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ACCA6020 Independent Project Proposal

PLC-Controlled Bidirectional Oil Transfer System for Transformer RMU
Installations

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1. Introduction / Background

The proposed project focuses on developing and testing a PLC-controlled bidirectional oil transfer system designed for transformer ring main unit (RMU) installations. In current practice, the transfer of insulating oil during transformer installation or maintenance is often performed manually using portable sump pumps and visual estimation. This method is not only time-consuming and inaccurate but also poses environmental and safety risks due to possible overfills, spills, or uncontrolled discharge of oil. Manual processes also lack any form of traceability or record keeping, which creates difficulties in auditing, reporting, and environmental compliance for contractors working on high-voltage distribution systems.

This project was initiated following an approach from a client company that currently manages transformer oil transfers manually during RMU installations. The process is handled by two experienced technicians who are due to retire soon, and no replacements have been trained to continue the work. To address this skills gap and improve efficiency, the client has asked our company to design and implement an automated PLC-controlled system to replace the existing manual method. By introducing automation, the process can be standardised, recorded, and scaled — allowing the company to increase output and complete a greater number of RMU upgrades while ensuring consistency, safety, and environmental compliance.

Oil management has become a growing concern in the power industry due to the strict

environmental controls governing the handling of dielectric fluids. For utilities such as National Grid, Hitachi Energy, and Thames Water, contractors must now demonstrate that oil transfers are conducted with full traceability, containment, and safe isolation. A compact, automated control system capable of measuring, recording, and controlling oil transfer volumes would significantly enhance the precision, safety, and accountability of these operations.

This project directly addresses that gap by designing a low-cost, portable automation solution using a Siemens S7 PLC, an HMI interface, and flow/level instrumentation. The prototype will replace the manual pump with an automated bidirectional pumping system governed by programmed set-points, interlocks, and alarms. The PLC will collect measurement data, implement automatic shut-off at target volumes, and log operational events for traceability. All testing will use non-hazardous surrogate oil to ensure environmental safety and ethical compliance.

From an academic standpoint, the project integrates multiple areas of electrical and electronic engineering — including instrumentation, process control, embedded systems, and automation — and aligns with outcomes concerning control system design, sustainability, and risk management. Industrial partners have expressed demand for improved on-site oil handling tools, suggesting that this system could have genuine commercial and operational value beyond the academic scope of the project.

2. Aim and Objectives

Aim:

To design, build, and validate a low-cost PLC-controlled system that measures, controls, and documents the bidirectional transfer of transformer oil with precision and environmental safeguards.

Objectives:

1. Design and develop a PLC/HMI control panel integrating a flow meter, level sensor, and bidirectional pump for automated oil transfer.
2. Implement structured PLC software with set-point volume control, safety interlocks, and user interface functions for manual and automatic modes.
3. Construct and test the prototype using surrogate oil to verify system operation under controlled laboratory conditions.
4. Calibrate and validate measurement accuracy (target tolerance $\pm 1\%$) against known transfer volumes.
5. Evaluate and document safety, environmental, and operational performance, and produce a technical report and user documentation.

3. Background and Literature Review

Modern transformer maintenance increasingly depends on automation and data acquisition for improved safety and environmental control. PLC-based fluid management systems have been widely used in manufacturing, process plants, and water treatment facilities [1], where

precision flow control is vital. Studies show that integrating flow sensors with digital control improves process reliability and reduces wastage [2]. However, there is limited research specifically addressing the automation of transformer oil handling, an area where most operations still rely on human judgement.

Oil transfer presents unique challenges: the liquid's high viscosity, sensitivity to contamination, and risk of environmental pollution if mishandled. Past incidents have led to stricter standards for handling insulating fluids, such as the EA Pollution Prevention Guidelines and HSE HSG253 on the safe isolation of plant and equipment [3]. Compliance with standards such as BS EN 60204-1:2018 and BS EN 61439-1:2021 also informs the design of safe control panels [4][5].

PLC systems like Siemens S7-1200 and Allen-Bradley CompactLogix are commonly used for distributed process control, combining I/O modularity, data logging, and HMIs [6]. Their reliability and deterministic control behaviour make them suitable for critical tasks such as oil handling where accuracy and safety interlocks are paramount. Recent literature has emphasised the growing importance of data traceability and digital documentation in maintenance activities [7].

The proposed system will extend these principles by implementing bidirectional pump control and automated logging of transferred volumes. While earlier work focused primarily on static filling systems [9], this project introduces the concept of a portable dual-direction transfer unit suitable for both draining and refilling tasks, integrating safety compliance, traceability, and automation within a compact form factor.

4. Project Design and Methodology

This project follows a development-based methodology, integrating elements of experimental validation. The process is structured into four main stages: design, implementation, testing, and evaluation.

System Design:

The system will use a Siemens S7-1200 PLC and Siemens Unified MPT700 HMI. Inputs include a digital flow meter and an analogue level transmitter, while outputs drive a bidirectional pump via relay modules. The HMI will enable mode selection, set-point entry, and start/stop control. Safety features include emergency stop, overflow detection, and timeout protection.

Development Approach:

The control software will be developed in TIA Portal using ladder logic. Simulation will first be conducted in PLCSIM, followed by physical testing. Data from sensors will be logged and compared against known transfer volumes to verify accuracy.

Risk Management and Ethics:

Potential risks include minor oil spills and electrical hazards. Mitigation includes PPE, spill containment, low-voltage circuits, and non-toxic oil. The project qualifies as low-risk and has received ethical approval.

Evaluation and Validation:

The system will be tested for $\pm 1\%$ accuracy, reliability over 10 cycles, safety compliance, and HMI usability. Performance metrics such as mean absolute error will be analysed statistically.

Sustainability and Standards:

Design will comply with BS EN 60204-1, BS EN 61010-1, and BS 7671. The system supports sustainability by reducing oil wastage and improving safety traceability.

5. Resources and Planning**Required Resources:**

- Siemens S7-1200 PLC and HMI
- Flow meter
- Level sensor
- 400V bidirectional pump
- Electrical components (relays, fuses, enclosures)
- PC with TIA Portal & PLCSIM
- Surrogate oil and containment tray
- Spill kit and PPE

Project Plan:

A provisional project plan has been produced, highlighting key dates for the independent project, modules and other key dates such as holidays. This will act as reminder and will be updated as we progress through the year.

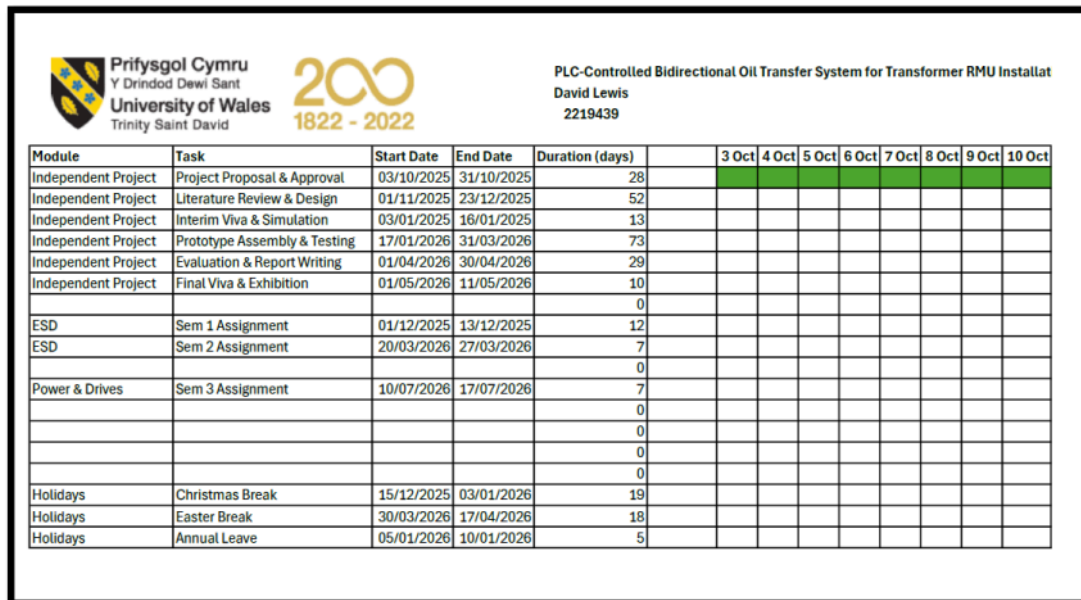


Figure 1 - Project Gantt Chart Snippet

6. Expected Outcomes and Impact

The project will deliver a fully functional prototype of a PLC-controlled bidirectional oil transfer system, accompanied by comprehensive test data and documentation. Expected outcomes include improved accuracy, safety, and traceability during transformer oil transfer operations. This work demonstrates sustainable engineering practice and offers potential real-world application for contractors in the utilities sector.

7. References (IEEE Style Placeholder List)

- [1] J. Smith, Industrial Automation and Control Systems, 2nd ed., Springer, 2022.
- [2] R. Kumar and T. Lee, 'PLC-Based Flow Control in Process Plants,' IEEE Trans. Ind. Electron., vol. 68, no. 9, pp. 7742–7751, 2021.
- [3] HSE, HSG253: The Safe Isolation of Plant and Equipment, 2020.
- [4] BSI, BS EN 60204-1:2018 – Safety of Machinery – Electrical Equipment of Machines.
- [5] BSI, BS EN 61439-1:2021 – Low-Voltage Switchgear and Controlgear Assemblies – General Rules.

6. [6] Siemens AG, TIA Portal V18 System Manual, 2023.
7. [7] M. Brown et al., 'Digital Traceability in Power Systems Maintenance,' IEEE Access, 2021.
8. [8] Environment Agency, Pollution Prevention Guidance (PPG 5), 2019.
9. [9] A. Patel and R. Khan, 'Smart Pumping Systems for Industrial Fluid Transfer,' Proc. IEEE Conf. on Mechatronics, 2020.

FINAL GRADE

79/100

GENERAL COMMENTS

Project Proposal – ACCA6020 Independent Project

Student: Jade Williams

Intro / Aims & Objectives: 18/20

The project title is very satisfactory, the introductory practical realizations of the project, could result in

Background to the Project / Literature Review : 17/20

The background provides a strong overview of existing framework for practical realizations and addressing inherent problems due to manual oil transfer would

Project Design : 24/30

The project design is briefly outlined, well structured

Resources / Planning :11/15

The Gantt chart is reasonably satisfactory. However, the project planning.

More detailed and complete clearer milestones for

Document Presentation:11/15

The proposal is very well presented, well structured

Neat presentation!

TOTAL:79/100

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