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**Eng. Dr. Harrison
Mutikanga**

Chairperson,
Joint Editorial
Committee

Message of the Chairperson JEC

It is with great honour and pride that I present to you the inaugural issue of The Engineer Magazine, a joint biannual publication of the Engineers Registration Board (ERB) and the Uganda Institution of Professional Engineers (UIPE). This milestone reflects continued collaboration between our two institutions, united by a shared vision to strengthen the voice of the engineering profession in Uganda. Complementing our joint newsletter, this magazine is dedicated to showcasing cutting-edge research and innovative engineering solutions by Ugandans and for Ugandans.

This publication comes at a time when engineering has assumed a central role in shaping Uganda's socio-economic transformation. From energy to transport, from water to ICT, our nation's development agenda relies heavily on engineers who are innovative, competent, and responsive to emerging challenges. The magazine will therefore act as a bridge linking academia, industry, government, and the public, highlighting achievements, lessons, and opportunities in the engineering sector. It is a space for engineers to showcase their work, exchange ideas, and reflect on how we can better serve society while upholding the highest professional standards.

I commend the authors and contributors who have shared insightful articles in this issue. Their work showcases the depth of talent and expertise within our engineering community. We invite engineers, researchers, and innovators across Uganda to contribute articles for upcoming issues of the magazine, ensuring a richer exchange of ideas. As the Joint Editorial Committee, our role is to ensure that this biannual publication remains a reliable, informative, and inspiring resource for practitioners, students, and policymakers alike.

May this magazine ignite dialogue and foster collaboration, while inspiring the next generation of engineers. Together, let us continue building a strong, professional, and globally competitive engineering fraternity that will contribute to public safety and the realisation of Uganda's Vision 2040 and the Sustainable Development Goals.

“ It is a space for engineers to showcase their work, exchange ideas, and reflect on how we can better serve society while upholding the highest professional standards.

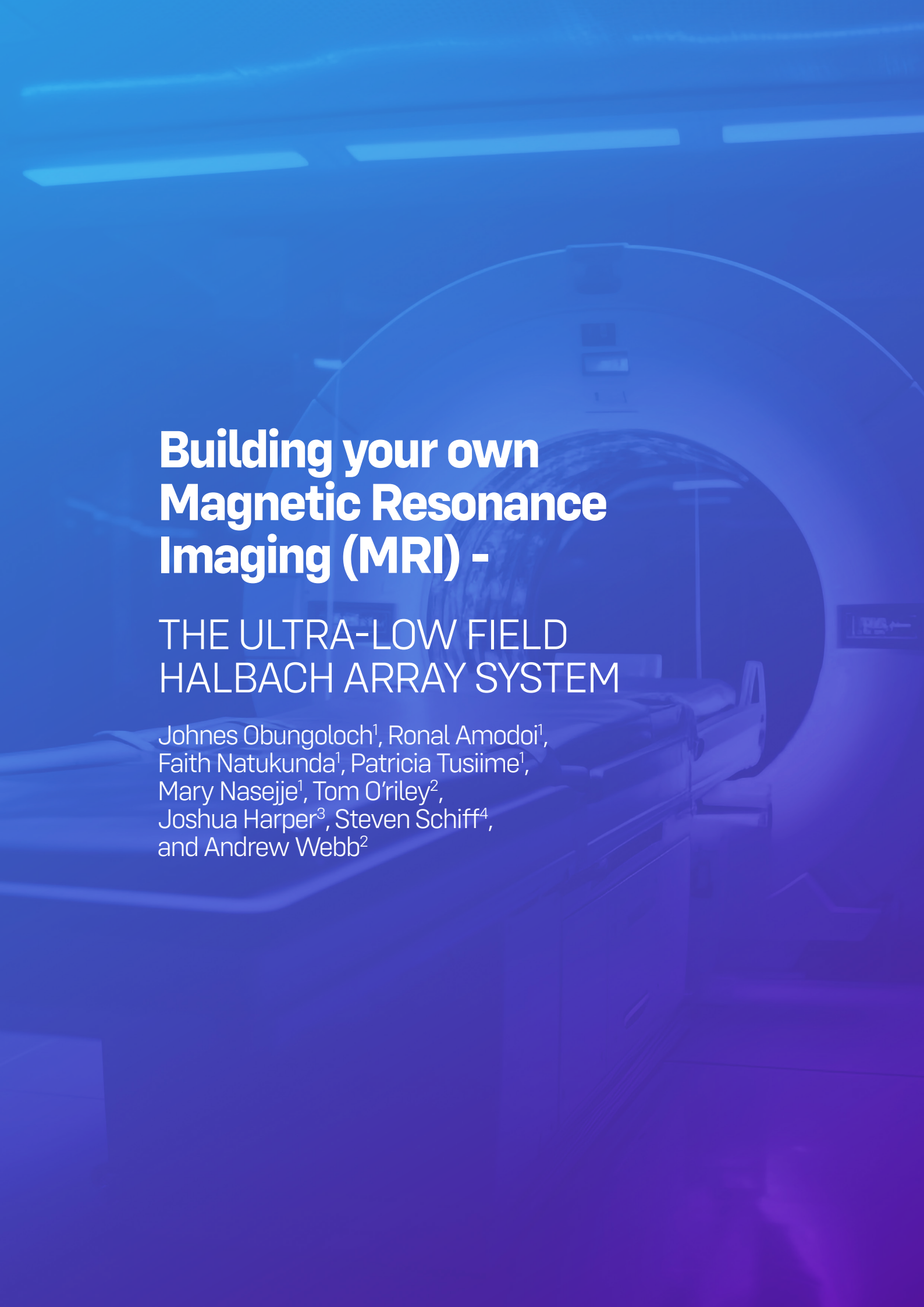




Eng. Dr. Johnes Obungoloch is the Dean of the Faculty of Applied Sciences and Technology (FAST), at Mbarara University of Science and Technology (MUST). He is a Senior lecturer in the department of Biomedical Engineering. He holds a bachelor's degree in Electrical Engineering from Makerere University, a Master's degree in Biomedical engineering from Keele University in the United Kingdom and a PhD in Biomedical Engineering from the Pennsylvania State University in the United States.

Eng. Dr. Obungoloch's research interests is in the fields of medical technologies and medical imaging, specifically magnetic resonance imaging. He is the current interim president of the Uganda National Association of Medical and Hospital Engineering (UNAMHE), a corporate member of the Uganda Institution of Professional Engineers (UIPE), and a former member of the World Health Organization's Strategic Technical and Advisory Group on Medical Devices (STAGMEDEV).

Eng. Dr. Obungoloch is also the president of the African Chapter of the International Society of Magnetic Resonance in Medicine (ISMRM).



Building your own Magnetic Resonance Imaging (MRI) -

THE ULTRA-LOW FIELD HALBACH ARRAY SYSTEM

Johnes Obungoloch¹, Ronal Amodoi¹,
Faith Natukunda¹, Patricia Tusiime¹,
Mary Nasejje¹, Tom O'riley²,
Joshua Harper³, Steven Schiff⁴,
and Andrew Webb²

Abstract

This paper describes the process of building a low field magnetic resonance imaging (MRI) from 3D printed and laser-cut components. The construction of the system was done by hand and simple tools at the MRI lab at Mbarara University of Science and Technology. Components used in the construction were machined and shipped from Leiden University Medical Center (LUMC) in the Netherlands.

An operational prototype of a Halbach MRI system was built by a collaborating team in a period of about 11 days demonstrating the feasibility of building your own MRI system.

INTRODUCTION

1.0

Magnetic Resonance Imaging (MRI) is arguably one of the best imaging modalities in the medical field but also one of the most expensive (Sahu et al., 2020). As a result, MRI, invented in 1973 (Wilson et al., 2023), is a widely-used imaging modality in high-income countries for the diagnosis and administration of intracranial diseases. However, access to MRI imaging services in low- and middle-income countries (LMICs) is very limited (Anazodo et al., 2023). According to the International Society of Magnetic Resonance in Medicine (ISMRM) study group, MRI systems are classified

according to their magnetic field strengths as ultra-low field (<0.01 T), low-field (0.01 – 0.1 T), mid-field (0.1 T– 1 T) and high field (>1.0 T). Conventional clinical MRI scanners fall in the category of midfield and high field.

They are very expensive to purchase, operate and maintain and have very high technical requirements (Anazodo et al., 2023). These limitations can be overcome by developing affordable, portable and low-field MRI scanners that can be used to diagnose conditions that may not require particularly very high spatial and temporal resolution.

The Halbach array MRI system is one such low field system that meets the requirements of low resources settings (Gualart-Naval et al., 2023). A Halbach system uses a special arrangement of permanent magnets to increase the field on one side of the arrangement and reduce the field on the other side. This is achieved by rotating the north and south poles of the magnets through small incremental angles (Blümli & Soltner, 2023).

If the magnets are arranged in a circular ring, a magnetic field is formed inside the ring with the outside of the ring having a very weak magnetic field that does not extend a few centimeters from the ring. This article describes the process of designing and fabricating a Halbach array ultra-low field

MRI system with a field strength of 50mT using $2.54\text{cm} \times 2.54\text{cm} \times 2.54\text{cm}$ permanent magnets. The system was designed to operate at room temperature without electromagnetic shielding.

METHODOLOGY

The design of the MRI system and sourcing of components were done in the Netherlands in collaboration with the Leiden University Medical Center (LUMC). The components were then shipped to Uganda via Air Cargo.

2.1 Design and operational parameters

To make the system portable, the weight of the Halbach array system was set not to be more than 100kgs. The magnetic field was set at 50mT as generating higher fields than 50mT would require the system to be more than 100kgs. The bore size diameter was set at 22cm. This size is suitable for imaging children but adult heads can also fit into the system to allow brain imaging (Kiet et al., 2012). The system used small neodymium boron iron (NdBFe) permanent magnet cubes of dimensions $2.54\text{cm} \times 2.54\text{cm} \times 2.54\text{cm}$. The small magnets are arranged in rings and the rings stacked together to create a cylindrical MRI system. The system was also designed to operate at room temperature and

does not require room shielding. While the Halbach array uses a series of small magnets for the main magnetic field, the gradient and radiofrequency magnetic fields are generated using electromagnets. The system was therefore designed to use direct current (DC) voltage of up to 50V and current of up to 15A. A commercially available spectrometer system made by Redpitaya (Redpitaya, n.d.) was used to control the system. Other materials chosen were plexiglass for the magnet rings, polylactic acid (PLA) materials for 3D printed gradient and radio frequency magnet coil formers, brass for fastening rods and nuts for magnet assembly and aluminum frames for the magnet trolley. Electromagnet coils were made of 1.5mm² flexible copper wire.



Figure 2: a) Marked magnet poles -red for north pole and blue for south pole



Figure 2: b) Magnets being slotted into the rings



2.2 Shipping of components

Figure 1 shows components that were shipped from the Netherlands via Air Cargo. The components included custom-machined and 3D-printed parts, nuts and bolts, the gradient amplifier, copper wire for winding electromagnet coils, and necessary assembly tools for the low-field scanner, all packed in a crate measuring 1.2 m x 1.0 m x 0.8 m with a total weight close to 325 kg. A clearing and forwarding company with a liaison agent in Uganda was engaged for door-to-door handling and shipping at a cost of approximately \$2700 US.

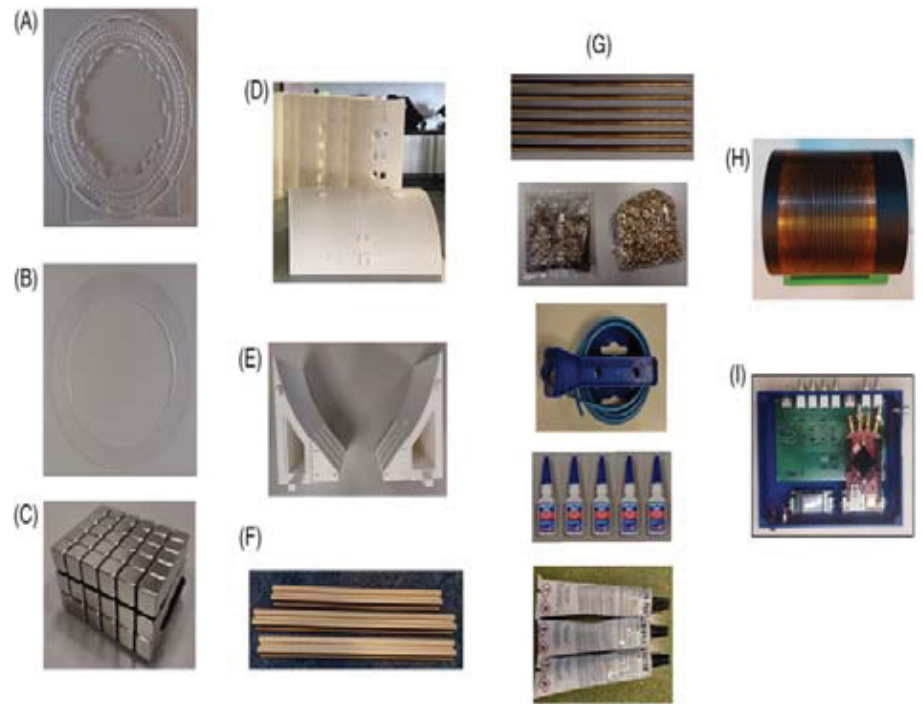


Figure 1 Photographs of the major components of the system. A: plastic rings in which the individual magnet elements are placed; B: lids for each side of the rings; C: mm3 NdFeB magnets; D: 3D printed gradient coils with grooves for wire insertion; E: 3D printed supports for the finished magnet assembly; F: aluminum used for the trolley; G: small parts—brass rods/nuts/bolts/wire/superglue/PMMA glue; H: simple wire-wound solenoid coil; I: custom-built spectrometer based on a Red Pitaya.

2.3 Assembly of the components

When the components arrived in our lab at Mbarara University of Science and Technology, the fabrication team was taken through a brief instructional video about building your MRI system available at <https://www.youtube.com/watch?v=LS14Q5Zwkdc>. The video was reinforced by physical training and instructions by collaborators who had travelled from LUMC.

2.3.1 Magnet Construction

Construction of the Halbach MRI system starts with marking magnet poles—the north and south poles (figure 2). In this case the north poles are marked red and the south poles are marked blue.

This is done to avoid confusion during placing of magnets into the slots on the magnet rings. Once marked, the magnets are then slotted onto the rings. Once the magnets are placed into slots, they have to be covered with another ring of plexiglass and glued to avoid

the magnets jumping out due to the forces of attraction between them.

2.3.2 Assembling the rings

After magnets have been slotted onto the rings, the rings are then assembled together using brass rods and nuts to form a cylindrical system with a bore size of 32cm and a homogeneous magnetic field of 50mT (figure 3). Brass rods and nuts are used as they are non-ferromagnetic and will not interfere with the magnetic field.

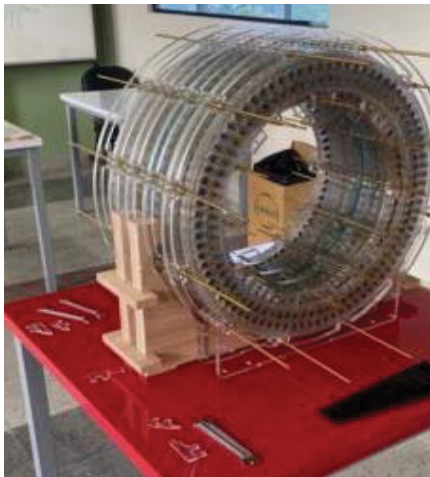


Figure 3: Magnet rings being assembled into an MRI system

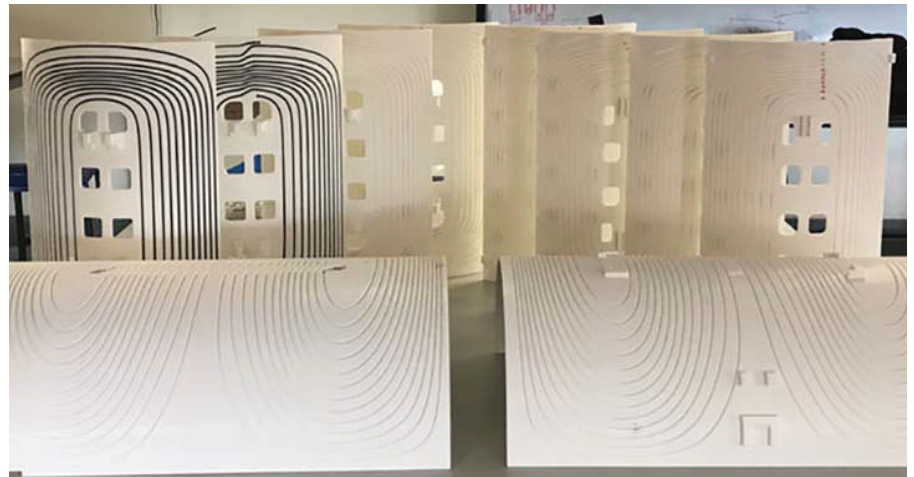


Figure 4: Gradient coil formers

The project was executed successfully and it demonstrated the feasibility of constructing an MRI system locally in Uganda.

2.3.3 Gradient coil Assembly

Gradient coils generate a spatially varying magnetic field in the x, y and z directions. The coils are wound on 3D printed formers as shown in figure 4.

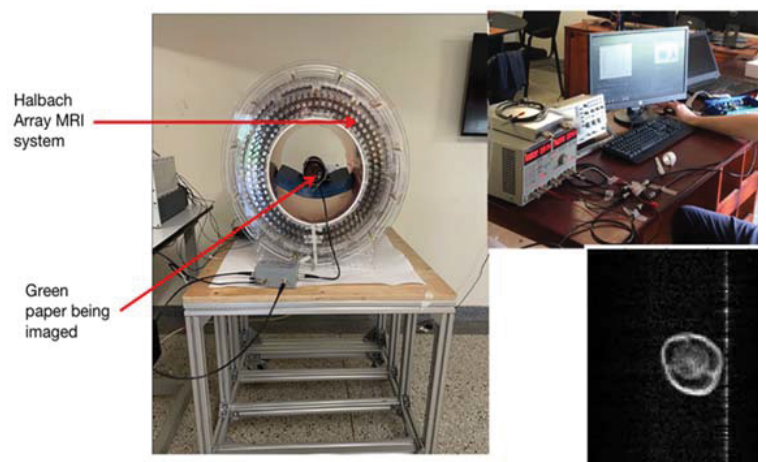
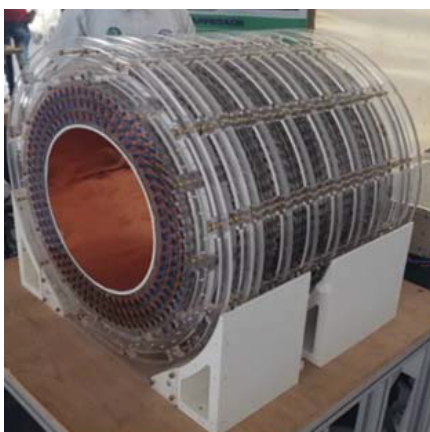


Figure 6: Imaging using the assembled Halbach MRI system

RESULTS

3.1 Final magnet assembly

The final Halbach MRI magnet assembly consists of magnet rings that are assembled into a cylindrical shape, the gradient coils which are made of electro-magnets and the radio frequency coil that generate a radio frequency magnetic field. The final assembly of the Halbach magnet system is shown in figure 5.

3.2 Imaging using the constructed Halbach MRI system

To validate the functionality of the system, an image of a green paper was acquired using the system. The set-up for imaging was done as in figure 6. The weighted image TI was acquired at a frequency of 1.967MHz, repetition time TR of 1000 micro seconds, echo time TE of 300 micro seconds and a bandwidth of 33kHz. Acquiring an image meant that the project was successful.

4.0 Discussion

The magnetic field of the system was measured and found to be 46.8mT instead of 50mT. Variation in the magnetic field is attributed mainly to the inconsistency in the magnetic field strength of the individual magnets. The system used 4200 small magnets in total each with a surface magnetic field strength of 2T but this is not normally the case.

The project was executed successfully and it demonstrated the feasibility of constructing an MRI system locally in Uganda.

5.0 Conclusion

The Halbach low field MRI system has the potential to increase access to MRI services in low resources setting. The system costs roughly \$5,000 in components and parts minus the electronics. Most of the components, though shipped from the Netherlands, are available locally and at lower costs. The system works with very low power and in an unshielded environment making it suitable for rural areas. A sample phantom image of the green paper was acquired but the system can be fine-tuned to acquire better resolution images. High power gradient amplifiers and better image processing software are needed to achieve better performance.

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Design & Implementation of a Solar- Powered Irrigation System at Agule Village, Katakwi District - Uganda

Eng. Aloysius Mubangizi
Head of Design,
Nexus Green Limited

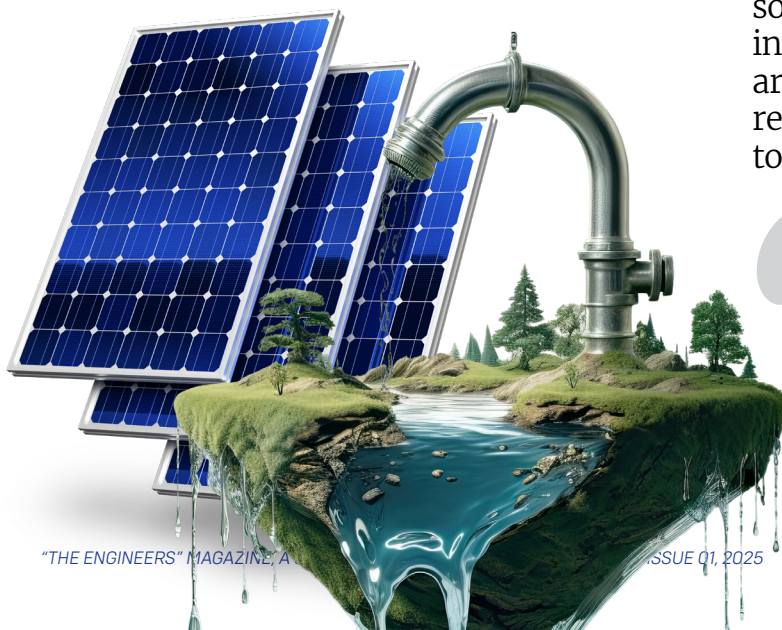


Abstract

This article presents a case study on the design and implementation of a 5-hectare solar-powered irrigation system in Agule Village, Katakwi District, Uganda. The project was developed with several other schemes under the Ministry of Water and Environment (MWE) with funding from the Government of Uganda and UK Export Finance, implemented by Nexus Green Limited as the EPC contractor. The project aimed to improve water access and food security for smallholder farmers. Drawing water from Lake Bisina using a solar-powered system, the solution demonstrates sustainability, energy efficiency, and engineering innovation. System design was based on detailed technical feasibility assessments and modelled to balance cost and performance through deficit irrigation. The project aligns with Uganda's Vision 2040, the National Irrigation Master Plan (2010–2035), and SDGs 6 and 13.

1. INTRODUCTION

Agule Village, in drought-prone Katakwi District, was experiencing recurring agricultural losses due to erratic rainfall. To combat food insecurity, Nexus Green Ltd was commissioned to implement a five-hectare solar-powered irrigation scheme that would enable sustainable year-round farming, aligning with the national goals for agricultural transformation and climate adaptation.



2. JUSTIFICATION

The implementation of a solar-powered irrigation scheme in Agule Village was found critical for addressing the persistent drought conditions and food insecurity challenges identified in the Katakwi District Hazard, Risk, and Vulnerability Profile 2014 (UNDP, 2014). Despite Agule Village's proximity to Lake Bisina, the lack of irrigation infrastructure limited crop farming to the rainy season. Farmers rarely utilized the lake for irrigation due to safety concerns, including the risk of drowning while fetching water. This project aimed to address these challenges by enhancing agricultural resilience, mitigating drought risks, and enabling year-round farming, thereby improving food security and livelihoods in the region.

2.1 Justification for solar power

The use of Solar power was identified as the most suitable solution due to its sustainability, cost-effectiveness, and adaptability. Unlike diesel- or petrol-powered systems, solar technology proved more cost-effective over time, with minimal maintenance compared to fossil-fuel alternatives. Solar energy is a clean, renewable resource that eliminates fuel costs and reduces greenhouse gas emissions, aligning with Sustainable Development Goals (SDGs) 7 and 13 on clean energy and climate resilience. Given the limited electricity access in Katakwi District especially in areas near the lake, solar-powered systems ensured a reliable, independent water supply for farming. They are also more cost-effective in the long run, requiring minimal maintenance compared to fossil fuel alternatives.

“the lack of irrigation infrastructure limited crop farming to the rainy season.”

2.2 Justification for location in the Agule village

The adoption of solar-powered irrigation is also in line with Uganda's National Irrigation Master Plan (2010–2035) and Vision 2040, both of which emphasize the sustainable utilization of irrigation potential through renewable energy sources. In addition, the Ministry of Water and Environment National Irrigation Master Plan (MWE, 2011) stipulates the priority irrigation development areas and schemes over short, medium and long terms, emphasizing that areas near natural water resources like lake Bisina be prioritized.

2.3 Alignment with national and international programmes

This project aligns with national programs including Uganda's Parish Development Model (PDM) and Vision 2040, which seek to transform Uganda from a peasant-based to a modern and prosperous economy. It is also aligned with Uganda's 2020 National Development Plan (NDP) III (2020/21 – 2024/25), which prioritizes irrigation development as a strategy for increasing agricultural productivity and economic transformation. Additionally, the project is in line with the 2020 Food and Agriculture Organization (FAO) findings on water scarcity in both irrigated and rainfed agriculture, highlighting the need for innovative water management solutions.

At a global level, the project contributes to achieving Sustainable Development Goal (SDG) Indicator 6.4.2, which measures water scarcity in irrigated areas. Furthermore, the project supports more international development frameworks such as the 2030 United Nations' Agenda for Sustainable Development (UN, 2015) and the African Union's Agenda 2063 (AU, 2015), which highlight the importance of efficient water use and climate-smart agriculture.

By implementing this project, Katakwi District aimed to reduce the vulnerability index of Agule Subcounty, ensuring sustainable food production and improved community livelihoods through climate-smart irrigation solutions.

3. FEASIBILITY STUDIES

The technical feasibility covered socio-economic studies and site-specific conditions such as water suitability (Ayers and Westcott, 1985) and availability, soil characteristics, and topography. Socio-economic studies engaged beneficiaries in participatory design sessions, gathering information that helped in designing both a cost-effective and a socially acceptable irrigation system. The scheme was deemed socially acceptable and suitable for a five-hectare irrigation scheme, with land voluntarily offered by five landlords to host the project supporting 48 beneficiary farmers, that were already operating in eight farmer groups renting land at Shs. 70,000 per acre per season and the landlords agreed to maintain same cost after the irrigation scheme has been installed. Soil and climate analyses revealed suitable conditions for horticulture with minimal soil conditioning. Additionally, a topographic survey conducted to determine elevation profiles and optimize pipeline routing. The adopted projection and coordinate system was in ARC1960 Datum in UTM Projected to Zone 36N at a scale of 1:2,000 and grid interval of 50. This was done with the help of a GPS and RTK

4. SYSTEM DESIGN

The design was undertaken through a series of equations in FAO and MWE design guidelines (MWE, 2013; FAO, 2002 and Allen, et. al., 1998)

4.1 System Design

The total water demand, including crop and livestock, was calculated at 361.91 m³/day. While FAO studies indicate that crops can tolerate up to 75% water deficit, they recommend limiting deficit irrigation to 50% to minimize yield reductions. Deficit irrigation was optimized through an iterative process to minimize investment costs while maintaining acceptable yields. By adopting a 50% deficit strategy, the daily water demand was reduced to 181.48 m³/day, as modelled in FAO Cropwat software, which projected a cumulative yield reduction of only 4.2% per season. The use of deficit irrigation, allowed the use of smaller-diameter pipes (90 mm instead of 110 mm), reducing both capital and energy costs. Lake Bisina, the selected water source, after performing a water balance, was found to be highly viable with an estimated storage capacity of 13.49 m³/s during dry years, of which only 0.075% would be required to meet the scheme's demand of 0.01 m³/s. The hourly water supply was calculated assuming seven daily sunshine hours available to the pump within the Agule area. The 7-hour pumping regime resulted in a pumping rate of 25.93 m³/hr that was used to size the water pump.

The system incorporates 36 solar panels of 475-Watt-peak, driving a pump rated at 26 m³/hr with 4bars to deliver water to the reservoir. Laser spray irrigation method was chosen for its uniform application, low clogging and easy to manage by the farmers. With an application efficiency of 85% (Omara, 2024), it presents an efficient irrigation solution that aligns with the needs of various crops. Unlike traditional sprinklers, laser spray irrigation operates at lower pressures of 0.7 bars (7-meter), facilitating gravity feed and reducing the need for two-stage pumping, making it ideal for solar-powered systems. The system is designed to deliver fine water droplets in a controlled manner that simulate rainfall, delivering a higher distribution uniformity to the crop's feeding roots.

From the reservoir balancing, a 40 m³ reservoir was sized to ensure balancing storage since irrigation was to be conducted simultaneously with water pumping. The design phase informed the development of standardized bidding documents, drawings, technical specifications, and bills of quantities in line with CESMM3 standards. The system design components are summarized in table 1.

Table 1 System design outputs

Item	Explanation
Intake	Sump depth 9m, Diameter 1.2m
Transmission	OD90mm HDPE PN10, 384.3 m
Pump	Flow, Q, 26m ³ /h, Head, 4bars
Solar panels	36 No. solar panels of 475 Wp each
Reservoir	40 m ³ on a 9m tower
Irrigation	20mm laserspray pipe, 16,800m
Submains	OD63mm uPVC pipe PN6, 900m
Main lines	OD90mm uPVC pipe PN10 1,080m

5. FINANCIAL FEASIBILITY

Cost optimization through engineering redesign iterations reduced the system costs to almost half, making the project financially feasible. Financial modeling showed an IRR of +32% at a discounting rate of 5%, supporting strong economic viability.

6. IMPLEMENTATION

The project exhibited a well-coordinated effort in implementation of small-scale irrigation infrastructure aimed at boosting agricultural productivity in Uganda. The engineering assignment covered the full project cycle, from tender preparation and construction supervision to quality control and institutional planning.

The standardized drawings, technical specifications, and bills of quantities developed after design informed the project implementation as supervised by M/S Sari Consulting Ltd (UK) in joint venture with SGAPI SrL (Italy) and the Ministry of Water and



Figure 1. Completed Agule intake structure of channel, silt basin and sump

Environment. Key engineering milestones included construction of pump station, intake infrastructure (Fig1 1), reservoir installation, pipeline networks, and installation of solar energy packages. Robust project controls ensured the system was delivered ahead of schedule, saving time and reducing costs by over 13%. Quality assurance was upheld through routine soil bearing tests, block compressive strength tests, slump tests, and pressure testing.

Additionally, the implementation embraced sustainable practices such as maximizing local content in material sourcing and labor engagement; a key ingredient in fostering community buy-in, and preparing a detailed Operation & Maintenance (O&M) manual. These efforts not only enhanced project ownership among local stakeholders but also ensured long-term functionality and sustainability of the irrigation system

The institutional model proposed a shift from farmer-led management to a structured irrigation committee with a chairperson that engage farmers on irrigation scheduling and strengthens long-term scheme sustainability.

This integrated approach highlights the importance of proactive engineering supervision, environmental safeguards, and stakeholder alignment in delivering resilient and sustainable irrigation solutions for small-holder farmers.

7. LESSONS LEARNED

The lessons learned from the Agule Irrigation Scheme implementation provide valuable insights for future engineering projects. One of the primary takeaways is the importance of adopting modern technologies to improve environmental assessments. Tools such as remote sensing and satellite precipitation products can complement traditional methods, offering accurate and timely data. This will enable better planning, particularly in areas where environmental conditions, such as rainfall patterns, are unpredictable and traditional data is unavailable.

Another critical area of focus is procurement strategy. The project revealed that engaging suppliers with favorable payment terms and bulk purchases can significantly reduce costs. Establishing partnerships based on mutual benefits and negotiating agreements with balanced trade-offs can ensure the procurement of quality materials at lower costs, enhancing overall project efficiency.

The experience also underscored the importance of dynamic decision-making and adaptability in project execution. Challenges, such as unforeseen environmental conditions, highlighted the need for comprehensive contingency planning to address unexpected scenarios promptly. Incorporating flexible strategies would ensure that projects can adapt to changing circumstances without major disruptions.

Additionally, fostering a culture of safety emerged as an essential element of project management. Ensuring workforce safety requires continuous education, engagement, and collaboration. Regular training and proactive safety programs can create an

environment where safety becomes a shared responsibility, minimizing risks during project implementation.

Lastly, the need for thorough geotechnical surveys during the design phase cannot be overstated. Encountering rocky ground conditions during excavation emphasized the value of detailed site investigations. Allocating resources for advanced surveys like geological surveys for intake works is crucial in planning for appropriate tools, such as rock-breaking equipment, will help projects overcome such challenges efficiently and smoothen the construction exercise.

By integrating these lessons into future projects, engineers can achieve greater resilience, cost-effectiveness, and sustainability in managing engineering projects while minimizing risks and ensuring successful implementation.

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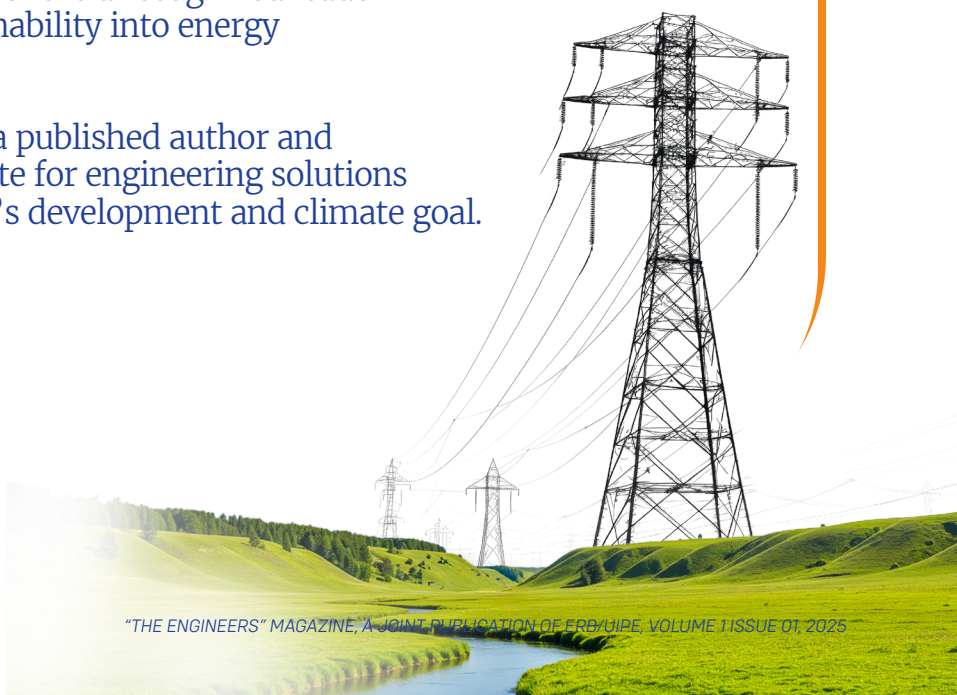
Figure 2. Installed Agule irrigation command area after irrigation event following an irrigation schedule.

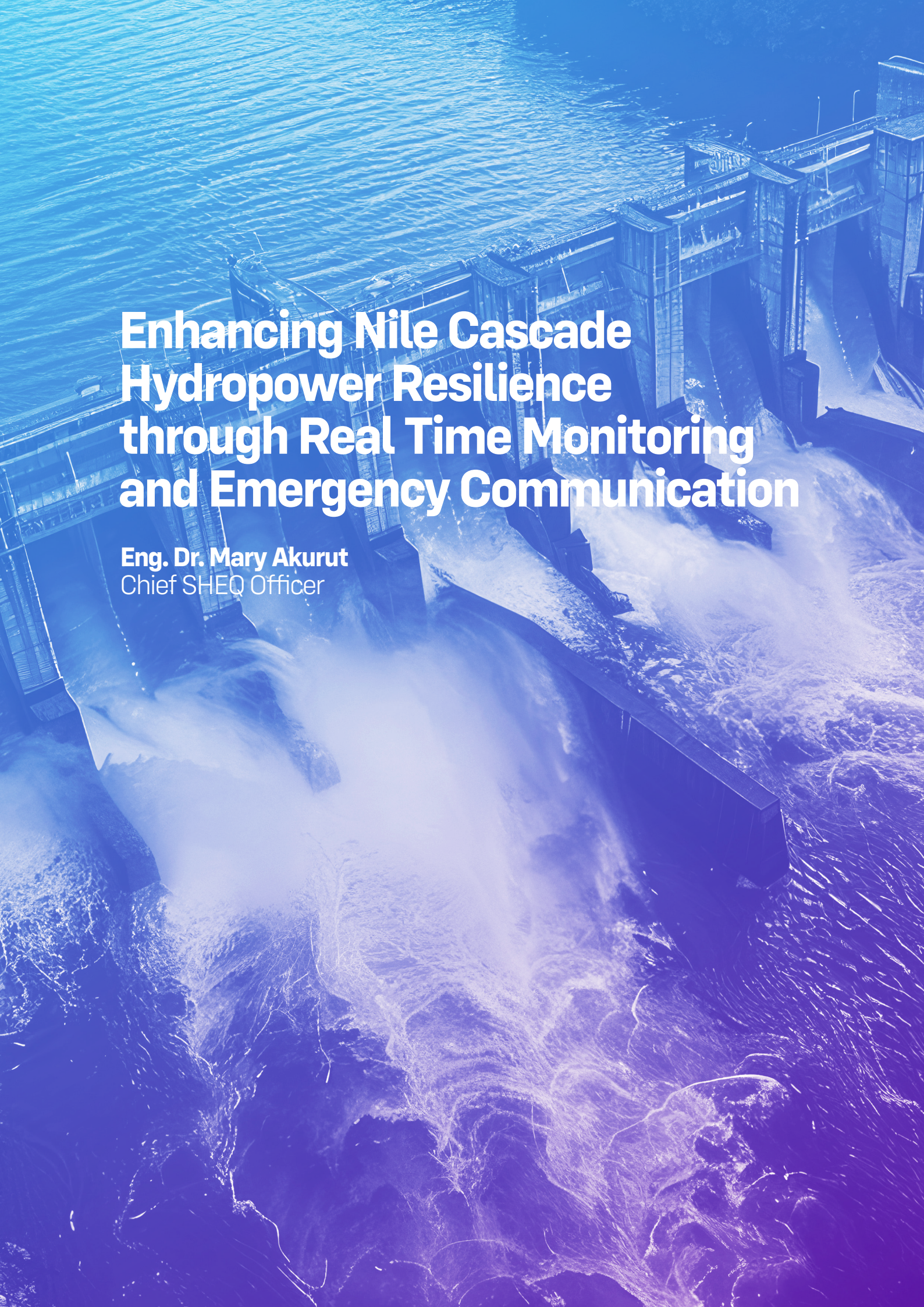


Eng. Dr. Mary Akurut is a Registered Engineer (ERB No. 1978) and Member of the Uganda Institution of Professional Engineers (MUIPE, PE/2049).

She currently serves as Chief, Safety Health Environment and Quality (SHEQ) Officer at UEGCL, where she leads her team in ensuring sustainability and safety of electricity generation projects. With over 15 years of experience in civil engineering, environmental management, and climate resilience, she is a recognized leader in integrating sustainability into energy infrastructure.

Dr. Akurut is also a published author and passionate advocate for engineering solutions that meet Uganda's development and climate goal.





Enhancing Nile Cascade Hydropower Resilience through Real Time Monitoring and Emergency Communication

Eng. Dr. Mary Akurut
Chief SHEQ Officer

Abstract

This project presents an overview of the design and implementation of a real-time flow monitoring and emergency communication system along Uganda's Nile Cascade hydropower plants, led by Uganda Electricity Generation Company Limited (UEGCL). The initiative aimed to address critical operational inefficiencies resulting from uncoordinated plant operations and limited data-sharing mechanisms. By installing automated gauging stations, integrating telemetry technologies, and establishing a centralized decision support tool, the project significantly enhanced hydropower planning, flood risk management, and emergency preparedness. The UGX 2.7 billion investment, with a major focus on high-precision equipment, sets a new benchmark for engineering-led solutions in Uganda's water-energy sector and offers a replicable model for future hydropower developments.

1. INTRODUCTION

The Nile Cascade—comprising Nalubaale-Kiira, Bujagali, Isimba, and Karuma Hydropower Plants operate independently. Historically, these stations functioned in isolation, without a real-time mechanism for monitoring inflows or a centralized emergency response protocol. This fragmented approach created inefficiencies in power production planning, increased flood risks, and strained the shared water resource.

By 2020, the rising levels of Lake Victoria and uncoordinated discharges posed a significant risk to dam safety and downstream infrastructure. The absence of flow gauging stations between key dams, particularly downstream of Bujagali, Isimba and Karuma, further hindered accurate forecasting and coordination. UEGCL responded to this challenge with a strategic vision: deploy a real-time flow measurement

network and an emergency communication system to unify and optimize cascade operations.

With the Government of Uganda's renewed commitment to strengthening power generation as a driver of socio-economic transformation, it is imperative that the planned downstream hydropower projects—Kiba, Oriang, and Ayago—are seamlessly integrated with existing plants through coordinated production planning and cascade-wide operational alignment.

1.1 Objectives and Scope

The core objectives of the project were to:

- Install automated hydrometric gauging stations at strategic upstream and downstream locations.
- Implement a telemetry-based monitoring system using GSM, GPRS, and satellite networks.
- Establish an emergency communication protocol across all cascade power plant operators.
- Train technical personnel to sustain and maintain the system.
- Integrate an online monitoring platform accessible to all relevant stakeholders, including the Ministry of Water and Environment (MWE).

The project covered a 50 km radius around each of the five major hydropower stations and involved stakeholder engagement, civil works, installation of sensors, and commissioning of the system.

This project exemplifies the intersection of engineering innovation, environmental management, and stakeholder coordination.

2. MATERIALS AND METHODS

2.1 Technical Implementation and Innovations

The stations were designed based on ICOLD Bulletins 118, 173, ISO 1100-1 and the World Metrological Organization (2010): Manual on Stream Gauging in accordance with the relevant National Laws and Regulations.

A preliminary site visit was conducted to authenticate the locations and accessibility of the Telemetric stations as shown in Table 1 in coordination with teams from DWRM and UEGCL.

Table 1: Preliminary survey station locations for the Telemetric sites

S/No.	Station Name	Longitude	Latitude
1.	Nalubaale Upstream	33°11'36''E	0°25'58''N
2.	Nalubaale Downstream	33°10'16''E	0°27'56''N
3.	Bujagali Upstream	33°09'13''E	0°29'16''N
4.	Bujagali Downstream	33°08'11''E	0°30'19''N
5.	Isimba Upstream	33°03'13''E	0°36'37''N
6.	Isimba Downstream	33°02'22''E	0°47'35''N
7.	Karuma Upstream	32°16'31''E	2°14'50''N
8.	Karuma Downstream	32°10'33''E	2°13'13''N
9.	Jinja Pier	Lake Victoria	Existing
10.	Bugondo Pier	Lake Kyoga	Existing
11.	Masindi Port	Lake Kyoga	Existing
12.	Kampala - Gulu Rd	R. Kafu	Existing

The site locations directly influenced the type of civil structures constructed, particularly the elevation of foundations, which were determined in relation to anticipated flood levels derived from the design flow analysis illustrated in Figure 1.

The civil works included reinforced concrete structures with anti-corrosion finishes, designed according to BS 8110 and BS 8004, to withstand design loads, flood forces and environmental exposure. The project also introduced an early warning system, linked to dedicated communication lines between plant operators. In case of abnormal flow conditions or flooding, alerts are instantly shared, facilitating quick decision-making and operational adjustments.

The real-time monitoring system was designed around redundant communication channels (GPRS and satellite) and cloud-based data access, enabling 24/7 flow visibility. Each gauging station comprised:

- Ultrasonic and pressure transducer sensors for high-precision water level detection
- Data loggers with telemetry capability
- Solar-powered energy systems with battery backup
- Stilling wells and automated floats for accurate discharge computation

2.1.1 Key Achievements

- Eight operational gauging stations and Two weather Stations were successfully installed and commissioned, despite COVID-19 disruptions and logistical delays.
- Online visibility of river discharges was established via Google Sheets, Polaris software, accessible to UEGCL and stakeholder agencies.
- Improved coordination among independent power plant operators, leading to better flood control, reservoir management and enhanced dam safety.
- Foundation for the Upper Nile Flood Forecasting System was laid, including technical inputs for Uganda's first Operational Decision Support System for Hydropower

(ODSS-HP) with capacity to forecast both seasonal flows and real-time hydropower capacity of the cascade.

- Capacity building of UEGCL staff to support long-term sustainability of the system.

3. CHALLENGES AND ENGINEERING SOLUTIONS

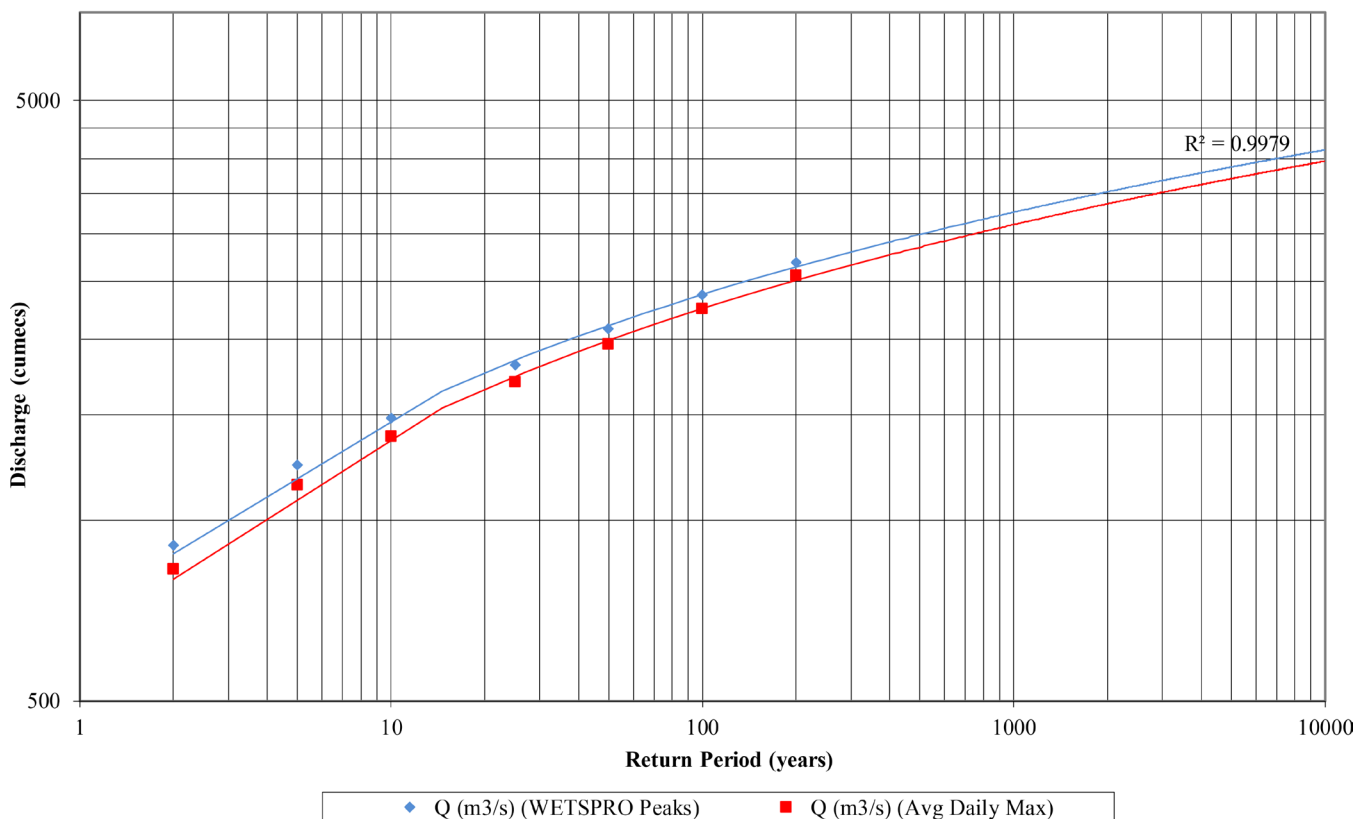
Several hurdles emerged during project implementation:

- Regulatory delays in securing site access, especially within protected areas such as Murchison Falls National Park.
- Equipment importation setbacks arising from global supply chain disruptions due to Covid19 Pandemic
- Flooding of project sites at Lake Victoria and Kyoga, complicating civil works.

These were mitigated through design modifications, site relocations, and adaptive scheduling. For instance, station elevations were adjusted using historical flood data, hydrological and flood frequency analysis, and community feedback, eliminating the need for additional hydrodynamic modeling. Log-Pearson Type III Distribution was applied for flood frequency analysis due to its effectiveness in handling skewed hydrological data and the results are presented in Figure 1.

The 2020/2021 flooding event coincided with a 1-in-200-year flood, providing historical maximum water levels for flood design and evidence for community ground truthing. This validated the maximum flood level for the proposed infrastructure. Structural designs incorporated additional scour protection and elevated platforms to reduce submersion risk.

Flood Frequency Analysis for River Nile at Isimba HPP using Log-Pearson Type III Analysis
(River Nile - WY 1899 - 2021)



3.1 Broader Impact on Engineering Practice

This project exemplifies the intersection of engineering innovation, environmental management, and stakeholder coordination. It underscores the importance of data-driven approaches in energy production and the central role of engineers in enabling sustainable infrastructure.

Moreover, it highlights how Ugandan engineers—working within local constraints—can deliver complex, multi-disciplinary solutions aligned with national development goals such as Vision 2040 and SDG 7: Affordable and Clean Energy

3.2 Lessons Learned

The following lessons were drawn from the project:

- Initiating integrated stakeholder engagement early in the project lifecycle is critical to success, especially when implementing cross-sectoral infrastructure initiatives.
- Telemetric systems should be designed with built-in redundancy and scalability to accommodate future climate-related risks and allow seamless expansion to additional projects.
- Local capacity building ensures project ownership and sustainability beyond the installation phase.
- Standardization of data sharing platforms enhances transparency and coordination among independent entities.

Future projects should prioritize early site assessments, streamlined approval processes, and pre-agreed communication protocols to fast-track implementation.

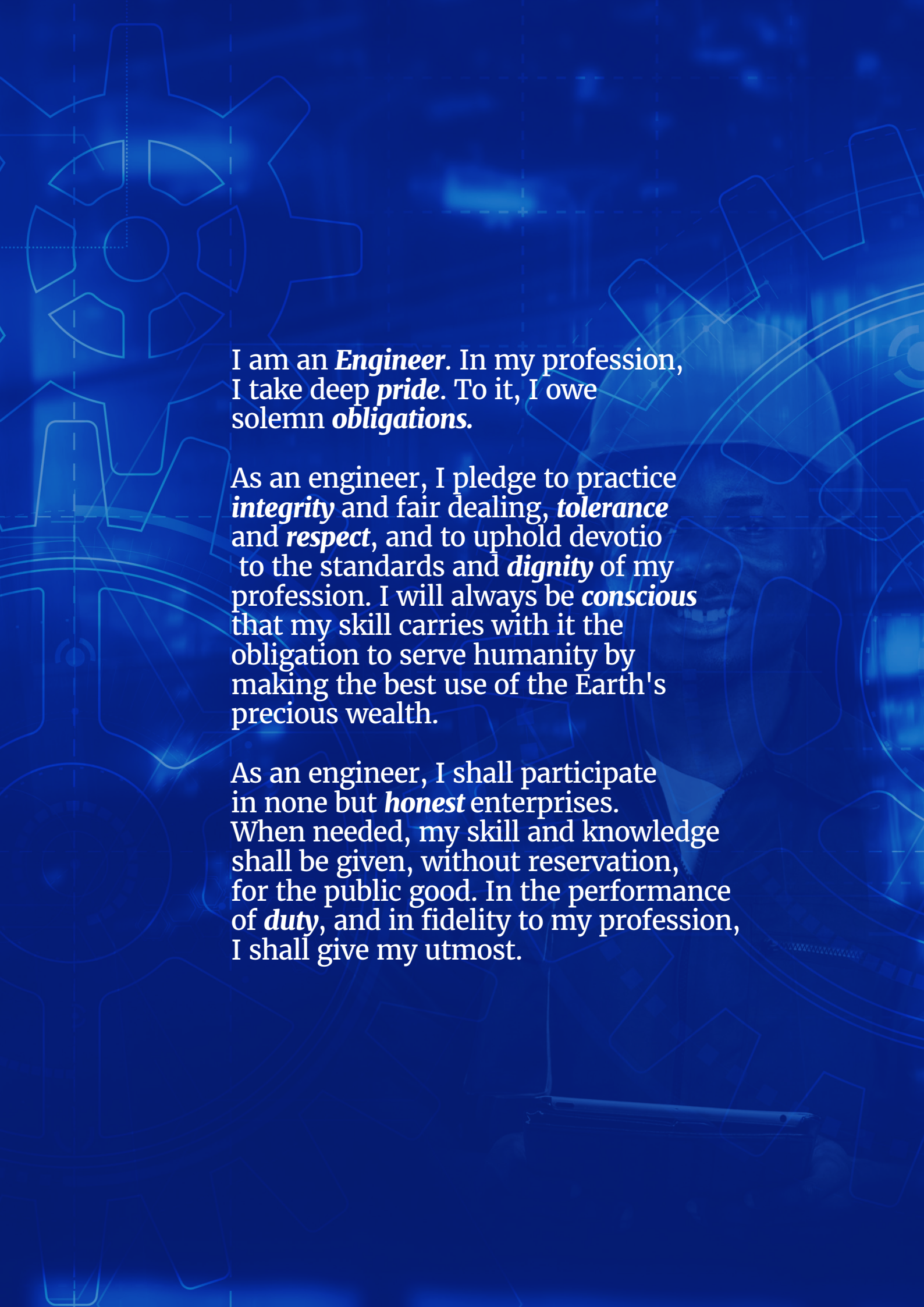
4. CONCLUSIONS

The design and implementation of real-time flow gauging stations and an emergency communication system across the Nile Cascade is not just an engineering project—it is a resilience-enabling intervention for Uganda's energy future. I am

honoured to have contributed to a solution that strengthens national hydropower operations, protects ecosystems, and ensures the safety of communities downstream. It is my hope that this initiative will inspire similar projects across the region and affirm the value of homegrown engineering expertise in solving Uganda's most pressing infrastructure challenges.

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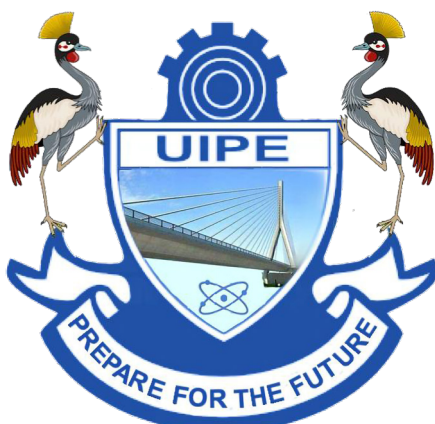
I am an **Engineer**. In my profession,
I take deep **pride**. To it, I owe
solemn **obligations**.

As an engineer, I pledge to practice
integrity and fair dealing, **tolerance**
and **respect**, and to uphold devotion
to the standards and **dignity** of my
profession. I will always be **conscious**
that my skill carries with it the
obligation to serve humanity by
making the best use of the Earth's
precious wealth.

As an engineer, I shall participate
in none but **honest** enterprises.
When needed, my skill and knowledge
shall be given, without reservation,
for the public good. In the performance
of **duty**, and in fidelity to my profession,
I shall give my utmost.



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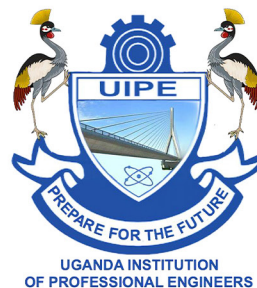
Plot 2 Gloucester Avenue
P.O. BOX 29267,
Kyambogo, Kampala.
Telephone: **+256-39- 3194 942**
Email: **info@erb.go.ug**
Website: **www.erb.go.ug**

UIPE Secretariat

Gloucester Avenue,
P. O Box 1308, Kampala
Kyambogo, Kampala.
Telephone: **+256-414 671 387**
Email: **info@uipe.co.ug**
Website: **www.erb.go.ug**



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Website: **www.erb.go.ug**

UIPE Secretariat

Gloucester Avenue,
P.O Box 1308, Kampala
Kyambogo, Kampala.

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Email: **info@uipe.co.ug**

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