolers for lube oil pumps [3] are concerned with the relevant monitoring and control of the lube oil system. The current monitoring and controlling device is relay logic and each function is run separately. This research work has included level monitoring of MOT, pressure monitoring of lube oil coolers, and redundancy devices using the PIC Microcontroller for lube oil pumps in a single system.

Keywords: lube oil pumps, oil cooler, PIC Microcontroller, single system.

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1. INTRODUCTION

To prevent friction, lubrication oil when sprayed at this pressure, produces a protective oil layer around the shaft. A soft coating of white metal is used in the journal bearing to reduce friction after the oil is applied [4, 5]. The lubrication oil system used at present does not implement the various parameters available in the field. In this paper, we incorporate the various parameters present in the device, such as pressure, temperature, and level of lubricant oil. This high temperature oil should not be used again because, with increased temperature, the viscosity of the oil decreases so the oil should be cooled again to maintain its viscosity. The oil would exchange the heat in the chamber for the soft water that flows through the chamber [6]. Then it repeats the process. The measured variables are sent to a controller and there are predefined programmes present in the controller that will perform the required action for various measured signals [7]. The lubrication is so important that a variety of redundant pumps are supplied to the system.

In our lube oil system prototype, the initial power supply is provided. It retains the oil film in the turbine system. The level in the main oil tank is tracked simultaneously and the level is also shown on the display [9]. The oil makeup goes ON via relay through the driver circuit if the level goes below 1430 mm and the level is preserved. The OTCV valve will open if the oil temperature reaches 450C. Using the PIC Microcontroller, the overall process is managed and tracked. Continuous power supply can be ensured without catastrophic failure using a real-time steam turbine lube oil system and monitoring using a PIC controller.

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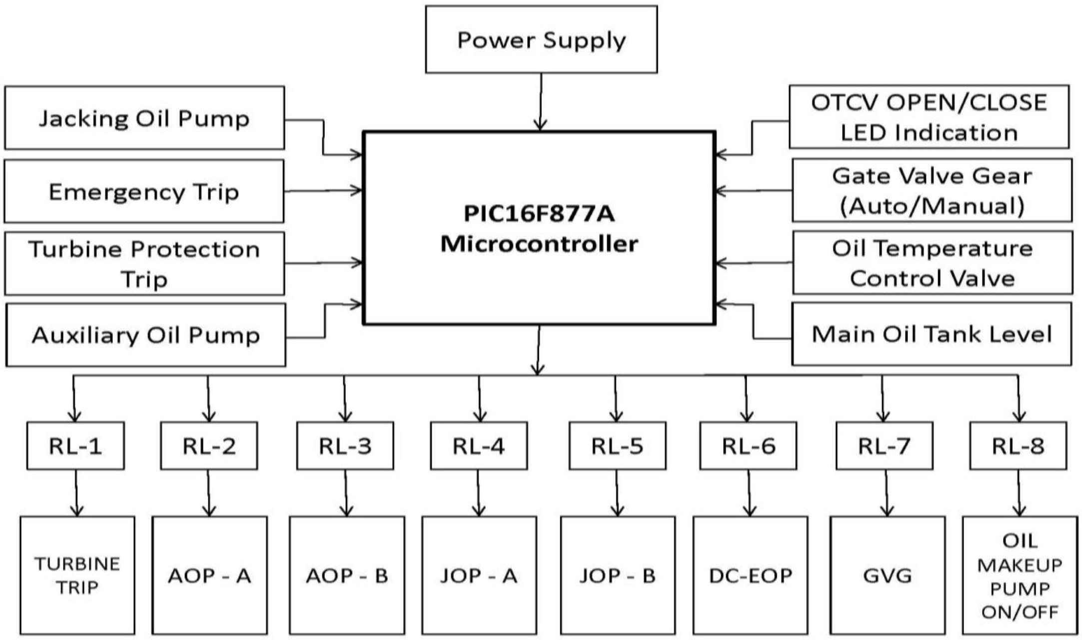

Figure-1. Block diagram of lube oil system.

- The shaft is supported by Journal Bearings.
- Seven journal bearings. Located at HPF, HPR, IPR, LPR, GF, GR & ER.
- An oil system from the MOP or AOP turbine provides the bearings with lubrication.
- DCEOP supplies lubrication to the bearings during supply failure.
- JOP is used for the application of the barring gear to lift the shaft.
- MOT is the oil storage tank.

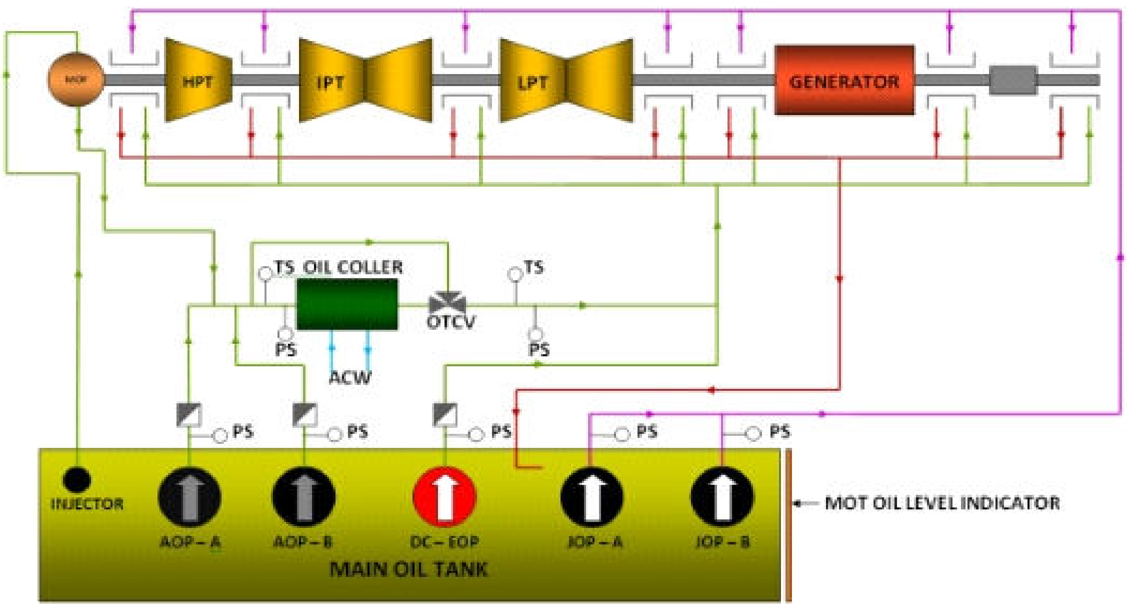

Figure-2. Layout of lube oil system.

2. ARRANGEMENT OF LUBE OIL SYSTEM

2.1 HPT, IPT, LPT

A steam turbine has three parts, which are high pressure, moderate pressure, and low pressure turbines. All three are mounted on the same shaft that rotates in the generator to generate electricity at 3600 rpm. As it leaves the high pressure, the main steam goes over multi-stage blades and expands to decrease the temperature.

2.2 Main Oil Pump

The main oil pump is the one that provides all the oil requirements for the turbine generator at high pressure during normal operation. It is powered directly from the turbine shaft and can be positioned at either the shaft's turbine or generator end. For small units, a gear pump is usually the main oil pump. A gear pump may not be able to produce the necessary amount of oil at the desired pressure for large units and, in this case, a centrifugal style pump is used, but the turbine shaft is still powered. Since the centrifugal pump is not self-priming, a lube oil powered booster pump is fitted with large units with centrifugal main oil pumps to keep the main oil pump primed since the main lube oil pump is a connected pump that operates at the speed of the turbine shaft. The main oil pump doesn't turn quickly enough to produce the necessary pressure or flow during start-up and shutdown. The speed at which the main oil pump is capable of handling the requirements of lube oil is normally about 90-the operating speed.

2.3 Auxiliary Oil Pump

The auxiliary oil pump has two functions: it works during start-up and shut-down when the turbine shaft does not rotate rapidly enough to provide the necessary pressure and flow for the main oil pump and serves as a backup lube oil pump in the event of a failure of the main oil pump. A maximum flow and full pressure pump is the auxiliary lube oil pump that will fully satisfy the needs of the turbine and generator oil. In the event of a failure of the main lube oil pump, the auxiliary oil pump is capable of providing all the bearing and control oil requirements to enable full power operation to continue [15].

2.4 Jacking Oil Pump

When the strong turbine generator shaft is at rest, the oil film will be squeezed by the bearings from under the shaft. There would be metal to metal rubbing if the shaft is then rotated so the oil can work its way underneath. The shaft does not rotate quickly enough to maintain a good "oil wedge" between the shaft and the bearing surface when the unit is rotated on the turning gear. This condition can also lead to metal contact. To prevent this situation, the jacking oil pump injects oil into the bearing at the bottom of the shaft at high pressure (around 6.9 megapascals) [12].

A few hundredths of a millimeter off the bearing helps to raise or jack the shaft so that there will be no contact between metal and metal [11, 14]. The rotation of the shaft will maintain an oil wedge under the shaft and the jacking oil pump is no longer needed once the turbine speed has risen above the turning gear speed. Whenever the turning gear is working, the jacking oil pump will usually operate and will shut down when the turning gear shuts down. Either from the oil line supplying the bearings or directly from the oil tank, the jack oil pump may take suction [20]. However, in any case, a lubricating oil pump is initiated. Furthermore, because the flow from the jacking oil pump is very limited, adequate oil flow cannot be provided to cool the bearings it supplies. The jacking oil pump is normally a pump of the reciprocating plunger type and supplies the bearings to each bearing through individual lines from the pump.

2.5 DC - EOP (Emergency Oil Pump)

Usually, the time needed for a turbine to operate from operating velocity to a stop is 20 to 45 minutes [13]. Unless the turbine is supplied with a source of bearing lubrication, if the bearings did not receive lubrication during this time, they would easily overheat and be damaged. A turbine trip combined with a lack of AC power would result in bearing damage during the coasting down of the turbine [18]. There is no way that a modern large turbine generator is secured at operating speed against the total loss of lubricating oil [16]. Providing a sufficient number of alternative power supply lube oil pumps is the only method of security to ensure that all lube oil flow is not lost.

2.6 Oil Cooler

The generator and compressor are the rotating equipment that the lube oil cooler uses to cool the lubricant oil used by cooling water for the lubrication. It is usually produced in the form of a shell and tube, but there is also a plate type [18, 19].

2.7 Shaft Turbine Gear

In axial T / C, where the bearing support is at the end and the rotors are in the center, this type of lubrication device is used. This device includes a self-contained type of gear pump powered by the turbine shaft. It pulls oil from an individual bearing sump and supplies the bearings with pressure.

2.8 Main Oil Tank (MOT)

The MOT includes the oil required for the various previously stated requirements. It assists in desecrating the oil, in addition to acting as a storage tank. The tank capacity ($32m^3$) is so selected that the entire amount of oil flowing through the system is maintained for a managed period to ensure sufficient sedimentation and air removal. The space above the maximum oil level in the tank is adequate to hold the oil that is in the circuit and, in the event of the set being released, will flow back into the tank. Oil overflows into the adjacent portion of the tank from the riser section via a basket style strainer. After rotating around the longitudinal partition of the tank, the pumps, placed on the top of the tank, draw off the oil. The oil vapor extractor is placed on the tank, which creates a small vacuum in the tank, holding pedestals and drain lines, so oil vapor is exhausted in a controlled manner. The tank is made as airtight as much as possible.

3. METHODOLOGY

The turbine should have a secure guard system in case of emergencies that may cause harm to staff or equipment. Automatic tripping is provided to shut off the supply of steam to the turbine and carry the engine to the

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barring gear for most of the abnormal conditions in the turbine. The protections provided for the turbine are:

1. Emergency Trip (Remote - UCB)
2. Over-speed Trip I,
3. Over-speed Trip II,
4. Low vacuum mechanical Trip,
5. Thrust bearing Trip,
6. Fire protection trip,
7. Low vacuum Electrical Trip,
8. Drum level high trip, &
9. Main steam temperature low trip.

It is possible to identify the defense mechanism as hydraulic and electrical. The hydraulic is used to start over-speed, thrust bearing, low vacuum, and local manual trips. All other defenses are enabled by solenoid energization [20].

4. RESULTS AND DISCUSSIONS

The implementation of hardware defines the different types of devices that are implemented, including the power required, source, pin information, characteristics, applications, and series used. A proper bridge rectifier is chosen based on the specifications of the load present. When choosing a rectifier power supply for an acceptable electronic circuit application, the device ratings and specifications, breakdown voltage, temperature levels, transient current level, forward current rating, mounting requirements, and other considerations are taken into account.

The hardware proposed system consists of:

- Transformer
- LCD Display
- Power Source
- PIC 16F877A Microcontroller
- Relay

The goal is to incorporate the Main Oil Tank level monitoring, Lube oil cooler pressure monitoring, and lube oil pump redundancy scheme into a single system using a PIC Microcontroller.

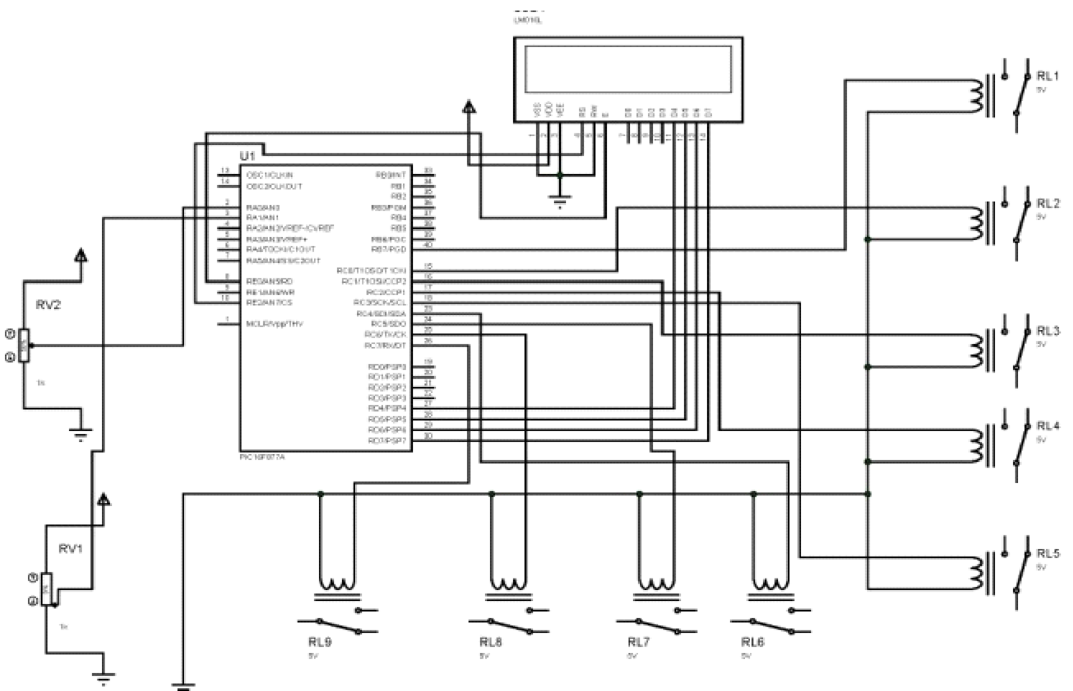

Figure-3. Circuit diagram of steam turbine lube oil system.

For the proposed device, the hardware package represents the connection. There are peripherals attached to the PIC16F877A Microcontroller. (-)0.700ksc-low vacuum, Auxiliary oil pump ON / OFF indication, Jacking oil pump ON / OFF indication, DC-Emergency oil pump ON / OFF indication, GVG-Gate Valve Gear Open / Close indication, Turbine lube oil inlet temperature or Cooler outlet temperature, Lube oil level of the Main Oil Tank (low-normal-high), ON / OFF Makeup Pump, Turbine Speed, Turbine running at 3000rpm [Turbine in Service]. Whenever the machine senses the turbine trip signal, then the Auxiliary Oil Pump, Jacking Oil Pump, GVG cut-in. Figure-4 below indicates the hardware outcome. The AOP starts on the car at 2850 RPM (i.e.) when the turbine trips on safety (or) hand trip at control oil pressure is less than < 4.5 ksc. JOP "A" is started at 510 RPM on auto, if JOP "A" is big, JOP "B" is started on auto.

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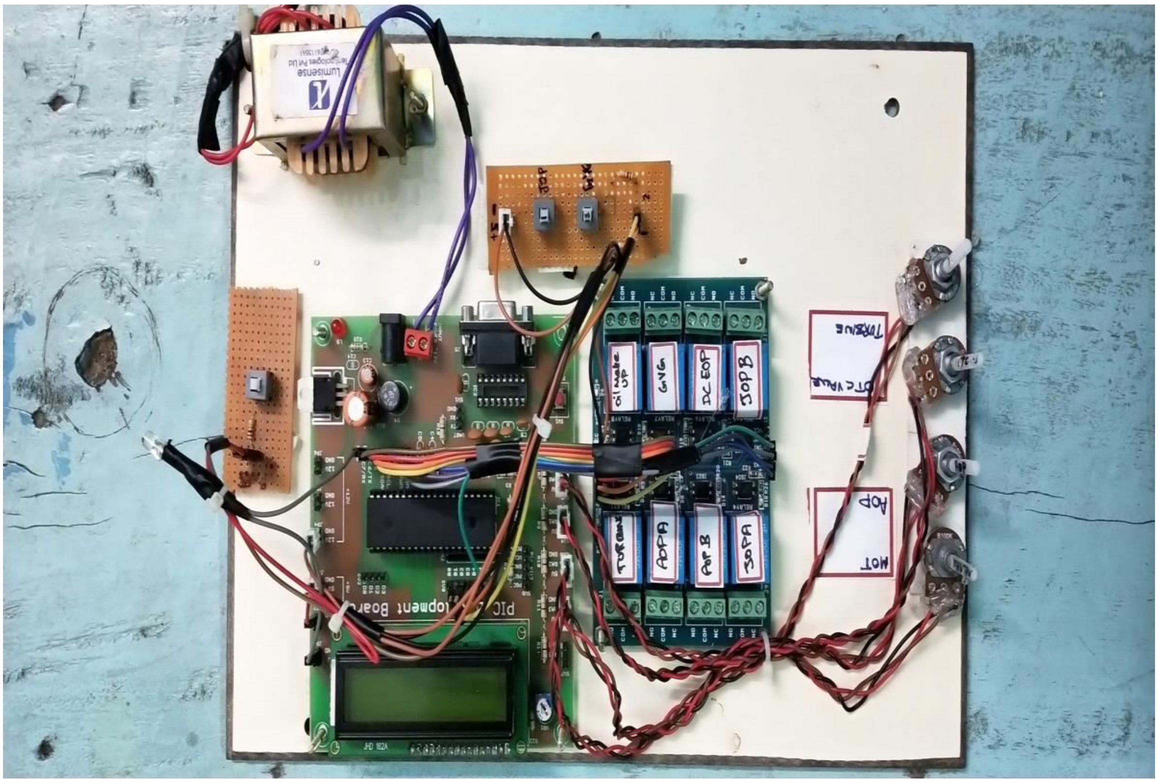

Figure-4. Hardware of lube oil system.

Table-1. Summary of the pressure, speed and relay domain parameters.

Pumps & Its Discharge Pressure	Turbine Speed in rpm	Lube Oil Pressure in ksc	Relay
Turbine Tripped @ Protection	Low vacuum	-0.700 ksc	RL1-ON
AOP ‘A’ – 6.8 ksc	2850 rpm	<4.80 ksc	RL2-ON
AOP ‘B’ – 6.8 ksc	2850 rpm	<4.56 ksc	RL3-ON
JOP ‘A’ – 120 ksc	510 rpm	-	RL4-ON
JOP ‘B’ – 120 ksc	510 rpm	-	RL5-ON
DC EOP – 2.3 ksc	-	<1.2 ksc	RL6-ON
GVG – Gate Valve Gear	210 rpm	-	RL7-ON

Table-2. Summary of the MOT oil level and OTCV domain parameters.

MOT - Oil Makeup	1480 mm (Normal)	1430 mm RL8-ON	1480 mm RL8- OFF
Oil Temperature Control Valve (OTCV)	45°C (Normal)	<45°C LED-OFF	>45°C LED-ON

PROTEUS is a simulation and design software tool developed by Lab Center Electronics for the Design of Electrical and Electronic Circuits that simulates the proposed device. It also has a drawing feature for 2D CAD. A proprietary software toolset used mainly for electronic design automation is the Proteus Design Suite. The programme used for drawing schematics and simulating the circuits in real time is ISIS. During run time, the simulation allows human access, thus offering real time simulation. Figure-5a represents the simulation circuit diagram of the proposed system.

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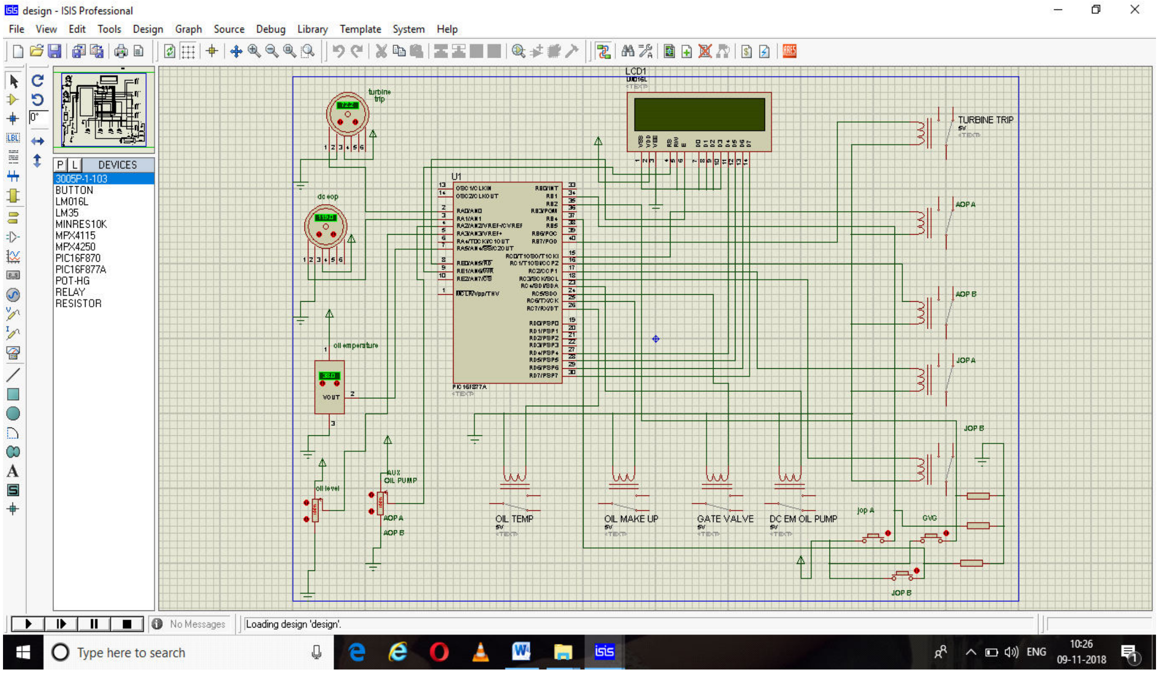

Figure-5a. Simulation circuit diagram.

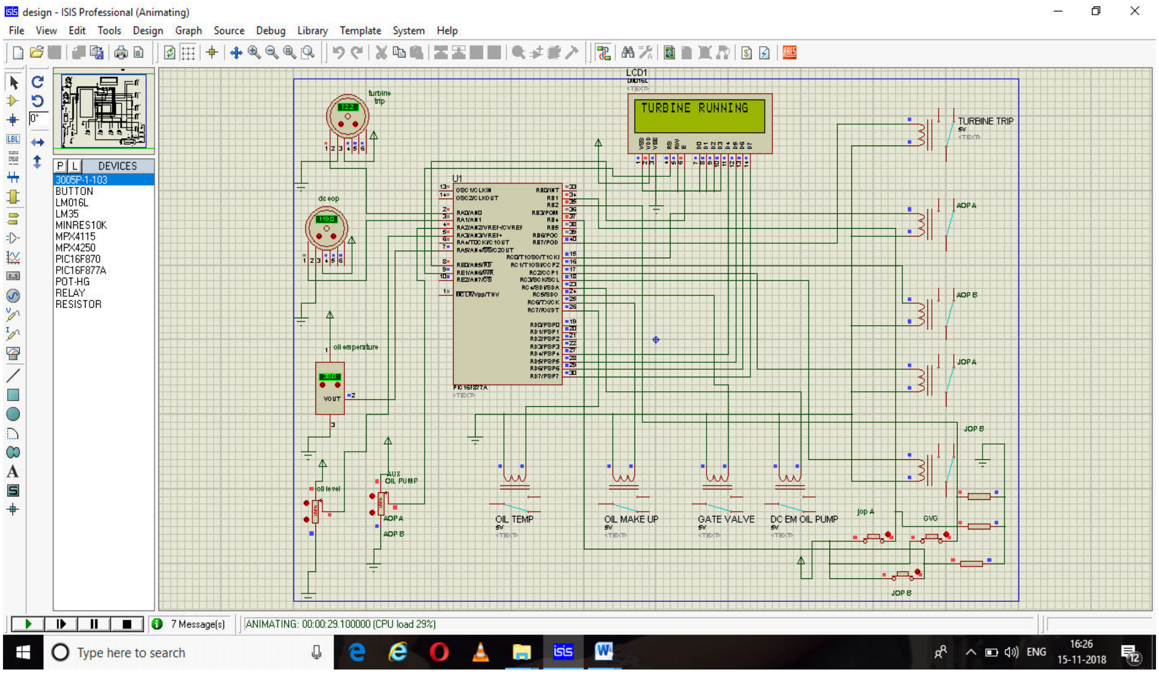

Figure-5b. Turbine running simulation result.

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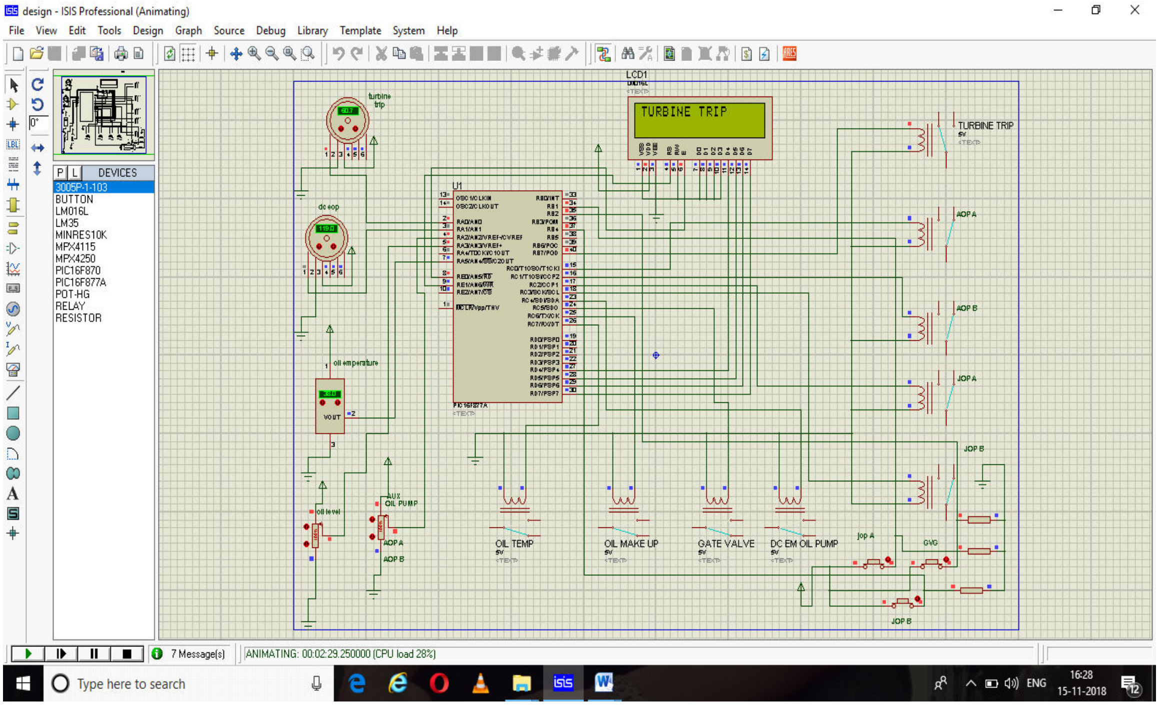

Figure-5c. Turbine trip simulation result.

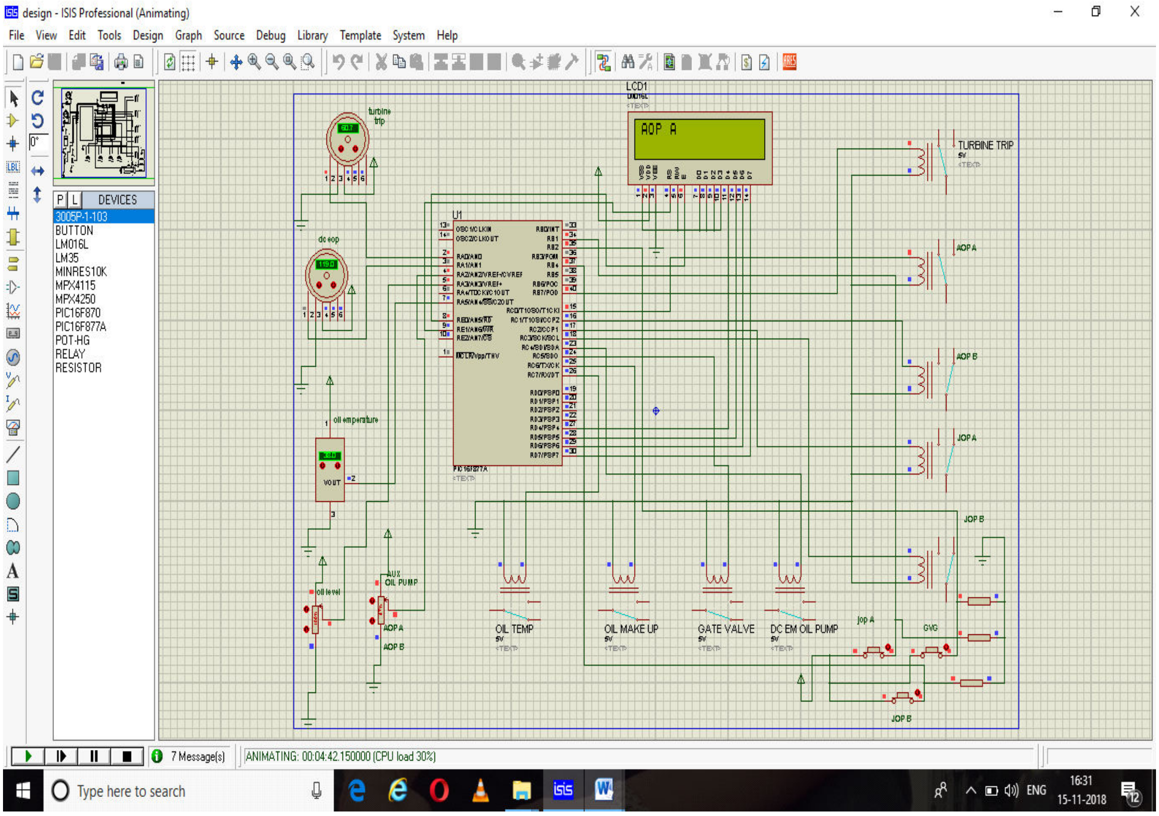

Figure-5d. AOP ‘A’ ON simulation result.

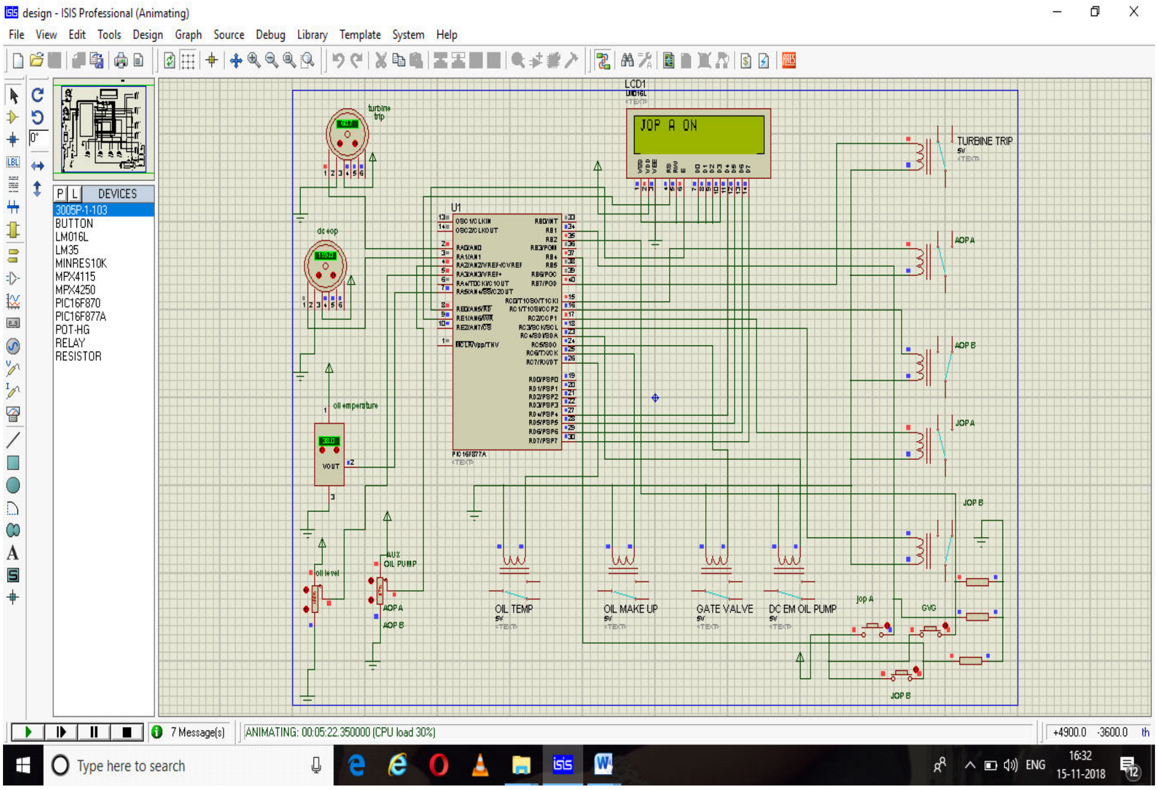

Figure-5e. JOP 'A' ON simulation result.

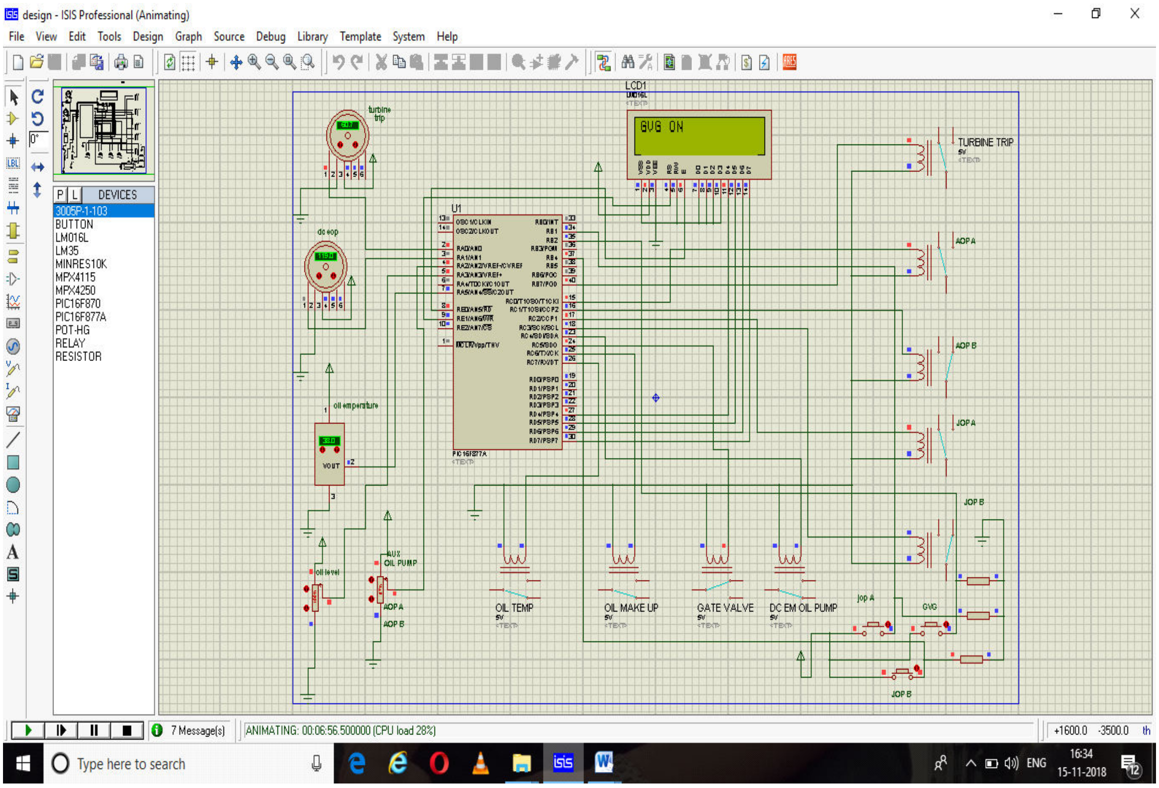

Figure-5f. GVG ON simulation result.

VOL. 18, NO. 23, DECEMBER 2023 ISSN 1819-6608
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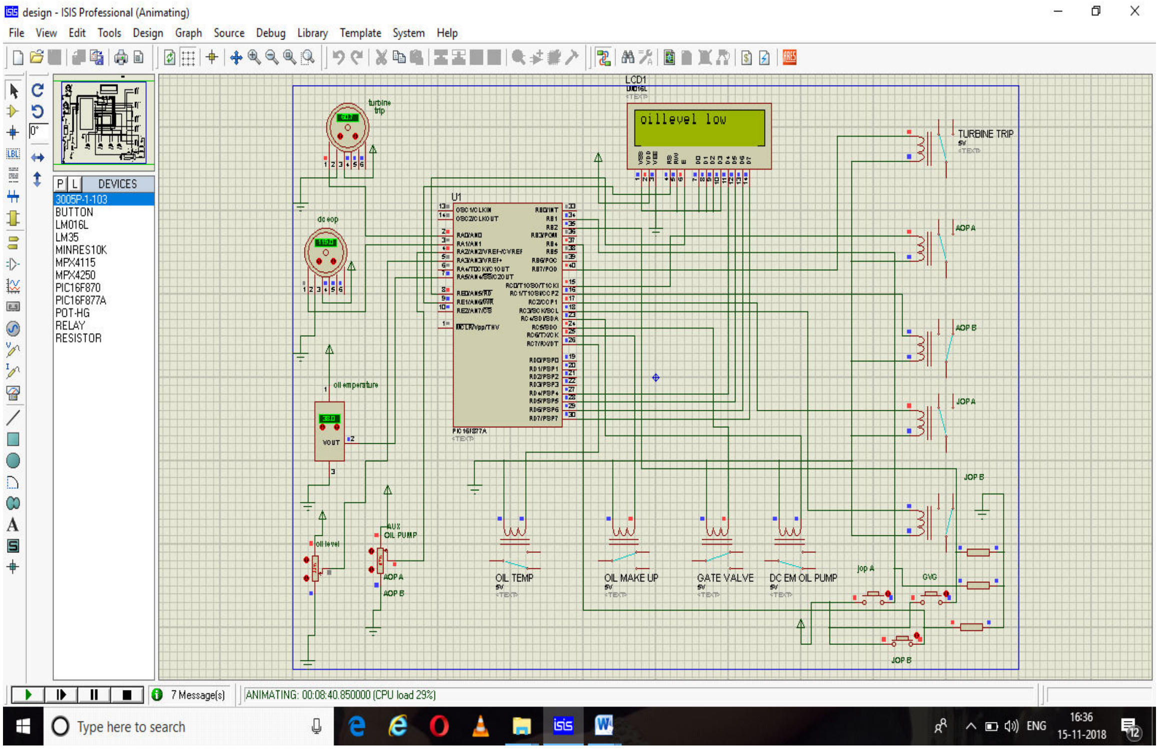

Figure-5g. Oil level low simulation result.

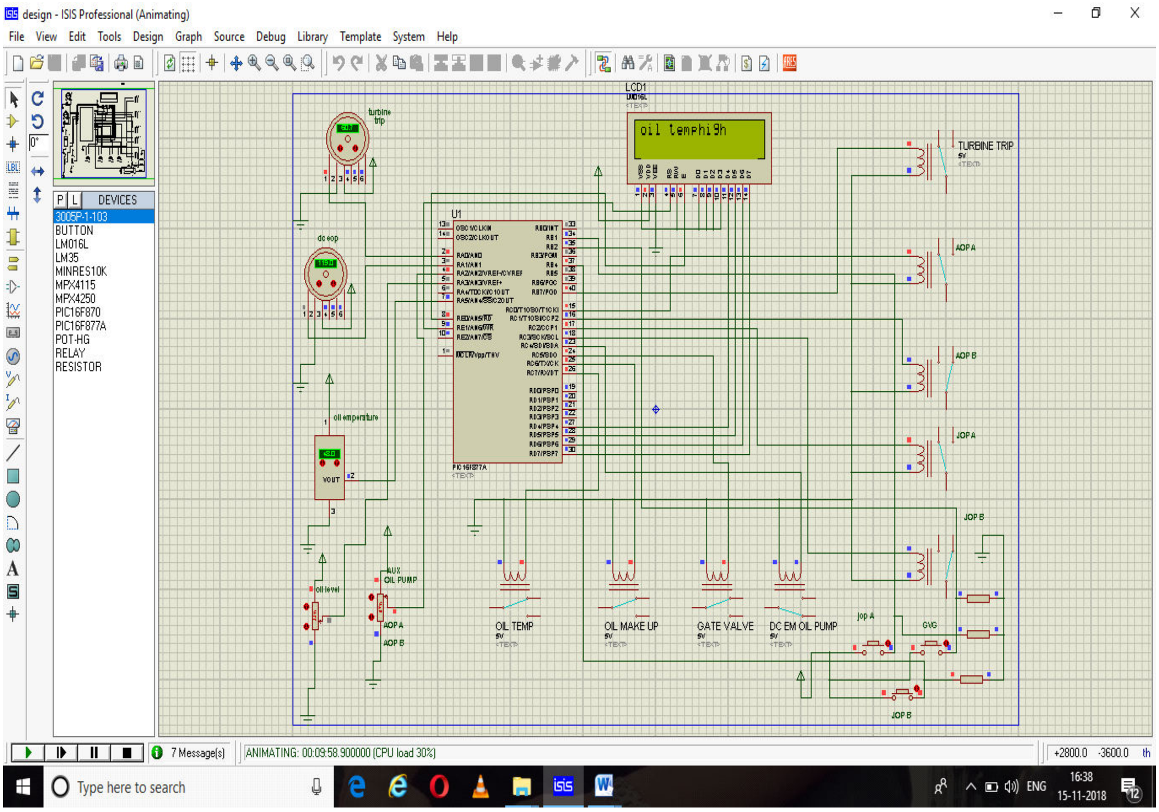

Figure-5h. Oil temperature high simulation result.

For the suggested method, the simulation presents the simulation relation. The controller has peripherals attached to it. The Lube oil pressure (Lube oil pressure, Auxiliary oil pump pressure, Jacking oil pump pressure) is shown by the simulation output function. Whenever the device detects the turbine trip signal, then the Auxiliary oil pump, Jacking oil pump, and cut-in GVG. Figures 4.3 to 4.8 above indicate the outcome of the simulation. The

AOP, JOP, and Oil Pressure are shown in Figure 4.9 above. The AOP starts on the car at 2850 RPM (i.e.) when the turbine trips on safety (or) hand trip at control oil pressure is less than < 4.5 ksc. JOP "A" is started at 510 RPM on auto, if JOP "A" is big, JOP "B" is started on auto. When both AOPs are not available, the DC EOP auto ON is lower than < 1.2 ksc. The Gate Valve Gear opens at 210 rpm in the engine. The oil is made up of (normal 1530 mm) RL8 ON at 1430 mm, and RL8 OFF at 1580 mm. The oil temperature set point of the OTCV (Normal 45oC) goes above 45oC and the OTCV RL9 is ON.

5. CONCLUSIONS

The entire sub-system was merged into a single system in this research work and made it an overall supervisory control & monitoring using PIC microcontroller. For that, oil level, temperature, lube oil pressure in the device feedback to the microcontroller ADC is made primarily for the display of parameters. The pump changeover scheme, oil temperature control using a cooler, and tank level control are accomplished using this feedback. These systems are not inter-connected in the current Turbine lube oil system and each has a separate control module & monitoring. There is no overall supervisory oversight of this system. This drawback key is therefore addressed by this method of lube oil monitoring and control.

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