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Generator Sump Level Monitoring and Automatic Control System with Alarm Features

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Abstract - A generator sump tank is a reservoir that stores lubricating oil for the generator's engine. It serves as a holding space for the oil and facilitates its circulation throughout the engine for lubrication. In most designs, the sump is integrated into the engine's crankcase. Manual monitoring is often unreliable and may result in overflow, pump damage, or dry running. This project introduces a microcontroller-based system to automate sump tank monitoring, pump control, and alarm management using level sensor switches and buzzers. The tank is equipped with a level indicator for local monitoring, along with a dipstick and sensor switches that function as control elements. These sensor switches transmit signals to automatically start and stop the pump. Additionally, they provide input to the monitoring and alarm system, enabling status indications for pump operation and triggering alarms for low-low and high-high oil level conditions. The developed system achieved 100% accuracy in pump control and alarm activation throughout the testing phase, demonstrating high reliability and operational consistency.

Keywords: Automatic Pump Operation, Generator Sump Tank, Level Sensor Alarms, Microcontroller-Based Automation, Oil Level Alarm System

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1.0 INTRODUCTION

In maritime operations, the reliability of generator systems is vital to ensuring a continuous power supply during voyages. A sump tank within a generator, stores lubricating oil which is essential for minimising friction, reducing wear, and extending the operational life of the engine. However, manual monitoring of sump oil levels has proven unreliable due to human error and delays in corrective action. Improper monitoring may lead to sump overflow, pump failure, or oil starvation of the engine, compromising vessel safety and operational performance. This study aims to design and implement an intelligent generator sump level monitoring system, equipped with automated pump control and alarm capabilities. The integration of sensor technology with microcontroller-based automation ensures effective monitoring, real-time alerts, and immediate corrective action without the need for constant human intervention.

2.0 RESEARCH CONTEXT

Recent research in marine automation increasingly focuses on smart monitoring systems to enhance operational reliability, safety, and environmental compliance. Alqadami et al. (2020) emphasise that integrating sensor-based monitoring with automated decision-making can significantly reduce mechanical failures and operational risks in marine engineering systems. Similarly, Chen et al. (2022) demonstrate that the use of smart sensors in pump monitoring improves predictive maintenance accuracy, thereby reducing downtime and extending equipment lifespan.

Traditional sump level monitoring in ships typically involves manual oil inspections using dipsticks or visual gauges. While cost-effective, this approach is time-consuming, prone to human error, and often lacks real-time responsiveness (Sharma, 2020). The transition to microcontroller-based monitoring addresses these limitations by enabling continuous data acquisition, processing, and automated control. (Che Kar et al., 2022).

Recent developments in Internet of Things (IoT) integration, as demonstrated by Mat Hussain et al. (2025), enable microcontrollers to process signals from multiple level sensors, display readings in real time, and trigger alarms for abnormal conditions. These advancements align with the International Maritime Organization (IMO) objectives on energy efficiency and safety, as outlined in the Ship Energy Efficiency Management Plan (SEEMP) (IMO, 2021). Furthermore, predictive maintenance supported by data analytics (Latrach, 2023; Hashemipour & Singh, 2025) ensures proactive intervention before critical failures occur, thereby reducing both maintenance costs and environmental impact.

3.0 PROCEDURES

The proposed microcontroller-based sump tank monitoring and control system is designed to automate lubrication oil level management for shipboard generators. The design draws inspiration from industrial pump automation systems (Chen, Zhang, & Li, 2024; Community Project, 2022) and is optimised for marine environments, where equipment reliability and safety are paramount.

3.1 Procedure Relevance

This methodology aligns with contemporary automation design principles in marine engineering, combining sensor networks, microcontroller-based control, and predictive maintenance frameworks. It leverages proven approaches from industrial IoT monitoring (MDPI Authors, 2024; Allahloh et al., 2023), tailoring them to the operational requirements of shipboard sump lubrication systems.

The system consists of the following units:

1. Sump Tank Unit: Equipped with four level switch sensors and a level indicator (High-High Alarm, Auto Stop, Auto Start, and Low-Low Alarm), along with transistors.
2. Transfer Pump Unit: Includes a relay, pump, power supply for the pump, 3-way switches (Remote, Local Start, Local Stop), and an Emergency Stop Push Button.
3. Pump Control Unit: Utilises a PIC16F84A Microcontroller, crystal, capacitor, power supply with switch, resistor, and an Emergency Stop Push Button.
4. Monitoring & Alarm System: Incorporates a PIC16F84A Microcontroller, crystal, capacitor, transistor, power supply with switch, 16x2 LED display, buzzer, and LED alarm indicators.

The system can operate in either automatic or manual mode. Under normal conditions, it primarily operates in automatic mode (Djalilov et al., 2022; IJERT, 2024). In this mode, two level switches control the pump's operation:

- When the oil level drops, the pump remains inactive.
- Once the Auto Start level sensor is deactivated, the pump begins operating until the Auto Stop level is reached, at which point it automatically shuts down.

In manual mode, the user can directly start or stop the pump at any desired oil level. Monitoring may be performed using the level indicator or, traditionally, with a dipstick.

The system is equipped with two alarms: High-High (HH) Alarm(IMO, 2021; Smart Genset Control, 2025) and Low-Low (LL) Alarm (Hashemipour & Singh, 2025).

- The LL Alarm is typically triggered if the pump is running in manual mode without monitoring, if the Auto Start sensor is defective, or in the event of a major oil leak. It protects the generator from oil starvation, which can cause excessive friction, overheating, and potentially catastrophic engine failure. It also provides an early warning for the operator to take corrective action, such as topping up oil or checking for leaks, before the pump runs dry.

- The HH Alarm is generally triggered if the pump is operated in manual mode without monitoring, if the Auto Stop sensor fails, or in the event of a heavy or continuous fuel leak into the lubrication system. This alarm serves as an early detection mechanism to help reduce fuel wastage in line with the Ship Energy Efficiency Management Plan (SEEMP), as per the International Maritime Organization (IMO). In addition, it prevents overflow that could result in oil spillage, fire hazards, and environmental pollution. The HH Alarm also also protects the pump from overpressure or flooding, thereby reducing the risk of mechanical damage.

In compliance with maritime safety guidelines (IMO, 2021), the system is equipped with two emergency stop push buttons, located at both the local control side and the remote-control side for safety purposes. The figures and table below provide a clearer understanding.

Figure 1. The flowchart illustrates the operational logic of the automatic generator sump monitoring system, including process flow and response actions. The system ensures that the pump operates efficiently, preventing overflow or dry running while maintaining safe sump levels.

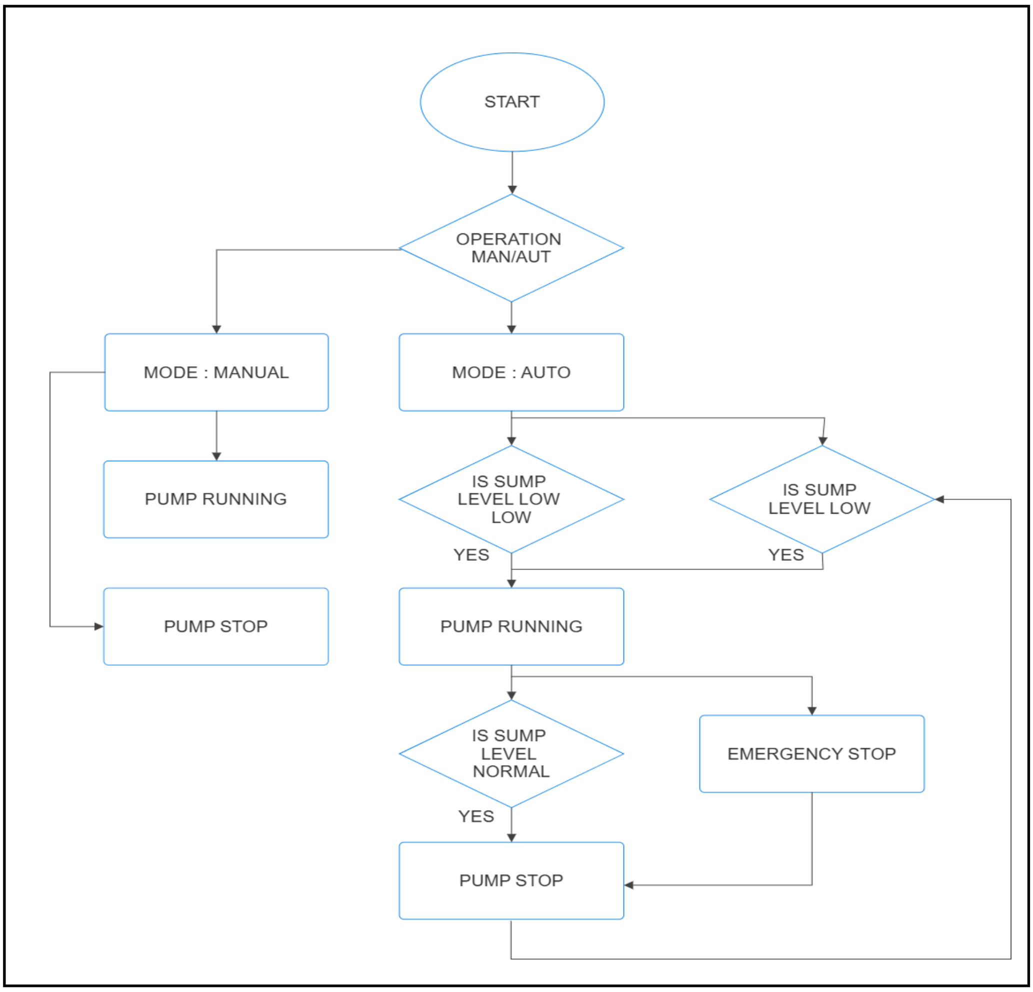

Figure 1. Generator Sump Monitoring Process Diagram

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Table 1. Shows the control logic matrix for a pump automation system based on different alarm and operational conditions, namely High-High (HH) Alarm, Auto Stop, Auto Start, and Low-Low (LL) Alarm. The table summarises the system responses for three main components: Pump, Display, and Buzzer.

Action	HH Alarm	Auto Stop	Auto Start	LL Alarm
Pump	0	0	1	1
Display	1	1	1	1
Buzzer	1	0	0	1

Figure 2. illustrates the automatic sump tank monitoring and control system circuit, which integrates multiple subsystems namely the sensor switch unit, monitoring and alarm system, level indicator, control unit, and transfer pump. This setup is designed to automatically control pump operation based on sump levels, while providing visual and audible alarms for abnormal conditions.

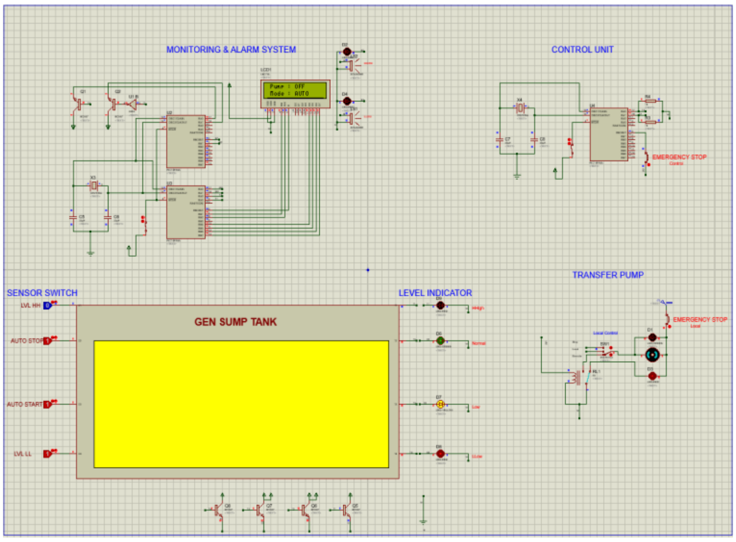

Figure 2. Generator Sump Monitoring Process Diagram

Figure 3. Shows the Tank unit and components such as four level switch sensors, level indicator (High-High Alarm, Auto Stop, Auto Start, Low-Low Alarm), and transistors.

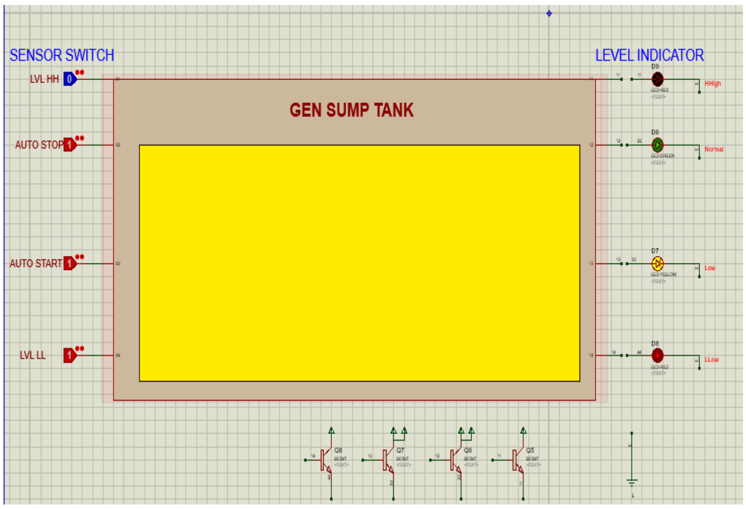

Figure 3. Tank Unit

Figure 4. Shows the Transfer Pump Unit and Components such as relay, pump, pump power supply, 3-way switches (Remote, Local Start, Local Stop), and an Emergency Stop Push Button.

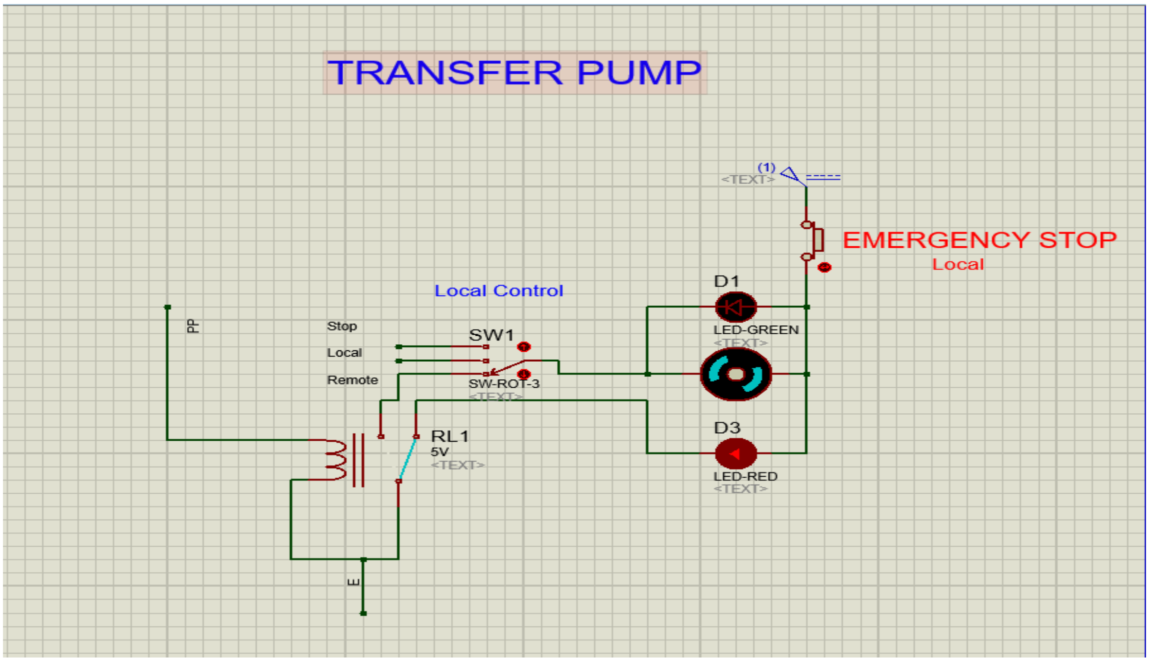

Figure 4. Transfer Pp Unit

Figure 5. Shows the Pump Control Unit and Components: PIC16F84A microcontroller, crystal, capacitor,

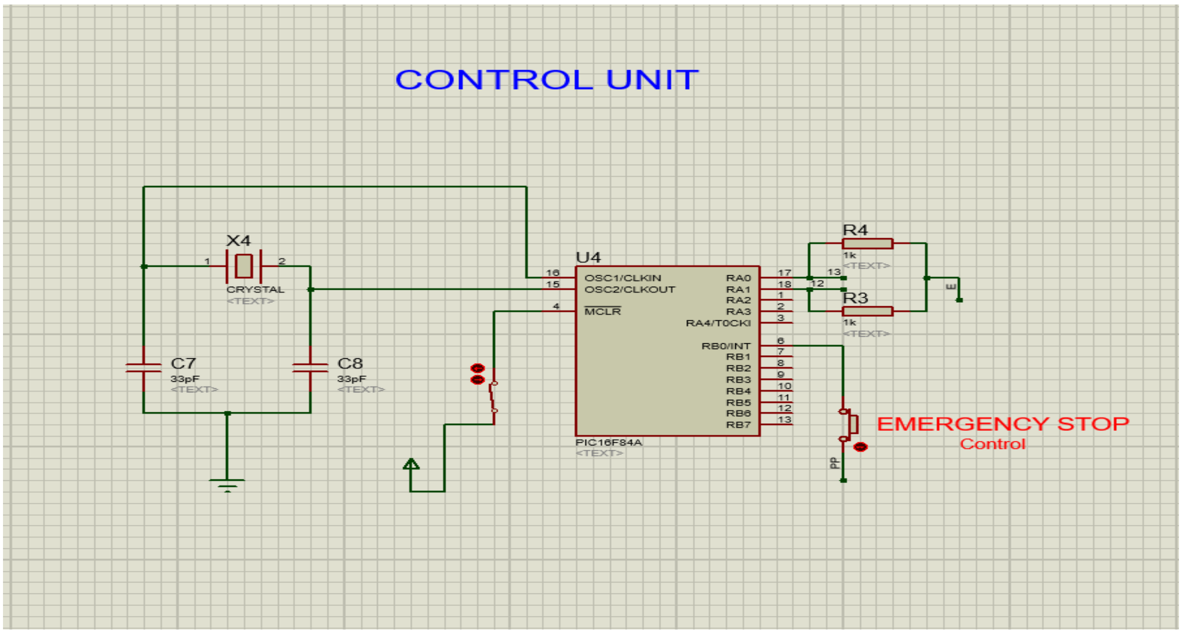

Figure 5. Pump Control Unit

Figure 6. Shows the Monitoring & Alarm System with following components: PIC16F84A microcontroller, crystal, capacitor, transistor, power supply with switch, 16x2 LED display, buzzer, and LED indicators.

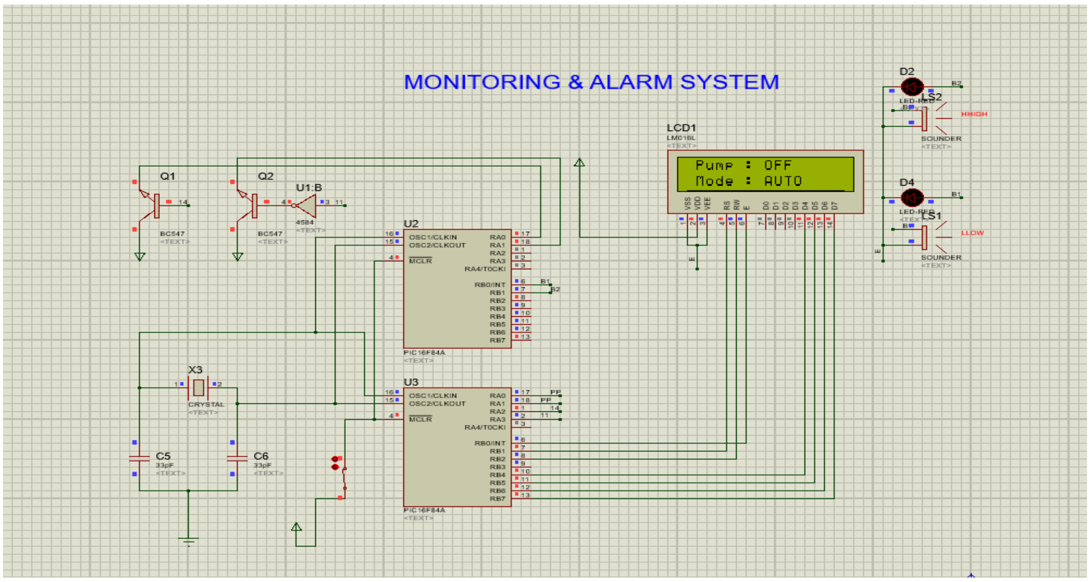

Figure 6. Monitoring & Alarm System

4.0 RESULTS AND ANALYSIS

The intelligent generator sump level monitoring and auto-control system was tested under simulated operating conditions in a controlled laboratory environment. The evaluation focused on the accuracy of level detection, pump responsiveness, alarm functionality, and overall system reliability.

4.1 Automatic Mode Performance

Automatic operation yielded consistent and timely responses to oil level changes. When the oil level dropped below the designated Auto Start point, the pump activated within one second and continued operating until the Auto Stop level was reached, at which point it shut off automatically. This ensured optimal sump oil levels without human intervention.

4.2 Manual Mode Performance

In manual mode, the pump was operated using the manual start switch. The level indicator provided real-time visual monitoring, while the dipstick served as a reliable backup method. Operators were able to successfully start and stop the pump as required, without system errors.

4.3 Alarm System Functionality

The HH and LL alarms were tested under fault and abnormal conditions:

- Low-Low (LL) Alarm: Triggered reliably when oil levels reached critically low points. This provided early warning of possible oil starvation and allowed operators to intervene before damage occurred.
- High-High (HH) Alarm: Successfully activated when oil exceeded the safe limit, preventing overflow and potential oil spillage. In both cases, the buzzer and LED indicators provided clear audible and visual alerts, ensuring operators were promptly informed.

4.4 Safety Features

The dual emergency stop push buttons, installed at the local and control panels, functioned effectively during testing. Immediate shutdown was achieved upon activation, confirming the system's compliance with safety standards.

4.5 System Reliability

Over the course of 50 operational test cycles, the system achieved 100% accuracy in pump control and alarm triggering. No false alarms or operational delays were observed.

5.0 DISCUSSION AND CONCLUSION

The intelligent generator sump level monitoring and auto-control system has demonstrated high effectiveness in ensuring safe and reliable oil management. By integrating microcontroller-based automation with level sensors and alarms, the system successfully reduces reliance on manual monitoring, which is often prone to error. The automatic mode ensures precise control of oil levels, while the manual mode provides flexibility for operators when required.

The inclusion of High-High (HH) and Low-Low (LL) Alarms is a critical feature, as it protects the generator from two major risks: oil starvation and overflow. These alarms, combined with visual and audible indicators, provide early warnings and enhance the overall safety of generator operations. The emergency stop push buttons further reinforce safety, allowing immediate system shutdown during abnormal conditions.

Overall, the system improves operational efficiency, reduces the risk of mechanical failure, and strengthens safety standards in maritime generator operations. Future enhancements could include the integration of wireless communication for remote monitoring, as well as data logging for predictive maintenance and performance tracking.

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