AUTOMATIC MAINTENANCE OF SUBSTATION GROUND RESISTANCE

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Abstract: The main purpose of power system substation grounding system is to maintain reliable operation and provide protection for personnel and apparatus during fault condition. However, in practice, ground resistance value of substation often did not meet the required value. It can results to serious failures such as apparatus malfunction and lost of revenue. This paper presents a prototype for automatic monitoring and maintenance of those grounding system. It basically consists of a PC, Terminal Measurement Unit, Data Acquisition Unit, and Relay Board. It measures the grounding resistance and has the ability to actuate fluid sprinkler system at substation grounding system, thus improving and maintaining substation grounding system resistance to an acceptable level. This system will ultimately increase the reliability and efficiency of substation particularly when under transient overvoltage due to switching and lightning phenomena by reducing lethal ground potential rise.

Key Words: substation, grounding, ground resistance, automatic, maintenance, reliability.

I. INTRODUCTION

Electricity is playing an ever-increasing role in the lives of almost everyone in the world. In almost every country, electric energy is now being utilized in everyday life at an ever-increasing rate. To meet the ever-increasing demand for electricity, larger and large power stations are being planned, builted, and commissioned for efficient utilization of water power, conventional fuel, and nuclear fuel. Longer transmission lines are constructed. The substations are concurrently built to provide wider distribution of power to consumers. Design, construction, commissioning and maintenance of the substations are critical in ensuring reliable, continuous, efficient, and resilient to transient overvoltages in power distribution. Proper grounding system is necessary to produce high performance of substation.

According to the ANSI/IEEE Std.80-1986 [1], in principle, a safe earthing system has two objectives:

1. To provide means to carry electric currents into the earth under normal and fault conditions without exceeding any operating and equipment limits or adversely affecting continuity of service.
2. To assure that a person in the vicinity of grounded facilities is not exposed to the danger of critical electric shock.

The important common denominator of substation types is the existence, within a confined area, of high voltage equipment which receives power from an electrical utility and transfers it to a customer load. Because of the possibility of accidental energization of the metallic structure making up the substation equipment and supporting structures, a grounding system is installed throughout the substation area in order to keep electrical potential as low as possible during such an energization. The grounding system resistance (GSR) for the substations is normally maintained at value less than 5 ohm depending on the local condition [1]. Low GSR is very important because it limits hazardous GPR at safe level for equipment and personnel particularly current whenfault discharge or lightning discharges to the ground. The lower the resistance of grounding system, the better protection it provides [2]. However without proper and effective maintenance procedures, low the GSR cannot be maintained continuously. This paper describes a system that can improve the grounding system reliability and efficiency for substation based on computer aided technique. In this case it is known as Automatic Monitoring and Maintenance of Grounding System (Amomagsys). This PC-Based system also provides remote monitoring and maintenance of those grounding systems from engineer control room in the main office, thus reduce the cost and increase the efficiency of operation and maintenance exercise.

II. MAIN IDEAS

Capability of the earth to accept the energy due to electric current discharge into the ground depends on the resistivity of the soil at a particular location of the substation, and in the case of structures, the effectiveness of the electrical connection to the earth. In other words, the GSR depends on local soil characteristic of the substation. The soil resistivity primarily depends on a number of factors [3][4][5]:

(a) Soil type and nature of soil
(b) Concentration and composition of the dissolved substances in the immediate neighborhood
(c) Temperature of the soil
(d) Moisture content of the soil
(e) Water content
(f) Ion concentration

With reference to the above mentioned factors, the resistivity can be obtained accordingly. Hence, the low GSR is achieved with low resistivity.

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III. PRINCIPLE OF OPERATION

The main function of Amomagsys is maintaining specific grounding system at a desired value of ground resistance refer to remote earth. This system uses a PC-based system for monitoring with maintenance program is incorporated. It also has ground resistance measurement unit (GRMU). It basic principle of operation based on improved Fall-of-Potential Method i.e: by injecting a computer controlled variable frequency electric current between two points, the ground electrode under test and the current probe. If the ground resistance value measured by GRMU higher than the required one, a signal-conditioning unit (SCU) generates a signal that will trigger an open fluid sprinkler, located at the monitoring end. Because of this the ground surrounding the grounding system and the grounding rod is moistened, consequently lowers the ground resistance value.

IV. HARDWARE DEVELOPMENT

A. Modified Grounding Rod (MGR)

Driven rod is one of the earth electrode types widely used in application of grounding system, because it is easier to install. Driven rod electrodes are normally is made of galvanized steel coated with copper. This type is not suitable for installation of grounding system on soil of high resistivity, because it is difficult to achieve low resistance path to the earth. Beside that, this type cannot provide consistent GSR value in the long run. An alternative earth electrode to overcome the problem above by using modified grounding rod (MGR) [8][9]. MGR uses the idea of maintainable grounding rod. The chemicals content in the hollow cooper tube, sip through the surrounding ground via the tube side holes. Low resistance contact between MGR and soil, allows the existence of low ground resistance to remote earth.

B. Ground Resistance Measurement Unit

The measurement of ground resistance is necessary, because its to ensure the value of the ground resistance does not increase dramatically. Accurate measurement of the grounding system resistance is an important aspect in maintenance program of the grounding system. Without the accurate measurement of grounding resistance, maintenance program of grounding system can be quite misleading and leading to wrong judgement. The basic principle of ground resistance measurement unit (GRMU) of the proposed method is based on the modified Fall-of-Potential Method whereby the power source is a controlled frequency current. The figure 1 shows an quivalent circuit when controlled frequency current is injected in to the ground.

If the frequency of the injected current of a value as such $X_L = X_C$ i.e X = 0, the circuit is in resonant where ωL = 1/ωC. The impedance of the circuit equals the ohmic resistance *R*. The current is maximum. It is being limited by value of *R* only.

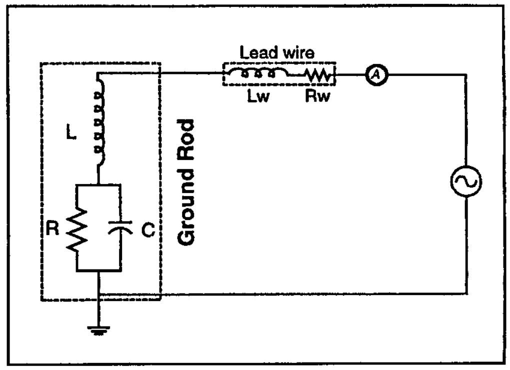

Fig 1. A simple equivalent circuit

If the impedance of lead wire is neglected, the output impedance of the measuring system in Figure 1 is:

$$Z(\omega_0) = \frac{R}{1+(\omega CR)^2} + j\left(\omega L - \frac{\omega CR^2}{1+(\omega CR)^2}\right) \text{........(1)}$$

At resonant frequency ω_0,the complex number *j* is zero, the equation (1) will be:

$$Z(\omega_0) = \frac{R}{1+(\omega CR)^2} \text{..................................(2)}$$

Because the value of ground capacitance is very small (from nano farad up to piko farad), so $(\omega CR)^2$ considered is zero, the equation (2) will be:

$$Z(\omega_0) = R \text{...(3)}$$

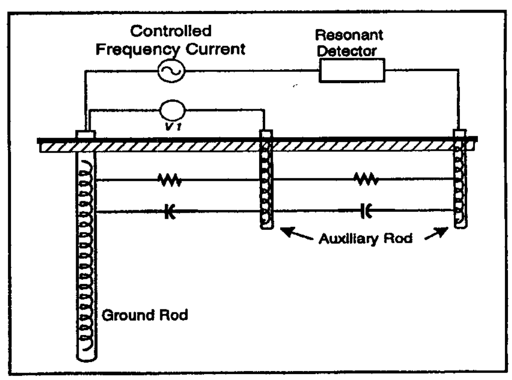

Fig 2. Field measurement arrangement, based on modified Fall-of- Potential Method

The basic principles of operation of GRMU involves the utilization of a current injection unit injecting a computer controlled variable frequency electric current between two points, the ground electrode under test and the current probe.

Since the ground is treated as a R-L-C ladder network, while the current is of high frequency source, therefore there will be a time when at that particular set frequency, the input current is at maximum value i.e at resonance. With determination of inter probe voltage V_I and input current I of the measuring system as in figure 2, thus ground resistance R_g at resonance can be found.

C. PC Interface System

It consists of Analog to Digital Converter (ADC), Digital to Analog Converter (DAC), and Digital Input Output (I/O). The ADC is used for converting analog value into digital value from GRMU and other sensors. The chip "brain" of ADC in this project is MAX 172 12 bit ADC with 10μs conversion time. The digital I/O is 82C55A CMOS programmable peripheral inter-face. This chip provides 24 programmable digital I/O channels. It is use for driving the signal-conditioning unit (SCU) which triggers the darlingtons array transistor (DAT) chips subsequently activate the relay board. Lastly the DAC is designed to control frequency output source of GRMU. The digital command from a PC is converted into analog value before driving oscillator controller of signal generator of the GRMU. The AD 7537 is DAC chip which contain 12 bit current output on one chip.

D. Signal Conditioning Unit (SCU)

The function of the SCU is to adjust the value of analogue input from the GRMU, the temperature, and the humidity sensor, to ensure signal matching with the ADC. This is can be implemented by adjustment of gain from the input side of the operational-Amplifier. Beside that, the SCU also functions as a relay triggering unit which activates the motor pump, the open fluid sprinkler and the burglar alarm. The SCU basically consists of a power supply, Op-Amp, relay board, and DTA amplifier.

V. SOFTWARE DEVELOPMENT

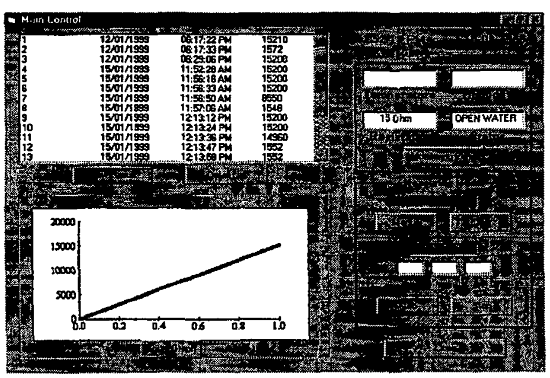

Fig 3. The front page of Amomagsys software

Development of the Amomagsys software basically uses the object oriented programming language. MS-Visual Basic™ provides a user-friendly object tool called *custom control.* The figure 3 shows an example of a user interface form called "Main Control.Frm". These include database result window, graph window, and other buttons regarding to each function. Using software, data reading like ground can be visualized The software which enables to collect all the parameters data like resistance, temperature, and humidity. The first version of the user-interface which has been developed possessed the capability for users to monitor the status of GSR value.

VI. SYSTEM SETUP

Generally, the Amomagsys consists of four major subsystems: PC, PC-Interface System, SCU, and GRMU. For remote measurement system it requires a modem and a leased line. The system block diagram of the Amomagsys is illustrated in Figure 4. The three major units in the GRMU (exclude PC and PC-Interface system) are current injection unit, input unit, and external hardware.

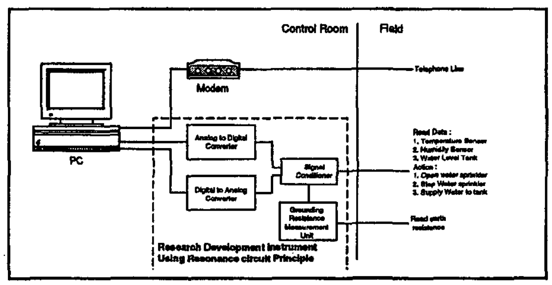

Fig. 4 Amomagsys Block diagram

The current injection unit comprises of six components: overvoltage protection, signal generator, buffer amplifier, operational amplifier, voltage conditioner, and current sensor.

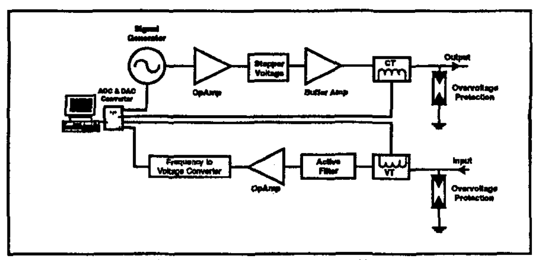

Fig 5. Block Diagram of Grounding esistance Measurement Unit

While the input unit consists of five components; overvoltage protection, active filter, operational amplifier, frequency converter, and voltage sensor. Beside that the external hardware consists of current and voltage probe, and lead wire. Figure 5 shows a block diagram of the GRMU. At this point of time, the measurement system has not been fully developed. The full-computerized system will be the next phase of the study.

VI. CONCLUSIONS

The PC-based Automatic Monitoring and Maintenance of Grounding System is useful for organizing maintenance activities for substation grounding system and can be easily implemented. Thus maintenance problem of the grounding system can be overcome. It is a stable, efficient and reliable of grounding system application. It is also suitable to be installed in areas of high ground resistivity. Cost savings will become more apparent to the user in maintenance activity and maintenance becomes manageable.

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