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Design and Implementation of a Transformer Vandalism Monitoring System

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Abstract: Transformer vandalism is becoming an alarming issue in the whole world. Power distribution companies are incurring losses of billions of money due to transformer vandalism. This paper is going to contributes to the design and implementation of a transformer vandalism monitoring system architecture that can be used by the power companies to deter or monitor the transformers against vandals. It is going to design a monitoring system that can be able to detect the presence of a vandal near the transformer, raise the alarm and send a message/call the control room officers or security officers in designated areas for response. The paper is going to have an algorithm that will be able to show the transformer location, transformer number and the necessary authorities near the transformer. The monitoring system will be a combination of Arduino hardware with Integrated Development Environment (IDE) program, sensors, and GSM for mobile communications. In this paper, the case study will be Kenya Power Company, a state utility company that is responsible for distributing electricity to consumers, emergency electricity services and lastly retails the electricity in Kenya.

Keywords: Transformer Vandalism, Arduino, Global Mobile Communication System (GSM), Arduino GSM Shield 2, Arduino library Integrated Development Environment (IDE), PIR Sensors (Passive Infrared)

1. Introduction

In the power Generation, Transmission and Distribution there are a lot of operational losses. The magnitude of these losses is increasing at the high rate in several countries in the world. Using Kenya as a case study for this proposal, for the last ten years, various towns and rural areas in Kenya have in one way or the other experienced vandalism of transformers or power lines. Due to these illegal activities, Kenya power has lost millions of money because it has to install new equipment or transformers and at the same time, customers in the affected areas incur a lot of losses due to power blackout that occurs now and then due to vandalism [1].

In addition, many people have lost their lives due to electrocution. The most affected equipment are transformers because they contain oil and copper materials that have high demand in the black markets leading to power shortage in the affected region [2]. More so, fuses found in transformers contain magnesium oxide that is used with other drugs like tobacco or heroine by drug addicts.

Uses of the Transformer Oil Locally

1. It is mixed with diesel and sold as fuel in the remote areas,
2. It is used as fuel in industrial especially for furnaces and at the same time as cooling system for welding sets
3. It is mixed with vegetable oil and sold as a cooking oil in black markets
4. It is used as cosmetic and treatment for wounds

Due to those demands, transformers are at high risk of being vandalized anytime. Mostly, vandalism occurs in big cities like Nairobi, Eldoret, Kisumu and Mombasa. Nairobi is the leading city in vandalism. The estates that are severely affected are Huruma, Thika, Ruiru, Dandora, Mathare, Kiambu, Kikuyu, Bahati, Limuru, Kayole, Njiru, Githurai and all parts of Nairobi east. Most of these places are slums, and it is believed all criminals in the city live in those areas. Mt. Kenya and Nyanza regions are also not left out. Power vandalism is one of the economic sabotage done by a well-organized syndicate that works in major towns within the country [3]. The markets for transformer oil and copper are

also found in those remote areas where it pays a lot of money hence encouraging more cases of vandalism. Vandalism also exposes danger to the customers who depend on electricity for the day today activities because at night they are at risk of being invaded by thieves due to darkness [4].

According to the data found in the Kenya power archives, in 2004, it lost 329 transformers that are equivalent to 212 million Kenyan shilling. In 2007, the company also lost 71 transformers worth 35.6 million to mention few. These are losses incurred directly without counting the losses caused by hours of power outages, stolen cables hence affecting private businesses that pay a lot of money to Kenya power [4].

Paper plan: In Section II, current systems are discussed, in section III, proposed system discussion, in section IV, hardware specifications, in section V, conclusion.

2. Current System

1. *Mulika mwizi* system- this is the anti-vandalism campaign on televisions, newspapers, radio station and meetings. The company has invested heavily in this public education initiatives as a way of partnering with citizens in the war against vandalism. The idea is good, but it has not achieved much as per its initial expectations due to the failure of the citizens to report some of their cases because in one way or the other the vandal is related to the witness or fear of victimization [4].
2. Kenya power has also tried other technologies to address vandalism challenge. Some of these strategies are the introduction of dry-type transformers that do not contain oil.
3. The method is using hermetically sealed transformers. This type of transformer design has no conservator. The dielectric insulating fluid in the transformer tank is completely sealed and has no contact with the atmosphere. This type of transformer is applicable in harsh climatic conditions like smoke, pollution and dusty environment and at the same time where there is a danger of vandals. The advantage of these transformers is that they don't need maintenance of the dielectric insulating fluids. However, once it is damaged, there is no room for maintenance hence making it less suitable to use for most parts of the country. It is also expensive [4].
4. Kenya power has also come up with other policies like using many single-phase, light transformers that are placed at a high position in the power poles to deter vandals. So the vandal takes the same time to vandalize a big transformer as it takes to vandalize a small transformer with very little amount of oil and less copper winding hence encourages vandals from wasting their time for the little amount of oil and copper wires with equal risks. In addition, the power company has also decided to raise both the transformer and fuses at a high height making it difficult for vandals to climb to the poles unless they have landers. But in case of a blackout, they take the advantage and manage to remove down the transformer using ladders.
5. Kenya power has come up with new specifications that require the suppliers to use special nuts or key on top of covers making hand for the vandals to open the transformer. But it is still challenging because most of the vandals prefer carrying the whole transformer and cut it somewhere else to remove the oil and the copper wires inside the transformer.
6. It also has welded the transformer terminals on metal poles hence challenging the vandals from carrying or removing the transformer. However, in case of any transformer technical issues that need to be repaired at the power laboratory, it becomes hard to remove it. The vandals also break the spindles to access the inside hence managing to tap the oil and take away the copper wires.
7. The power company has issued new guidelines to suppliers that require transformers to contain Aluminium winding as opposed to copper which is very attractive to vandals. The new requirement is expected to control the quality of the new transformers and at the same time prevent vandalism. All suppliers will be required to give the list of the raw materials used to manufacture the transformers for ease traceability of the parts and their quality. Also, the guidelines require the supplier to give a warrant for six years and five years from the date of delivery and commissioning respectively.

Why the Current Solution Is Not Perfect

1. Transformers are targeted due to lack of monitoring system that can deter or prevent vandals from carrying out this illegal activity.
2. Transformers are mounted at about 2.5m to 4.0 meters above the ground. Fuses and tap for oil chamber are exposed without any protection making them accessible by vandals from the ground using normal ladders.
3. To prevent these cases, the paper is going to design and implement a monitoring system with sensors programmed using Arduino to switch on the alarm and send an alert message to the control office or standby officers.
4. The system will also contain transformer details such as location, transformer number and pole number for easier accessibility.

3. Proposed Method

From the above initiatives, we can see that Kenya Power has managed to reduce the transformer vandalism by 30%, although more innovations need to be done to curb transformer vandalism. This paper is going to implement a better method that can be used to respond to any case or suspect found around a transformer [5]. The project will have a 24/7 monitoring system that will be able to raise the alarm and at the same time send a message/call to power control officers or nearby police posts. The project will comprise PIR sensors that will be installed on the transformer surface. The sensors will be able to sense any unusual activity around the

transformer and send a secret message/call to the authority without the knowledge of the victim.

The fuses and tap for oil chamber are exposed without any protection making it easy to be accessed from the ground surface using normal ladders. Now because vandalism occurs when thieves come to the transformer and remove the fuse or tamper with oil tap, the new monitoring system will be based on sensors that with be programmed using Arduino to switch on the alarm and send an alert message to the control office or standby officers or nearest police posts [6].

The sensors are going to switch on the alarm and send a message at the same time when it senses a presence of something and stays near the transformer for some minutes that are set in the program. In addition, the system will rely on the database related to individual transformer and location to avoid confusion.

3.1. Advantages

1. It will offer 24/7 security monitoring system regardless of the weather conditions and locations.
2. It is cheap to maintain and construct
3. Does not require personal attendance unless when there is a technical problem.
4. It will protect the electrical appliances to ensure continuous supply of electricity to customers
5. It will save money lost due to vandalism of electrical appliances.
6. It will ensure there is reliable power to the customer throughout the year unless when there are power operation and maintenance.

3.2. System Architecture

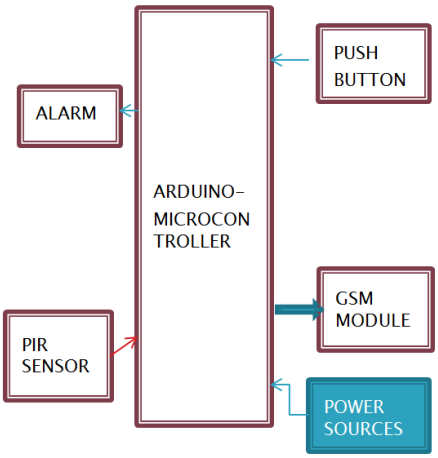

Figure 1. *System architecture.*

4. Hardware Specifications

4.1. Sensors

This is a device that measures the physical quantity and converts it into a signal that can be analyzed by the instrument or controller. This project is going to rely on the sensors that will be mounted on the surface of the transformer near the oil tank and fuses. The sensor is one of the growing technologies that have boosted security in different places. Currently, sensors are used in everyday objects, for example, touch sensitive elevator buttons and lamps. Other applications of sensors are cars, medicine, aerospace, machines, manufacturing and robotics. These sensors generate an electric field and measure the attenuations that have affected the field [7].

The main work of the sensor is to indicates the changes of its output when the changes of the measured quantity changes. Mostly, sensor acts like transducers hence change one form of energy into another when it detects unnecessary behavior according to its designed purpose. Therefore, sensors are classified depending on the type of energy they detect.

Characteristics of a good sensor:

1. A good sensor should be highly sensitive to the required property
2. A good sensor should be insensitive to other property that is not designed for it
3. A good sensor should not be manipulated my environment and should not influence the measured property.

In the practical, sensors are designed as linear where its output is linearly proportional to the measured value. The sensitivity for sensors is hence the ration between the output signal and the measured value.

4.1.1. Motion/Movement Sensor Detectors

The project is going to use a Passive Infrared sensor (PIR). This is an electronic device that is used to measure infrared (IR) light radiating objects with its field of view. Passive infrared sensors are technically used to manufacture PIR-based motion detectors. Therefore, this sensor is going to be installed within the transformer area to monitor any apparent movement around the transformer. The unnecessary movement around the transformer can be detected when the infrared source such as human temperature, cross in front of an infrared source with another temperature like the wall of the posts or walls around the transformer [7].

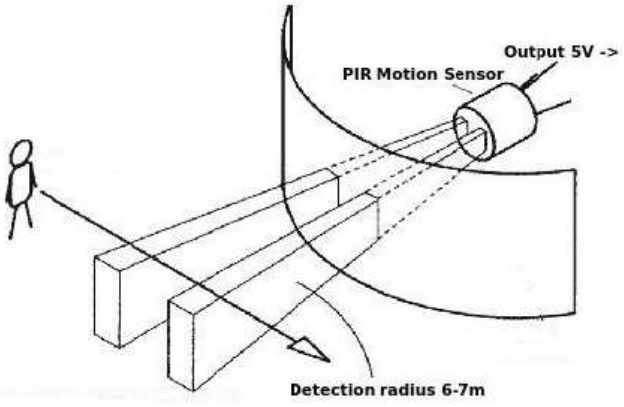

Figure 2. *PIR sensor.*

Any object that passes through the infrared rays emits black body radiation. This is the thermal, electromagnetic

radiation within a body in thermodynamic equilibrium. Its spectrum and intensity depend only on the temperature of the body. The infrared radiation is invisible to the human eye; however, it can be detected by electronic devices. Using the word passive actually means that the PIR device cannot emit an infrared beam but accepts incoming radiation passively [8].

TYPICAL CONFIGURATION OF A PIR SENSOR

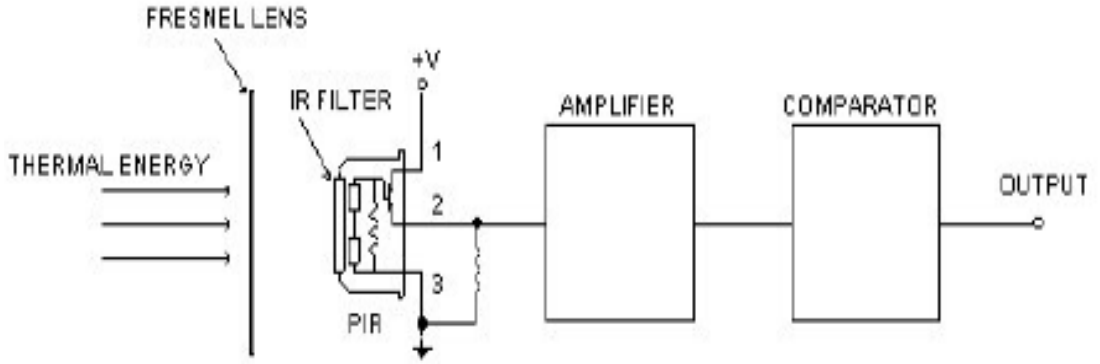

Figure 3. *Internal structure of PIR sensor.*

There are various ways one can create a motion sensor. For example,

1. One can use motion sensors in stores by having a beam of light crossing the room near the door and a photo sensor on the other side of the room. In this case, when a client breaks the beam, the photo sensor detects the change in the amount of the light and notifies the owner by ringing the bell.
2. The other example is in grocery stores with automatic door openers that can use a simple form of radar signals to detect the presence of someone passing the door. The box installed above the door sends out a burst of microwave radio energy and waits for reflected energy to bounce back. When the person interacts with the microwave energy, it changes the amount of reflected energy, and the box opens the door.
3. The same case applies to ultrasonic sound waves by bouncing the waves off the target and waits for the echo.

All those are active sensors. They always inject energy into the environment to detect a change of some sort. The motion sensing feature on most lights is a passive system that detects infrared energy.

4.1.2. Pin Representation of PIR Sensor

The PIR module has three pins. One is for +5 volts input, a ground pin and digital output pin. The +5v from the Arduino is connected to Vcc of PIR sensor module, the grounds of both the Arduino and PIR are grounded together, and the output pin (out) is connected to any digital pin of the Arduino. The sensor module has one digital output mode. This means there are only two possibilities of output values-either a HIGH or a LOW. Therefore, when there is no a vandal passing around the transformer (range of PIR sensor), its output is supposed to be a LOW value or 0V. But when a vandal passes near the transformer, its output immediately turn to HIGH value or +5V [9].

4.2. Arduino

Arduino is defined as "an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software." In simple, Arduino is an open-source electronic board that can control any Do It Yourself (DIY) hardware project. Purposely, Arduino is designed for artists, designers, hobbyists and anybody willing to create interactive objects or environments [10]. In addition, Arduino is used by designers and manufacturers of micro-controller kits for building digital devices and interactive objects that can sense and control objects. The products used in the projects are distributed as Open-Source Hardware and Software under the license from GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL). Arduino boards are readily available in the market hence making the project more affordable and reliable.

Arduino board designs use various microprocessors and controllers. The boards have sets of digital and analogue input and output pins that can be connected to other boards (shields) and circuits. Some of the features of the Arduino boards are serial communications interfaces that include Universal Serial Bus (USB), that are used to load programs from the computer or laptops [10]

4.2.1. Arduino Library

This library will enable the Arduino board to do things like using a mobile Global System for Mobile Communication (GSM)-send and receive messages, and connect to the internet over General Packet Radio Service (GPRS) network. This technology will be used to send messages to the control room to alert them in case of any unnecessary activities near the transformer surface. The GSM shield transfers data from the serial port to the GSM network through a modem. The modem is going to execute operations via a series of AT commands.

4.2.2. Arduino GSM Shield 2

The Arduino GSM Shield V2 allows the Arduino board to make/receive phone calls, send/receive SMS and connect to the internet. It uses a Radio modem M10 by Quectel. It can communicate with the board using AT commands

(instructions used to command modems).

The shield uses digital pins 2 and 3 for software serial communication with the M10. Pin 2 is connected to the M10's TX pin and pin 3 to its RX pin. The M10 is a quad-band GSM/GPRS modem that works at frequencies GSM859MHz, GSM900MHz, DCS1800MHz and PCS1900MHz. It can support TCP/UDP and HTTP protocols through a GPRS connection. GPRS data downlink and uplink transfer speed maximum are 85.6 kbps. The board also requires a SIM card that can be provided by network operator [10].

The AT commands are as well noted as Hayes AT commands. Sometimes they are called "Attention Terminal" commands or "Attention Telephone" commends depending on the group of people. In this case, AT commands are viewed as giving instructions to both mobile phones and normal landlines telephones. These commands are sent to phone modem that is either a GSM modem or PC modem. However, different producers may have different sets of AT commands, but mostly they are the same commands.

Lists of available commands:

Table 1. *Common AT commands.*

AT command	Meaning
AT+CMGS	Send message
AT+CMSS	Send message from storage
AT+CMGW	Write a message to memory
AT+CMGD	Delete message
AT+CMGC	Send command
AT+CMMS	More messages to send

5. Buzzer

The buzzer is used to create sound alarm in case the sensor identifies an intruder near the transformer. The buzzer will be driven by transistor 2N2222 which will be acting as a switch and a current amplifier because of the current from the Arduino 20mA and it is not enough to drive the buzzer that requires more current. Therefore, a 2N2222 transistor of a 100 gain can have an output current of 1A that can be used to drive the buzzer. In addition, this transistor will be used as an isolator. Because there will be an isolation at the base region of the transistor where the base is connected to the Arduino, in case there is the destruction of the collector-emitter junction, the base will not be affected hence saving the Arduino from being burned. A resistor of 100 ohms will also be required at the base to limit the amount of current entering the transistor.

6. Switch

The design will need a push button switch to reset the alarm once the security officers attend the alert.

7. Conclusion

The design and development of transformer monitoring system against vandalism are one of the modern technologies that can help save a lot of money lost due to this illegal activity. Millions of dollars are spent every year due to power vandalism, therefore, this design will be able to offer 24/7 security. It is cheap to design and maintain and install on the transformer surface where the vandals cannot detect or see it. The suppliers should try to design the transformer that can accommodate this monitoring system in the future.

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