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Implementation of an SF6 Monitoring system for High Voltage Equipment

by

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Project submitted as part of the requirements for the
award of

BEng (Hons) Electrical and Electronics Engineering

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Introduction

High Voltage Gas-Insulated Switchgear (GIS) is a compact and efficient electrical equipment used for controlling, protecting, and isolating electrical equipment in high voltage applications. GIS is characterised by its use of gas as an insulating method, which allows for a significant reduction in the physical footprint compared to traditional air-insulated switchgear. Sulphur hexafluoride (SF6) gas is commonly used in GIS due to its excellent insulating properties and high electro-negativity, which allows it to effectively quench electrical arcs. SF6 has a high dielectric strength, meaning it can withstand high voltages without breaking down, making it ideal for high voltage applications. The use of sulphur hexafluoride (SF6) in high voltage electrical equipment is very common which poses significant environmental risks due to its high global warming potential. Current monitoring practices are often ineffective, leading to undetected leaks and non-compliance with environmental regulations. This project aims to investigate the effectiveness of existing SF6 monitoring systems and develop a more robust solution to ensure timely detection of leaks, minimise environmental impact and ensure compliance with regulatory standards.

SMART Objectives:

1. **Specific:** Design and implement a real-time SF6 gas monitoring system for high voltage equipment within six months to replace the existing system.
2. **Measurable:** Achieve a detection sensitivity of 0.1% for SF6 leaks and provide alerts detected to initiate safety measures to the system.
3. **Achievable:** Work with technology providers to integrate advanced sensor technology into the existing infrastructure of Baglan Bay 275kV Substation.
4. **Relevant:** Ensure that the monitoring system aligns with environmental regulations and company sustainability goals.
5. **Time-bound:** Complete the project within a 6-month timeframe, including design, installation, testing, and training to users.

Project Justification

- **Environmental Responsibility:** SF6 is a potent greenhouse gas, and reducing its emissions is critical for mitigating climate change. Implementing an effective monitoring system demonstrates the commitment to environmental management.
- **Regulatory Compliance:** With increasing awareness on greenhouse gas emissions, ensuring compliance with local and international regulations is vital to avoid penalties and maintain operational licenses.
- **Operational Efficiency:** Early detection of SF6 leaks can prevent costly downtime and equipment failures, leading to improved reliability and efficiency in high voltage operations.
- **Corporate Image:** Demonstrating proactive measures in environmental management enhances the organisation's reputation and aligns with corporate social responsibility initiatives including the NET zero targets.

Project Success

To ensure the success of the project, the following key actions must be undertaken:

- **Stakeholder Engagement:** Involve all relevant stakeholders, including engineering, operations, and environmental compliance teams/regulations, to gather input and ensure alignment with the organisations goals.
- **Technology Assessment:** Conduct a thorough evaluation of available monitoring technologies to select the most suitable sensors and data management systems.
- **Training and Support:** Provide a manual or training for operational staff on the new monitoring system to ensure effective usage and maintenance.
- **Data Management:** Establish a robust data management system to analyse monitoring data, generate reports, and enable decision-making.

Project Deliverables

The project will produce the following deliverables:

1. **System Design Document:** A comprehensive document detailing the design specifications, sensor selection, software management (PLC's) and integration plans for the SF6 monitoring system.
2. **Installed Monitoring System:** A fully operational SF6 gas monitoring system integrated with existing high voltage equipment.
3. **Training Materials:** User manuals or training guides to support staff in operating and maintaining the monitoring system.
4. **Final Report:** A detailed report summarising the project outcomes, including system performance, compliance status, and recommendations for future improvements.
5. **Compliance Documentation:** Records demonstrating adherence to environmental regulations and internal policies related to SF6 management.

By addressing the critical issue of SF6 emissions through this project, the aim is to enhance operational safety, ensure regulatory compliance, and contribute positively to environmental sustainability.

Background to the Project

The proposed project to implement an SF6 gas monitoring system is closely aligned with the literature review, which highlights the critical need for effective monitoring solutions in high voltage applications. Previous studies have identified that SF6 leakage not only causes environmental risks but also affects the operational efficiency of electrical systems [2]. The source emphasises the importance of real-time monitoring technologies and predictive maintenance strategies to mitigate these risks [3]

The project builds upon these findings by integrating advanced sensor technologies and data analytics to create a comprehensive monitoring solution. The work will also address gaps identified in previous research regarding the lack of standardised monitoring practices and the need for improved data management systems [4]. By leveraging insights from the sources, our project aims to develop a robust framework for SF6 management that enhances both environmental compliance and operational reliability.

Discussion of Ethical Issues Raised by the Project

The implementation of an SF6 monitoring system raises several ethical considerations:

1. **Environmental Responsibility:** Given the high global warming potential of SF6, there is an ethical obligation to minimise its emissions. The project aims to address this by ensuring timely detection and mitigation of leaks which results in contributing to environmental sustainability.
2. **Transparency and Reporting:** Ethical considerations also extend to the transparency of emissions reporting. The project will ensure that monitoring data is accurately reported to regulatory bodies resulting in trust and accountability.
3. **Impact on Stakeholders:** The project must consider the potential impact on various stakeholders, including employees and regulatory agencies. Engaging stakeholders throughout the project will help address concerns and ensure that the monitoring system serves the stakeholders' interest.

Existing Systems in the Field

The field of SF6 monitoring has seen large advancements in recent years. Key developments include:

- **Sensor Technology:** [2] Research has focused on improving the sensitivity and reliability of SF6 sensors. Various sensor types, including infrared and electrochemical sensors, have been studied for their effectiveness in detecting SF6 leaks.
- **Data Analytics:** [3] The integration of data analytics has been proposed to enhance predictive maintenance and leak detection capabilities. These approaches allow for real-time monitoring and analysis of SF6 levels, enabling proactive management.
- **Regulatory Frameworks:** [4] Studies have examined the regulatory standards surrounding SF6 emissions, highlighting the need for compliance with international standards. This has led to the development of best practices for monitoring and reporting emissions.

Existing System on Site

The images below illustrate the current system. This project seeks to modernise the existing system, which has become faulty following the liquidation of the system design/manufacture several years ago.



Figure 1 Existing Density Sensor

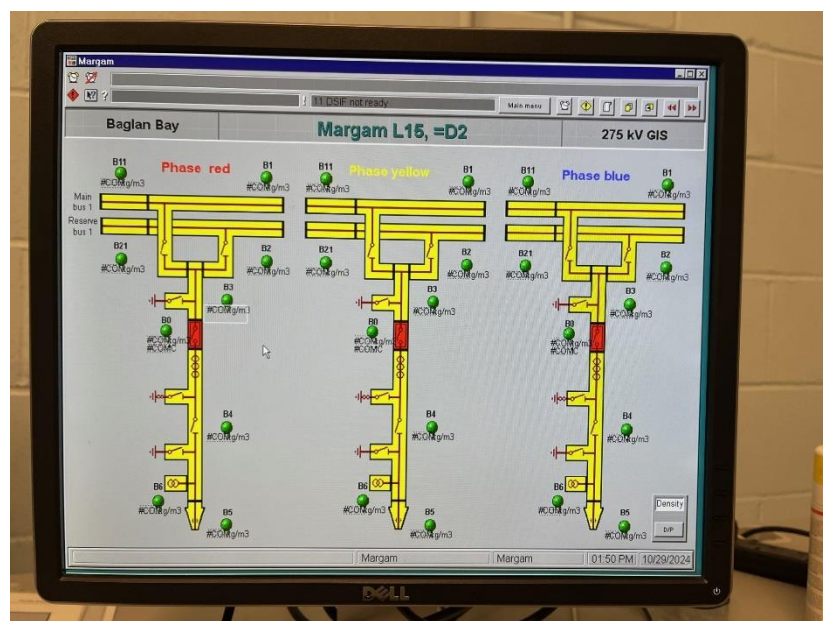


Figure 2 Existing Software

Selection of Relevant Models & Concepts

The project will utilise several relevant models and concepts, including:

- **Real-Time Monitoring Models:** These models will guide the design of the monitoring system, ensuring that it can provide timely alerts for SF6 leaks.
- **Predictive Maintenance Frameworks:** Leveraging machine learning algorithms to analyse historical data and predict potential failures will enhance the system's effectiveness.
- **Environmental Impact Assessment Models:** These models will help evaluate the potential environmental impacts of SF6 emissions and guide compliance with regulatory standards.

By integrating these models and concepts, the project aims to create a comprehensive SF6 monitoring system that addresses both operational and environmental challenges effectively.

Project Design

To provide a complete response the development methods, tools, and data analysis, techniques are detailed below that will be appropriate for the project.

Development Methods

1. Agile Methodology:

- Agile allows for iterative development, enabling to changes quickly and incorporate feedback throughout the project lifecycle. This is particularly beneficial in dynamic environments where requirements may evolve.

2. Waterfall Methodology:

- For projects with well-defined requirements and a clear scope, the Waterfall method provides a structured approach. It ensures that each phase is completed before moving on to the next.

Tools

The following list contains the type of tools that could be used within the project:

1. **SF6 Gas Analysers:** Devices specifically designed to measure the concentration of SF6 gas and detect any impurities.

2. **Pressure Sensors:** To monitor the pressure levels of SF6 gas within the GIS, ensuring that they remain within safe operating limits.

3. **Temperature Sensors:** To measure the temperature of the GIS, as temperature variations can affect gas density and pressure.

4. **Leak Detection Systems:** Hardware that can detect leaks in the GIS, which is critical for maintaining safety and environmental compliance.

5. **Data Acquisition Systems:** To collect and process data from various sensors, allowing for real-time monitoring and analysis.

6. **Communication Interfaces:** Such as Ethernet or wireless modules, to enable remote monitoring and integration with existing control systems.

7. **Control Units:** PLCs (Programmable Logic Controllers) that can process sensor data and trigger alarms or notifications in case of abnormal conditions.

8. **Calibration Equipment:** Tools for calibrating sensors and ensuring accurate measurements over time.

Data Analysis

1. **Quantitative Analysis:** We will look at data from surveys or experiments using statistical methods. This includes summarising the data and making predictions based on it.
2. **Qualitative Analysis:** We will analyse data from interviews or open-ended survey answers by identifying common themes and patterns. This helps us understand the views and experiences of participants.
3. **Data Visualisation Tools:** This makes it easier to understand complex information and share findings.

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