IoT based Transformer monitoring System

A.Niwomugizi and J. Mugyenyi
Carnegie Mellon University Africa
Kigali, Rwanda
{aniwomugizi,jmugyenyi}@africa.cmu.edu

***Abstract*— This report offers a description of an IoT system developed to address a problem faced by an African company in the delivery of its products or services. The aim is to use IoT to create a network over which data can be transferred to aid in the monitoring or control of certain processes in the given company's operation without requiring direct human interaction.**

Keywords—*Transfomer, Zigbee, Arduino, Temperature Sensor , Oil level Sensor, Moisture Sensor.*

I. Introduction

The selected sector is the Energy sector and the company targeted for our IoT solution is Eskom Uganda Limited, an electricity generation company located in Jinja, Uganda.
Eskom Uganda limited currently faces a challenge of transformers degrading due to a focus on corrective instead of preventive maintenance.

Currently, the company keeps track of the status of its transformers by employing technicians who on a daily basis collect and record transformer performance indicators on paper checklists. The information collected include wind and oil temperatures, conservator tank oil levels, cooling water temperatures, and moisture content. This is a very inefficient system as it's subject to a variety of errors during the collection and recording of this information which would negatively affect how the company plans and carries out maintenance operations on its transformers leading to inadequate asset management and monitoring. Therefore, the transformers could rapidly degrade and fail.

Our project will integrate a variety of sensors and communication modules to enable the accurate reading and collection of these transformation performance indicators [1].

II. IoT SYSTEM OVERVIEW

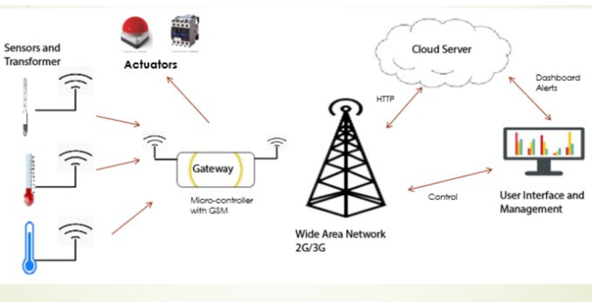

Figure 1: System Overview

A. Things:

The things considered in this project are transformers and sensors and how to utilize IoT to improve and prolong the transformer performance

B. Connect:

The transformer performance indicators such as temperature and moisture content are communicated to a database or analysis application. Zigbee is preferred for short range commnunication to the micro-controller because it costs less, consumes less power , ideal for low data rate situations and has a mesh network protocol. A 2G GSM module is used for long range communication to the cloud database.

C. Collect:

The performance indicator of the transformer that are measured (temperature and moisture content) are stored in a remote database along with their corresponding timestamps.

D. Learn:

Analysis is to be done on the collected data to determine health and status of transformers, predict probability of failure in order to make informed repair and maintenance decisions with minimal downtime.

E. Do:

Overall, the expectation is that the IoT system through real time communication will help the company quickly identify failing transformers and repair them rather than waiting for them to completely fail so the only course of action is to replace the equipment.

III. SYSTEM DETAILS

A. Things

The "things" the application is dealing with is a Transformer.Eskom Uganda limited has a total of 32 transformers on its premises that it uses in its operations. Eskom Uganda stretches over a wide area. The transformers being strewn over a large area poses a challenge for constant monitoring and maintenance. To mitigate the problem of degradation of the transformers caused by this challenge, our

IoT system proposes to monitor these transformers real time using a number of sensors.

1) Sensors

The transformer will be fitted with the sensors; temperature, moisture and oil level sensor. The readings from these sensors will be monitored constantly.

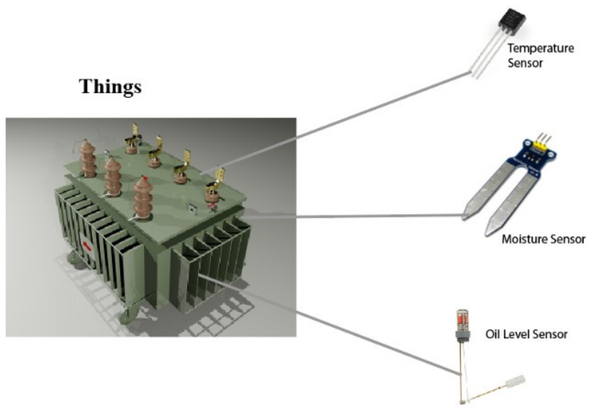

Figure 2: The transformer and associated sensors

The temperature sensor will monitor temperature of the transformer. Extreme temperature is a major cause of reduced transformer life. Transformers are designed to operate for a minimum of 20-30 years if properly sized, installed maintained [1]. Extreme temperatures in a transformers, if not checked early, would bring down that number.

The moisture sensor will monitor the level of moisture in the transformer. The level of moisture should not exceed a certain level. Moisture in a transformer affects its insulating properties which is a leading cause of transformer breakdown which is why it needs to be closely monitored.

The oil level sensor will monitor the amount of oil in the transformer which should not go below a certain level. A low oil level could result in exposed current carrying components which are supposed to be immersed in oil and this could lead to overheating and discharge [2] .

2) Microcontroller

The micro-controller of choice is an Arduino. The Arduino uses an 8 bit AtMel microcontroller manufactured by Atmel [3]. It has the properties below [4].

Component	**Specification**
Microcontroller	ATmega2560
Operating Voltage	5V
Digital I/O Pins	54
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 kB
SRAM	8 kB
EEPROM	4 kB
Clock Speed	16 MHz

It is chosen because it is easy to use and is relatively cheap for implementation.

B. Connect

Networking Technology

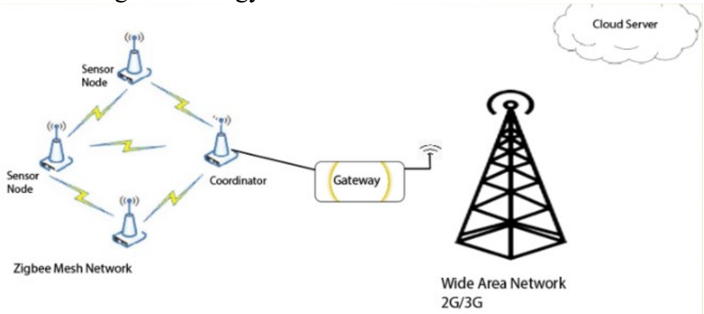

Figure 3: Network system

A mesh zigbee network is used for short range wireless communication from the sensors which locate the data to the gateway which allows it to be sent over a wide area network and stored on a cloud server.

Zigbee technology is selected because of the following reasons:

- It has a low power consumption
- Low data rate ideal for this application
- Low range enhance by its mesh network topology

A 2G modem is used as the gateway to send collected data from the sensors over a wide area network to be stored on a cloud server.

2G technology is selected for this application because it is widely available, easily accessible and comparably dependable especially with regard to the African context.

C. Collect

For collection of data for our application, ThingsBoard is used. ThingsBoard is an open source IoT platform that does integrated device management, data collection, processing and visualization for IoT applications.

It is chosen for its scalability, durability and the ability to customise it to the IoT application. ThingsBoard uses a Cassandra database(NoSQL) for data storage to achieve these.

ThingsBoard provides the ability to configure and customize dashboards for data visualization. Each IoT Dashboard may contain multiple dashboard widgets that visualize data from multiple IoT devices [5].

For this application, sensor data will be sampled every on e minute. The values stored will be the average of readings every fifteen minutes. This is configured in the HTTP program that communicates with ThingsBoard database from the sensors.

D. Learn

The data analytics to be carried out in the "learn" section of the IoT system include the following computations;

- Generation of alerts or warnings when set thresholds for temperature and moisture level are exceeded and when the oil level falls below a given set level
- The temperature reading, moisture levels and oil levels read every minute are average over a period of fifteen minutes and the results stored in the database
- Using the data collected from the sensors probabilities can be computed to predict the likelihood of failure of a given transformer

A classifier can thus be built using machine learning algorithms like SVM or logistic regression to classify the transformers into categories such as working and faulty. Tensorflow shall be used to create a model for classification.. ThingsBoard also provides a processor - to generate alarms or enrich incoming data with some server-side values [5].

E. Do

In the "Do" section of the IoT system, the user (Eskom) will be able keep track of the working status of each transformer through ThingsBoard end user application that can show through visualizations like charts and graphs the conditions for the transformers determined from the collected data and help Eskom make informed decisions as regards to preventative maintenance and thus forestall degradation and failure of the transformers due to poor management.

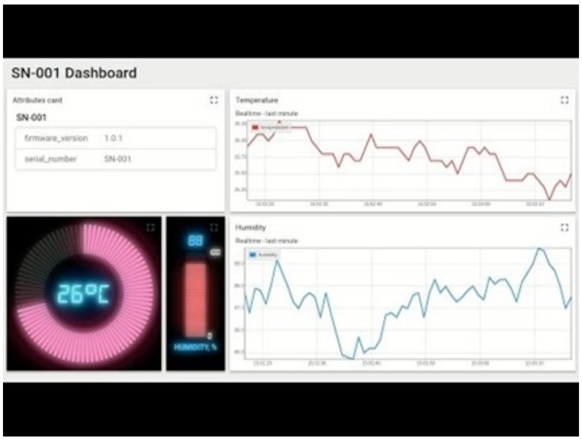

Figure 4: User Interface

IV. PROTOTYPE IMPLEMENTATION

The prototype implementation was done using an UDOO board. An UDOO board is a single-board computer with an integrated Arduino 2 compatible microcontroller [6].

The sensors used in the implementation were;

- Temperature sensor(for temperature)
- Moisture sensor (to simulate moisture sensor)
- Potentiometer(to simulate oil level sensor)

The IoT application will use ThingsBoard to access the data through a 2G connection from a GSM module connected to an Arduino board. This was simulated in the prototype with an UDOO board communication with WiFi.

In the prototype implementation, sensor data was read from the UDOO board and transmitted to the UDOO cloud by WiFi. The readings were then accessed from the cloud using WIFi and processed using Python code.

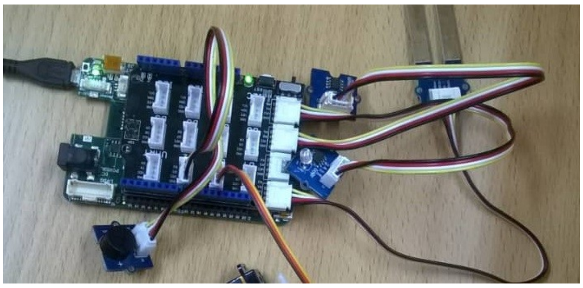

Figure 5: System Implemented on UDOO board

Transformer data is not very time critical therefore the application will sample the sensor data every one minute. This was simulated in the implementation by sampling every ten seconds.

Transformer data also does not change often and drastically over short time periods so data storage in the application will be the average of samples over fifteen minutes. This was simulated in the implementation by saving the values every one minute.

To indicate that the temperature was above certain temperature or moisture level above a certain threshold, there was an alert in the form of an LED going on. When the simulated oil level was below a certain level, a buzzer went off for 3 seconds.

Data collection was done by saving average temperature, moisture and oil levels every fifteen minutes in a csv file.

V. ASSESSMENT

A. Expected Impact

The proposed IoT system is expected to impact Eskom operations in the following ways:

- Eskom would be able to carry out real time monitoring of transformers and thus be able to carry out better asset management through making data driven decisions as to when to carry out maintenance operations on transformers
- Eskom would realize reduced costs in corrective maintenance as potential faults can be quickly identified and rectified before they result in failure of the transformer.

- Through proper collection and storage of electronic data, Eskom can also engage in failure prediction by analyzing this data which would be beneficial in allocation of financial and technical resources during budgeting.
- Eskom could reduce its down time by minimizing the potential of transformer failures through this more efficient IoT based monitoring and management system.

B. Expected Challenges

Limited internet connectivity would complicate IP based internet communication. This would complicate data storage in the cloud server and as such affect the accuracy of data analytics computations carried out on this data.

Cost of labor in Uganda is very cheap as such Eskom as a profit-making company would prioritize using cheap labor to monitor transformers over an expensive installation of an IoT system.

An inability to handle large chunks of data that stems from the fact that there is a limited resource in knowledge about data analytics and data science as the powerful tool that would reshape the company

Many African companies do not invest so much in Cyber-security. This means that information collected within the company would face very high breach potential making the assets from which the data is collected vulnerable to malicious actors.

C. Possible Alternatives

LPWAN (Low Power Wide Area Networks) such as LoRa could be considered for integration into the IoT system especially given the unreliable nature of cellular network services in Africa. LPWAN would provide a more reliable and suitable wireless communication system for the transfer and collection of data from sensors to the cloud server.

REFERENCES

[1] Copper development Association Inc., 2017. [Online]. Available: https://www.copper.org/environment/sustainable-energy/transformers/education/trans_efficiency.html. [Accessed 2018].

[2] Electrical Engineering Portal, 2013. [Online]. Available: http://electrical-engineering-portal.com/transformer-temperature-oil-level-and-pressure-gauges.

[3] T. Chou, " Precision, Principle, Practices and Solutions for the Internet of Things," 2016, pp. 21-22.

[4] Arduinoe-Tech, 2013. [Online]. Available: http://arduino-tech.com/arduino-mega.aspx. [Accessed 2018].

[5] ThingsBoard authors, 2018. [Online]. Available: https://thingsboard.io/docs/getting-started-guides/what-is-thingsboard/. [Accessed 2018].

[6] Wikipedia, "Wikipedia," 2018. [Online]. Available: https://en.wikipedia.org/wiki/UDOO. [Accessed 2018].