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Real Time Condition Monitoring of Circuit Breaker

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Abstract - *This paper is intended to give a real-time approach for monitoring and analysing circuit breaker so as to consistently diagnose its condition for carrying out a more efficient maintenance schedule. The problem of a large number of circuit breakers in a system causing long intervals between inspections can be resolved using this monitoring system IED located at the substation, which captures performance data of the circuit breakers and ensures reduced time lag and faster problem oriented maintenance. A remote access system can also be made with the help of a wireless module which enables the operator to monitor at a distance without manual interference.*

Key Words*: *Circuit breaker, condition monitoring, hardware, wireless.

1.INTRODUCTION

Circuit Breaker (CB) is an electromechanical switching device which is capable of making, carrying or breaking current under normal conditions as well as specified abnormal conditions such as that of a short circuit fault. CBs isolate the faulty part of the system in order to protect the downstream devices of the system. They also determine various topology configurations of power system. For such critical applications of a CB, it is necessary that it functions without interruption. CBs must cope with transients in the currents generated due to faults in the system along with voltage transients in the CB itself. Hence, CBs have harsh working conditions because of which they age over time and number of operations. Failure of CB can cause excessive damage to the system along with economic loss. To prevent mis- operation of CBs, regular monitoring and testing of CBs should be done. However, the vast number of CBs used in a system as well as the interval between the inspection and maintenance schedule of these CBs, which usually ranges from several weeks to a year, causes a number of deteriorating conditions to go undetected.

The existing CB inspection practice is to use portable recording devices that are carried from substation to substation and connected to the CB manually. These recording devices are temporarily connected to the circuit breaker's control circuit to record analog and digital signals. The operator opens and closes the CB each time the test is performed and compares with an earlier good case to see how different the new case is. This process is subject to interpretation and particular expertise of the individuals involved. Therefore, the post-inspection actions may vary from crew to crew and inconsistent CB corrective maintenance may result in different levels of readiness of CBs even after inspection is performed [1].

To overcome the problems stated above, an automatic and online monitoring system is required to monitor the health of CBs which will ensure a reliable and cost-effective approach to preventive maintenance. To improve system operation and to control system topology, the Circuit Breaker Monitoring (CBM) system can be integrated with Supervisory Control and Data Acquisition system (SCADA), which will enable status monitoring as well as condition monitoring of CBs. This paper aims to propose a system which uses open-source platform to continuously monitor and control the circuit breaker. As a result, minimisation of downtime and preventing unnecessary maintenance practice on healthy breakers can be achieved.

2. SYSTEM ARCHITECTURE

2.1 Hardware Architecture-

The hardware architecture consists of a CBM unit connected to each breaker located in the switchyard and one concentrator PC situated in the control room. The main task of a CBM unit is:

1. To acquire data from the control circuit of a circuit breaker and record it continuously. 2. Wireless transmission of files to the concentrator PC.

This task is performed by Circuit Breaker Monitor IED (CBM) in the following stages: field acquisition unit, concentrator unit and communication protocol. Using this system module, time synchronization is also achieved.

2.1.1 Field Acquisition Unit-

A) Signal Conditioning module: The main purpose of signal conditioning module is-

1. To scale the input AC voltage into a standard value of ±10 or ±5V required for analog to digital conversion because electronics devices operating range is ±5 to ±15V whereas the input voltage is 120V per phase.

2. To provide appropriate sampling rate for reconstruction of the signal. Usually sampling frequency of 10 kHz is desired for most of the applications.

Scaling also provides the overvoltage protection to other devices from the high voltage transients which may take place abnormally in the system.

B) Data Acquisition module: It consists of AD converter and microprocessor. The AD converter functions after the appropriate scaling is done by the signal conditioning module. The scaled ac voltage is converted into dc voltage with some ripples which are removed by the filter. A microprocessor is employed for controlling data acquisition parameters, detecting events and recording data for a specified duration, setting the sampling frequency and scaling factor, subsequently transmitting data to concentrator PC via communication protocol and wireless transceivers, and executing commands received from the concentrator

[2].

2.1.2 Concentrator Unit-

Every substation is equipped with only one concentrator unit. The concentrator gathers information through wireless communication, stores and pre-processes the data received from the field units, enables to access the data remotely, and sends the necessary command to the units located in the switchyard. Personal Computers are employed for this purpose.

2.1.3 Communication Protocol-

The wireless communication system is found to be cost-effective and easy to implement. If the data acquisition system were to be set up at each breaker in an entire substation, it would be very expensive to spread the wires to connect the field units to a control room. Therefore, a wireless RF module employing Zigbee technology is used to transmit the collected data to the concentrator PC. The mode in which transceivers work is called point-to-multipoint mode. In this mode, the field unit communicates with the concentrator unit and vice versa but there is no communication between the field units.

2.1.4 Time Synchronization-

Time synchronization is done where performance analysis of multiple breakers is required. Monitoring devices connected to each CB have to be synchronized in time. For this purpose, a distributed signal processing system is used which comprises of multiple CBs, each connected to its own AD converter which samples analog signals into digital signals. Each CB and its corresponding AD converter is called a node. These nodes are sampled at the same clock rate and interact with the central concentrator unit to perform online data acquisition and signal preprocessing. Pre-processing at the nodes is required for event (fault) recognition and time stamping. Every sample taken around the system needs to be sampled at the same time and stamped with common time stamp [4]. Time synchronization can be done using GPS clock signals.

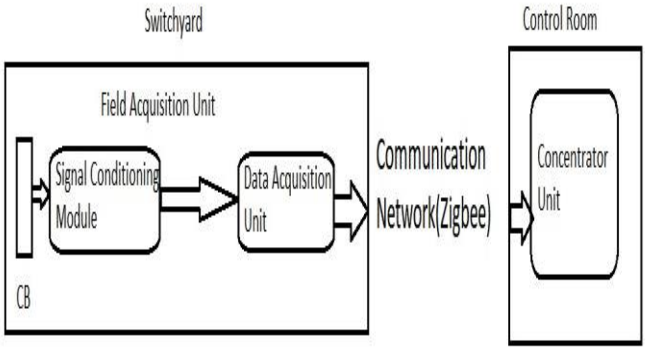

Fig-1: CBM System Architecture

2.2 Software architecture-

The system architecture comprises of two locations: one where data is collected by the CBM system situated in the substation, namely the hardware part, and other where data from all CBs are gathered at the central concentrator unit for further analysis, namely the software part. The software architecture is hardware independent. Software on a laptop is used for instant on-site analysis in a substation, whereas software on the server in central repository is used for off-site analysis which can be stored in the database for future reference.

Zigbee is a wireless communication protocol with RF modules. Its main function is wireless transmission of recorded data of the system to the laptop. It's one pair is connected to the microcontroller serial port with the help of the driver and the other pair is connected to the USB module present in the laptop. Zigbee can transmit and receive data simultaneously. The parameters like input voltage, output voltage, current, and temperature are recorded and automatically retrieved for the circuit breaker. Zigbee technology is of low cost and low power consumption wireless system. It is easy to implement with a shortrange wireless sensor network. The wireless transmitter is capable of transmitting data to distance mainly ranges from 10-100 meters based on the output of power as well as environmental characteristics.

In circuit breaker monitoring, real-time performance is the key point, using the highspeed PIC microcontroller as the CPU system. PIC Microcontroller 18F4550 belonging to the 'PIC 16F' family is used for controlling the data acquisition and running the communication protocols. The microcontroller operates to receive ON-OFF commands from remote locations and transfer those commands to relays. Relays are mechanical switches, used to trip the system on commands of microcontroller and microcontroller operated by the user interface. The user interface provides an ONOFF switch to operate from remote places.

The primary function of the relay is to provide control and protection to the circuit breaker.PIC Microcontroller has an 8 bit CMOS microcontroller with nano-watt technology. It has flash ROM ranges from 16 Kbyte to 64 Kbyte with internal RAM of 1.2 Kbyte and EPROM of 256 bytes. AD converter is already inbuilt in PIC

Microcontroller of range 10 bits. To speed up the flow of instructions given by the user interface microcontroller has a single clock cycle of order 2^{10}. This makes the system software fully automatic.

3. PARAMETERS SELECTION

Condition monitoring helps in state estimation, fault location and pre-alarming of circuit breaker. To determine these conditions of circuit breaker, some parameters are to be selected. The selection of appropriate diagnostic parameters depends of the overall effectiveness, accuracy, reliability and cost of measuring the parameters. These are the series of parameters that are chosen and corresponding methods can be used with various degree of monitoring complexity:

3.1 Contact resistance measurement-

Measuring the contact resistance determines the condition of Circuit breakers main and arcing contacts. If due to any fault, the resistance of circuit breaker varies from the normal value, the phase voltages and currents will differ. Such change in voltage leads to unnecessary losses and the CB becomes less reliable. To measure the contact resistance, phase voltage of the input as well as output of CB is measured with the help of Potential Transformer. The phase current of a phase is also measured. These values give the contact resistance.

3.2 Contact Erosion Analysis –

The operation of arc leans to wear and tear of arcing contacts. This may lead to shortening of the contact. This in result leads to decrease in the time difference between the operation of nominal and arcing contacts. There is a specified amount of time interval in which current should be transferred from nominal contact to arcing contact [3].

3.3 Delay time –

The open and break time of CB should be in the prescribed normal limits. The increase in delay time means that the CB is taking more time in switching states. This may lead to more time of arcing and more losses. The phase voltages on the input and output of CB are continuously measured. The difference of instances at which the voltage is supplied and is obtained after switching gives the delay time. Delay time measurement helps in predicting the condition of CB and reducing the losses.

3.4 Phase current –

The current across a phase is monitored which gives the breaker status. Abnormalities in any of the phases can be detected through phase current. Absence or fault in any phase of the three-phase line will lead to increase of current in other phases. This increased current can be detected using current transformer. Higher amount of current than the usual value for a longer period can also lead to CB damages.

3.5 Phase voltages –

Measuring phase voltages helps in determining the phase faults as well as in monitoring the CB faulty conditions. Phase voltages measured using Potential Transformer placed on the incoming and outgoing sides of CB contacts. Any phase fault can be detected as the voltage across the phases are monitored continuously. They also play an important role is determining the contact resistance, continuity of voltage through circuit breaker and monitoring the condition of CB.

3.6 Contact Temperature measurement-

Increase in resistance of contacts, increase in voltage, or any faulty condition may lead to increase in temperature of CB. This unnecessary increase of temperature results in more arcing spark and other abnormalities and hence lead to damage of contacts. Temperature sensor is placed at the contacts for temperature measurement.

3.7 Pre Alarm-

It is necessary for a CBM system to have preevent recording which is a waveform that determines CB status and specific control circuit condition before operation of CB.

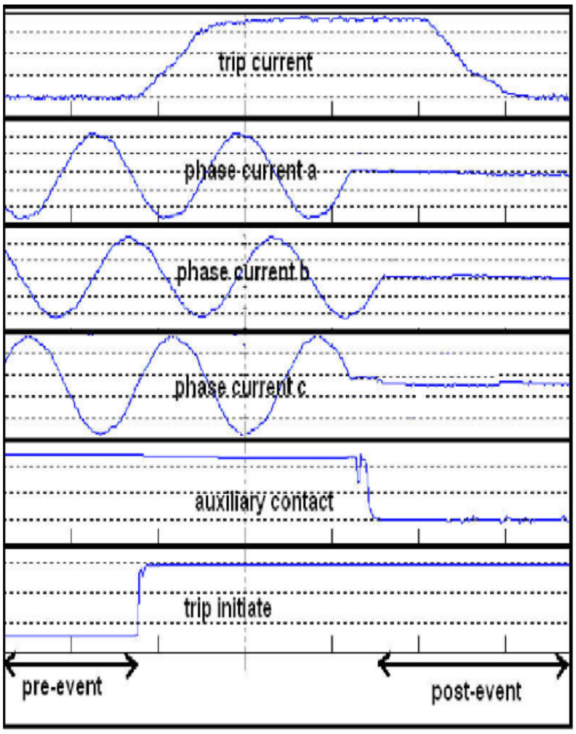

Fig-2: Pre-Alarm characteristics

Continuous monitoring of these major impacting parameters would result in smooth and reliable working of Circuit Breakers. These parameters will detect the faults and abnormalities. The system is so designed that all the threshold values are set and are calculated based on the normal operating condition of CB. Whenever these parameters exceed the limiting threshold value, a prealarm would be generated that will trip the CB. After the generation of pre- alarm, the CB can be allotted for maintenance.

4. FUTURE SCOPE

Condition monitoring of the power equipment is the major and inseparable part of smart grids. It accurately analyses every component for safe and reliable operation with the minimum amount of downtime. Therefore, condition monitoring and analysing of Circuit Breakers would be implemented and be a major part of future work as well. Data collected from this CBM system can be included in substation and control centre databases to exchange information over a cloud network. Satellite systems, mobile networks, and power line communications (PLCs) can be used as a link between the equipment and controlling system software. Using this technology of cloud ability enables us to gather a huge amount of data available over years in a single database. Such historic data can be used for more efficient monitoring. An integrated monitoring application in a remote control system within a real-time framework can be used [4]. Cloud data provide shared computing resources for the data stored in the cloud server. In this stage, various data processing tools can be considered, such as Machine Learning algorithms for data analytics. Cloud visualization displays the data collected over years in simpler forms of graphs, spectrograms, diagrams, curves, and so on. In this manner, the deviation trends can be analysed and decide the more appropriate actions. Cloud prediction tools can be used in the future which are mainly based on Machine Learning algorithms. It adds different characteristics to web-based studies using real-time data analysis [4].

5. CONCLUSION

Implementation of advanced signal processing which extracts relevant features from the signals recorded and an expert system that detects the abnormalities in the signals makes this an automatic model. Being an open-source platform the concern regarding reliability and security is eliminated since the complete source code implementation is open and fully accessible & controlled by the user. Using the wireless mode of transferring data from the CB monitoring system to the concentrator system PC increases the flexibility and reliability of the monitoring system over hardwired solutions. Real-time monitoring of CB facilitates the shift in maintenance approach from scheduled maintenance to as-needed maintenance. This shift in the maintenance paradigm helps in safety, failure prevention, asset replacement prioritization, maintenance optimization, and reduces unnecessary downtime.

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