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# Monitoring and Detection of Voltage Stress andFault in Underground Cables using IoT

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**Abstract**

Power transmission and distribution can be done either by overhead lines or power cables. Although overhead lines have been most reliable for many years, the deregulation of the electricity supply markets and growing environmental awareness are creating exciting new markets for power transmission solutions based on underground cable technology. Even though many protection methods for high-voltage cable systems this paper deals with the advanced monitoring and detection of voltage stress in MV or HV Underground cables. This system is implemented with the help of embedded system in which master slave concept. This paper uses a PIC16F877A micro controller as a master and the sensor network acts as slave. Thus, the master and slave communication can be implemented using i2c protocol. In case any abnormal voltage stress across the UG cable, the corrective action has done in both input and output side by using step-down transformer step up transformer. So that balanced output is maintained in the UG cables.

**Keywords:**Cable technology, voltage stress in MV or HV, hall sensor.

## 1. Introduction

Today the world is facing a great challenge due to deregulation and growing demand of electrical power. Optimum power flow in proper environmental conditions and on commercial terms has increased the responsibilities of the power utilities. So, its utilities work to provide most effective, environment-friendly, reliable and optimal power to consumer. A lack of effective power cable monitoring will lead to more frequent disturbance of electrical supply to commercial and domestic customers. Continuous on-line monitoring systems are being installed with the aim of reducing unexpected failures. This study presents work on the analysis and handling of acquired data, from the point of view of asset management and the PD activities observed in an on-line cable monitoring system. Initially, a review of on-line against off-line cable PD monitoring is presented, in terms of setups and their respective advantages and disadvantages. The study then presents the experience of applying wavelet based denoising techniques [both the discrete wavelet transforms (DWT) and the second-generation wavelet transform (SGWT)] to PD data de-noising. Networks of medium-voltage (MV) cables are used to deliver electrical power at a local level in the majority of the world's utility systems. The majority of the MV distribution cables, and the associated plant, in the UK's networks were installed during the 1950s and 1960.

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As the items, typically, have a design life of 40–70 years they are approaching, or have exceeded, their expected operational life. Despite reported indications of increasing failure rate in power plant, the operational and cost constraints affecting utilities requires that equipment continues to operate for a considerable time. Utilities in the UK and Holland have reported that half of outages to customers are due to underground cable failure. Private communication with a UK utility indicates that at the current replacement rate of 100 km per annum prior to 2010, it will take hundreds of years to replace the components in its underground cable network. The result of faults in distribution cable is 2-fold, firstly, interruption of electrical supply to customers as a result of the failure and secondly, inconvenience to the public through roads being dug up to carry out repairs. A lack of effective power cable monitoring will lead to more frequent disruption of electrical supply to commercial and domestic customers. This may have severe economic consequences for electricity suppliers and users, for example in July 2006174,000 New York residents lost power in a single incident. For failing to address pre-existing faults and for poor Maintenance, the company suffered a large financial penalty and the board was severely reprimanded. A typical MV distribution power circuit consists of multiple cable sections connected by joints which are assembled manually on-site. It has been reported that cable system failures because of the breakdown of electrical insulation between the conductors commonly occur at joints and terminations. A failure of cable insulation is normally preceded by a period during which material degradation takes place, this may last for months or several years. Identification, characterization and determination of the rate of degradation are fundamental to improving assessment of cable integrity and successful extension of operational life. Industry recognizes that, regardless of initiating mechanisms, deterioration of the insulating materials results in partial discharges at localized degradation site.

## 2. Proposed System

The proposed system is used to monitoring and detection of High voltage stress in MV or HV Underground cables. To implement the system, we use a Hall sensor, step-up & step-down transformer, and PIC micro controller. Every one-kilometre sensor (slaves) is placed to measure the voltage stress level. Thus, conversely provide the information about the UG cables. The data can be stored in master controller. Here we are using PIC micro controller as a master. In case any abnormal voltage stress across the UG cable, the correction can be done in input side by using step-down transformer. In output side can be controlled by step up transformer. So that balanced output is maintained in the UG cables.

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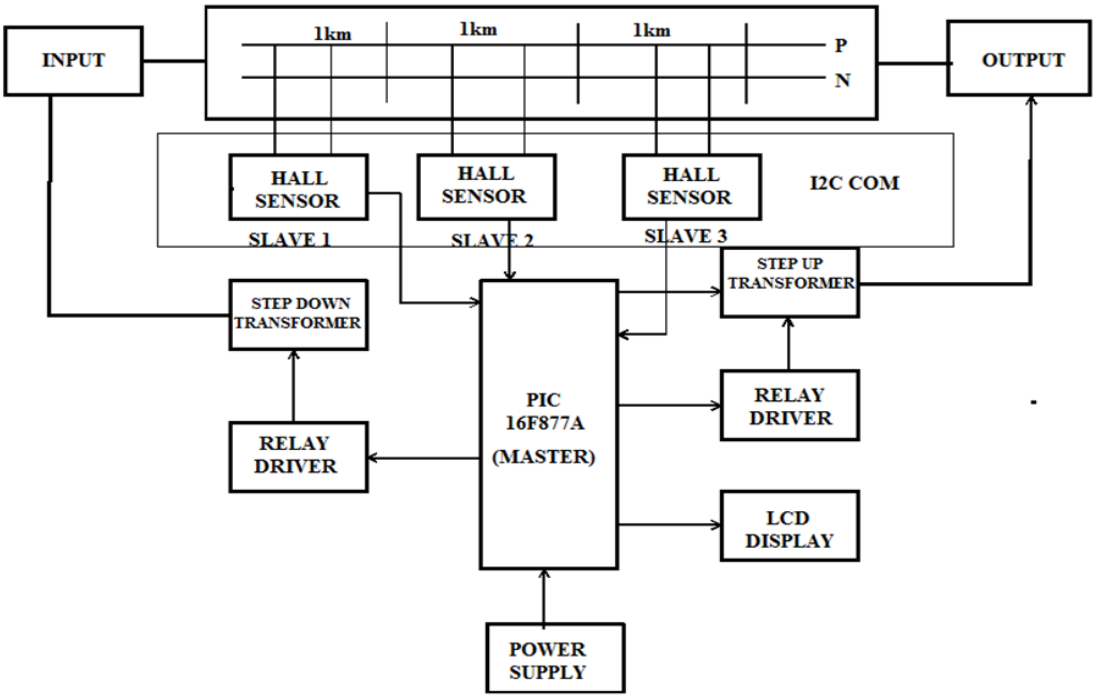


**Figure 1Block Diagram**

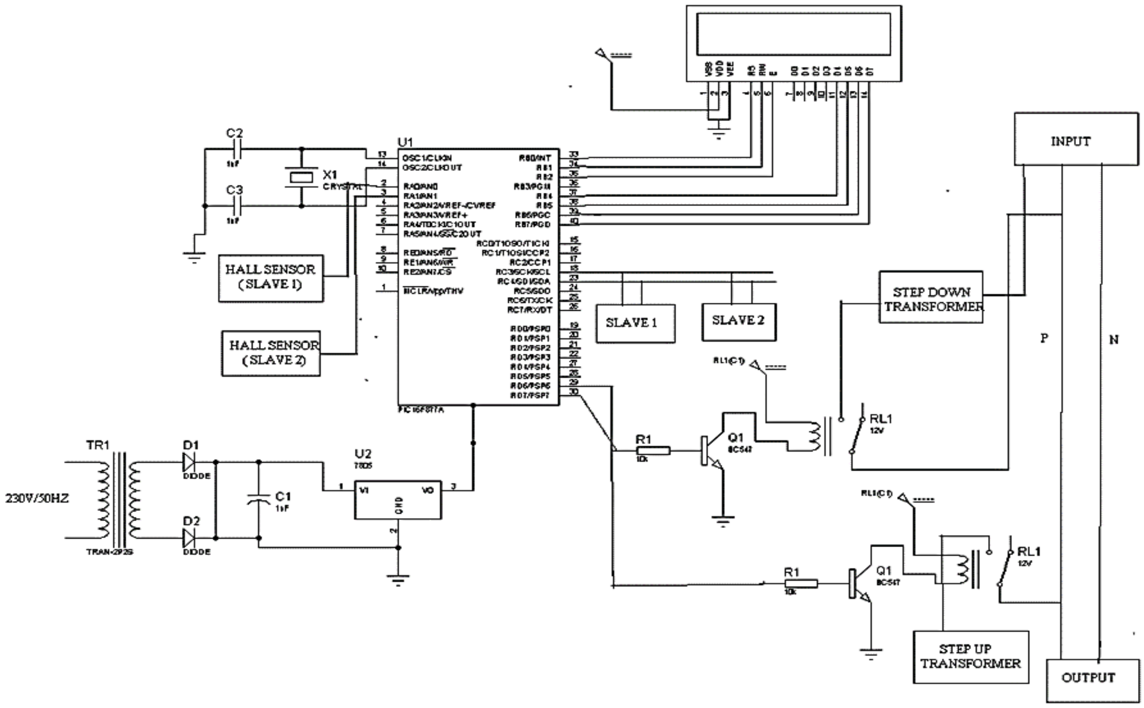


**Figure 2 Circuit Diagram**

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### *2.1 Circuit Diagram Explanation*

The transformer output is connected to the half wave rectifier it converts AC supply to DC supply. Then the converted supply is directly connected to the controller and other sensors. LCD is connected to the B port of the controller. Hall sensor 1,2 and 3 is connected to the analogue pins in A port, also the voltage measurement circuit is also connected in the A Port. The load side of relay and transistors are connected to the D Port then the IoT Microchip is connected to the C port of the circuit. The Microcontroller will send and receive data to these connections and controls the system operation.

### *2.2 I2C Bus Specification*

A typical embedded system consists of one or more microcontrollers and peripheral devices like memories, converters, I/O expanders, LCD drivers, sensors, matrix switches, etc. The complexity and the cost of connecting all those devices together must be kept to a minimum. The system must be designed in such a way that slower devices can communicate with the system without slowing down faster ones.To satisfy these requirements a serial bus is needed. A bus means specification for the connections, protocol, formats, addresses and procedures that define the rules on the bus. This is exactly what I2C bus specifications define.

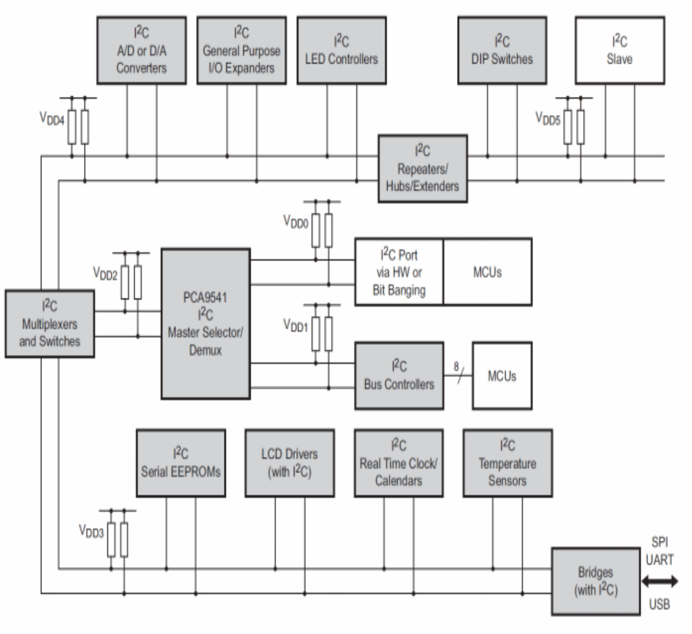


**Figure 3I2C Bus Specification**

The I2C bus uses two wires: serial data (SDA) and serial clock (SCL). All I2C master and slave devices are connected with only those two wires. Each device can be a transmitter, a receiver or both. Some devices are masters – they generate bus clock and initiate communication on the bus, other devices are slaves and respond to the commands on the bus.

In order to communicate with specific device, each slave device must have an address which is unique on the bus. I2C master devices (usually microcontrollers) don't need an address since no other (slave) device sends commands to the master.

## 3. Component Details

Based on the various reviews conducted on transformer protection and the above block diagram which was conceived out of those literature reviews conducted, numbers of components are required in developing the protection system

### *3.1 Microcontroller*

The microcontroller is required to serve the purpose monitoring the transformer information such as temperature, voltage and current through the LCD display, personal computer and triggering the relay when there is any fault. Modern power networks require faster, more accurate and reliable protective schemes. Microcontroller-based protective schemes are capable of fulfilling these requirements. They are superior to electromagnetic and static relays. These schemes have more flexibility due to their programmable approach when compared with the static relays which have hardwired circuitry.

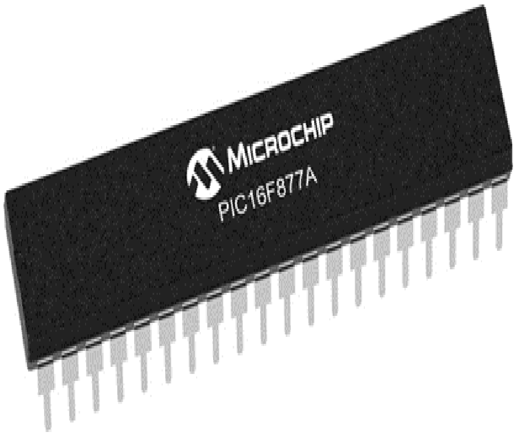


**Figure 4 Microcontroller**

Therefore, in order to achieve this task, the PIC16F877A microcontroller was chosen because of its suitability for this project such as speed, power consumption, universal synchronous asynchronous receiver transmitter (USART) functionality, in built ADC, and amount of RAM and ROM on the chip. The PIC16F877A is a low-power CMOS 8-bit microcontroller based on the Microchip enhanced RISC architecture. It has a High Endurance Non-volatile Memory segments such as 32K Bytes of In-System Self-programmable Flash program memory, 1024 Bytes EEPROM, 2K Byte Internal SRAM, write/erase Cycles: 10,000 Flash/100,000 EEPROM. The PIC16F877A microcontroller I/O pins are 40 in number, and most of them can be used as I/O pins. The input/output pins serve the purpose of connecting the ADC chip, LED, LCD display, alarm buzzer and in this case the port A, pin one, two and three were used to take care of ADC input since we are using three different analogue signals one for the voltage transformer other for the current transformer and finally for the temperature sensor.

### *3.2 ESP8266EX*

ESP8266EX is capable of functioning consistently in industrial environments, due to its wide operating temperature range. With highly-integrated on-chip features and minimal external discrete component count, the chip offers reliability, compactness and robustness. The ESP8266EX microcontroller integrates a Ten silica L106 32-bit RISC processor, which achieves extra-low power consumption and reaches a maximum clock speed of 160 MHz The Real-Time Operating System (RTOS) and Wi-Fi stack allow about 80% of the processing power to be available for user application programming and development.

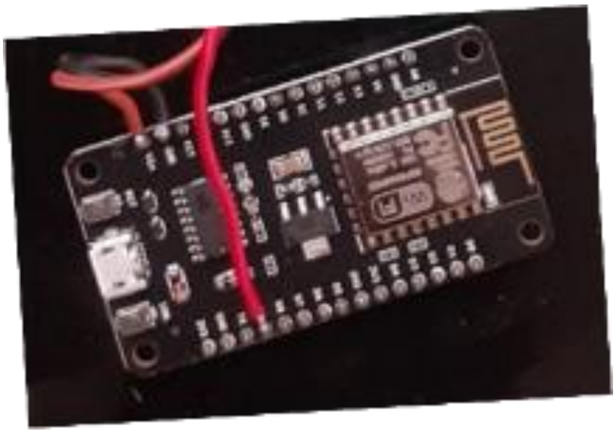

**Figure 5ESP8266EX**

### *3.3 Relay*

The relay is an electrically controllable switch widely used in industrial controls, automobiles, and appliances. It allows the isolation of two separate sections of a system with two different voltage sources. For example, a +5V system can be isolated from a 120V system by placing a relay in between them. One such relay is called an electromechanical or electromagnetic relay EMR. The EMRs have three components: the coil, spring and contacts.

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**Figure 6Relay**

In, a digital +5V can control a 230Vac lamp without any physical contact between them. When current flows through the coil, a magnetic field is created around the coil (the coil is energized), which causes the armature to be attracted to the coil. The armature's contact acts like a switch and closes or opens the circuit. The relay serves as the protective device of the entire system. The relay receives trip signal from the microcontroller and thereby cutting the transformer primary from the input ac source hence protecting the transformer. A relay should not be directly connected to a micro-controller, it needs a driving circuit due to the following reasons.A microcontroller will not able to supply current required for the proper working of a relay. The maximum current that pic microcontroller can sink is 15mA while a relay needs about 50 – 100mA current.A relay is activated by energizing its coil. Microcontroller may stop working by the negative voltages produced in the relay due to its back emf.

### *3.4 Relay Driver*

A relay driver circuit is a circuit which can drive, or operate, a relay so that it can function appropriately in a circuit. The driven relay can then operate as a switch in the circuit which can open or close, according to the needs of the circuit and its operation. In this project, we will build a relay driver for both DC and AC relays. Since DC and AC voltages operate differently, to build relay drivers for them requires slightly different setup. We will also go over a generic relay driver which can operate from either AC or DC voltage and operate both AC and DC relays. All the circuits are relatively simple to understand.

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**Figure 7Relay Driver**

***3.5 DC Relay Driver Circuit***

We will first go over how to build a relay driver circuit for relays which operate from DC power. To drive a DC relay, all we need is sufficient DC voltage which the relay is rated for and a Zener diode. All relays come with a voltage rating. This is called on a relay's datasheet its rated coil voltage. This is the voltage needed in order for the relay to be able to operate and be able to open or close its switch in a circuit. In order for a relay to function, it must receive this voltage at its coil terminals.

Thus, if a relay has a rated voltage of 9VDC, it must receive 9 volts of DC voltage to operate. So, the most important thing a DC relay needs is its rated DC voltage. If you don't know this, look up what relay you have and look up its datasheet and check for this specification. And the reason why a diode is needed is usually because it functions to eliminate voltage spikes from a relay circuit as the relay opens and closes. The coil of a relay acts an inductor. Remember that inductors are basically coils of wires wrapped around a conductive core. This is what relay coils are as well. Therefore, they act as inductors. Inductors are electronic components that resist changes in current. Inductors do not like sudden changes in current. If the flow of current through a coil is suddenly interrupted, for example, a switch opening, the coil will respond by producing a sudden, very large voltage across its leads, causing a large surge of current through it. From a physics or physical perspective, this phenomenon is a result of a collapsing magnetic field within the coil as the current is terminated abruptly. Mathematically, this can be understood by noticing how a large change in current (dI/dt) affects the voltage across a coil (V=L dI/dt). Since we are opening the switch, in this case, the current literally goes from full mode to 0 instantaneously. This creates a large voltage spike. Surges in current that result from inductive effects can create very high voltage spikes (as high as 1000V) that can have nasty effects on neighbouring devices with in the circuits, such as switches and transistors getting zapped. Not only are these voltage spikes damaging to other electronic components in a circuit but they are also damaging to the relay's switch contacts. The contacts will suffer from these spikes as well. The diode must be rated to handle currents equivalent to the maximum current that would have been flowing through the coil before the supply current was interrupted. Therefore, if the relay normally passes a certain amount of current through it during normal operation, the diode must be rated for a current rating above this value, as to not stop normal operation.

### *3.6 Transistor used as Driver*

The transistor is used as the driver and the basic function of the driver circuits to provide the necessary current to energize the relay coil. The Resistor R1 is used to set the base current for the transistor, the value of R1 should be such that when input voltage is applied to the transistor, it is driven into saturation i.e. it is fully turned ON and the Relay is energized. It's important that the transistor is driven into saturation so that the voltage drop across the transistor is minimum thereby dissipating very little power. The protection diode in the circuit is used to protect the transistor from the reverse current generated from the coil of the relay during the switch off time.

### *3.7 Liquid Crystal Display (LCD)*

LCD is a type of display used in digital watches and many portable computers. LCD displays utilize to sheets of polarizing material with a liquid crystal solution between them. An electric current passed through the liquid causes the crystals to align so that light cannot pass through them. LCD technology has advanced very rapidly since its initial inception over a decade ago for use in lap top computers.

Technical achievements have resulted in brighter displace, higher resolutions, reduce response times and cheaper manufacturing process. The liquid crystals can be manipulated through an applied electric voltage so that light is allowed to pass or is blocked. By carefully controlling where and what wavelength (colour) of light is allowed to pass, the LCD monitor is able to display images. A backlight provides LCD monitor's brightness. Over the years many improvements have been made to LCD to help enhance resolution, image, sharpness and response times. One of the latest such advancement is applied to glass during acts as switch allowing control of light at the pixel level, greatly improving LCD's ability to display small-sized fonts and image clearly. Other advances have allowed LCD's to greatly reduce liquid crystal cell response times. Response time is basically the amount of time it takes for a pixel to "change colours", in reality response time is the amount of time it takes a liquid crystal cell to go from being active to inactive.

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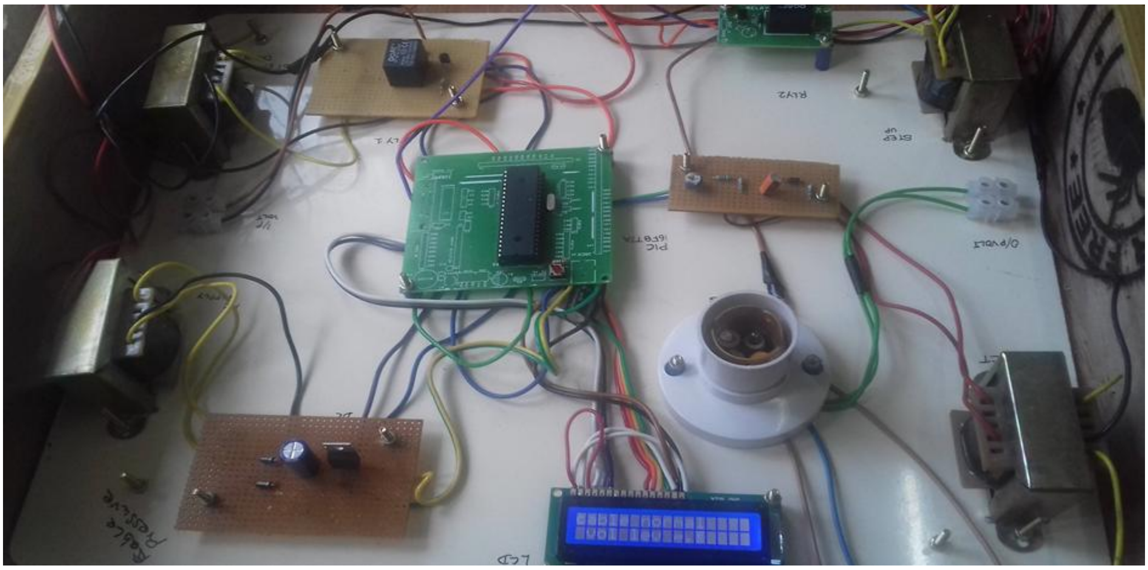

**Figure 8Hardware Kit**

## 4. Results

In this condition the system efficiency is increased, after implementing the proposed system. The voltage level increased up to 7% then the voltage in UG cable sending end and receiving end are corrected. By employing this scheme, we can control both input and output voltage with the help of step up and step-down transformers, so that voltage stress in UG cable can be normalized as fast as possible.

## 5. Conclusions

Monitoring and detection of voltage stress in MV or HV Underground cables can be done by embedded technology. I2C protocol was implemented successfully in this system. Master and slave operation controlled by PIC 16f877a microcontroller and IOT ESP8266 device.

Abnormal voltage stress across the UG cable could be corrected by using step up and step-down transformer. In this work the short circuit fault, low voltage fault, high voltage fault at a particular distance in the Underground Cables can be detected using Ohm’s Law which enables to rectify fault efficiently. This system can be beneficial to the underground cables

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