ILMOS

Insulator Leakage Current Monitor

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1) Introduction

The exposure of insulation structures to all atmospheric conditions has always been an integral part of insulating all transmission, sub-transmission and distribution systems. With the increased knowledge of overvoltages caused by lightning and switching surges and the improvement in apparatus to protect against these overvoltages, the problem of insulator contamination gained extreme urgency. This has been enhanced by increasing air pollution and the increasing number of transmission lines.

With deregulation of the power supply slowly taking over the energy market, traditional utilities are now facing increasing competition resulting in pressure to lower the cost of operation and hence reduce prices and to increase the system reliability by improving the performance of insulators. Some of the mitigation techniques involve increasing the leakage length of the insulators in the most vulnerable location, coating the insulators surfaces with hydrophobic materials (e.g. RTV and grease), periodic washing of the insulators or replacing the porcelain insulators with polymeric insulators.

All of these techniques have merits and disadvantages. Non-ceramic surfaces suffer from loss of hydrophobicity and degradation of surface conditions after prolonged exposure to pollution and electric discharges. Establishing a reliable washing and maintenance program seems to be a widely accepted practice to improve the situation, at a premium however. High cost and the need to highly trained labor make washing an expensive proposition. Figure 1 shows a picture of a maintenance chopper during an insulators washing mission.

Figure 1: Live line insulator washing of a transmission line.

To rationalize the cost of maintenance, pollution monitors are being used to establish suitable maintenance periods and at the same time avoid unpredictable flashovers. These systems make it possible to migrate to "status" based maintenance schedules, instead of time-based schedules that may require frequent planned outages of the systems for cleaning of insulators.

Pollution monitors can be used to:

- Measure the site pollution severity to determine the most troublesome areas of operation.
- Monitor insulators status in terms of pollution severity for maintenance purpose in order to determine when cleaning and/or maintenance greasing of insulators are needed to prevent pollution flashovers.
- Compare the effectiveness of different insulator designs (shape and length) and/or insulator materials under certain polluted environment to determine the best solution.

2) Insulator Flashover Due to Pollution

The pollution may reduce the power frequency flashover voltage of insulation significantly leading to unplanned outages and diminished reliability. Pollution flashover of an insulator is a complicated process that occurs through different phases, namely: the contamination layer build-up, dry band formation, partial arcing and, if conditions are favorable, flashover.

Contamination Layer Build-up

The pollution may be caused by a large variety of sources like fly ash, salt from the sea, dust from the industry etc. Contaminant deposition is governed by the interaction of several forces acting on its particles simultaneously (e.g. gravity, wind and electrostatic forces). The conducting component of the contaminant influences the flashover voltage of the insulator by providing, when wet, a conductive coating on the insulator surface. The inert component on the other hand, is the portion of the solid material that does not dissolve but forms a mechanical matrix in which the particles of the conducting component are embedded.

Moisture is provided by nature by two main mechanisms: condensation and impingement. Condensation represents a slow wetting process during which the conducting pollutant may dissolve completely. This process often takes place under conditions of fog or dew in the early morning hours. Mist and drizzle can also cause the same effect.

Dry Band Formation

When the conductivity of the surface layer is established by moisture in which the solid contaminants are dissolved, a surface current is then permitted to flow which results in ohmic heating of the layer. The conductivity first increases as the temperature rises, but as it reaches a certain value, water evaporation becomes appreciable and the solution is over-saturated with salt. The layer starts to dry out in the zones with highest energy dissipation and the conductivity of these zones drops quickly until it approaches zero. The distribution of the current flow is then modified enhancing lateral drying and creates dry bands.

Partial Arcing

When a full dry band is established, most of the applied voltage on the insulator is then imposed on it due to its higher resistance. The current is either interrupted or an air breakdown will establish an arc that will bridge this dry band and maintain the current. The arc carries the current in a highly concentrated channel releasing heat in a very concentrated form rather than distributing it over the surface, as does the surface layer. This leads to preferred elongation of the dry band width at the location of the end points of the arc, where the current density is highest. The arc may extend itself longitudinally and if it manages to cover a critical part of the leakage path length, flashover is practically inevitable.

The amplitude of the leakage current pulses is a good indicator of the insulator condition. It is known that the amplitude of the current is very decisive for the flashover.

3) **Leakage Current Monitoring Importance**

Pollution severity is usually determined by measuring the conductivity of a mixture of the contaminant removed from the insulator surface and a known amount of distilled water. The severity of contamination due to conducting materials is generally expressed in terms of ESDD (*Equivalent Salt Deposit Density*) in mg/cm^2, the amount of salt (NaCl) that must be dissolved in the same amount of water to obtain the same conductivity. The ESDD accounts only for the soluble part of the contaminant. Measuring the ESDD is an indirect and static method to determine the "status" of the insulator and provides only a snap shot of its condition.

Generally, the pollution layer on insulators builds up during months or years with intermediate periods with humid weather conditions. Leakage current monitoring during such periods provides the most direct and accurate way of determining the behavior of the insulator during pollution. It will then be possible to see how the pollution activity is increasing with time and also to see the effect of rain (natural washing) and to decide about artificial cleaning or insulator washing.

Chart 1 shows some guide lnes to the using the leakage current as an indication to the insulator status.

Leakage Current	Symptom
0-2 mA	No visible or audible effects
3-5 mA	Light Noise
5-10 mA	Night visible sparks
10-15 mA	Wooden cross-arm burning
15-100 mA	Heavy Sparking
Over 100 mA	Imminent Flashover

Chart 1: Leakage current as an indication to the insulator status.

In some situations where the contaminant is accumulated on the insulator surface and the wetting is followed more or less directly thereafter, it may not be possible to obtain enough time for cleaning. Real time leakage current monitoring could provide an advanced warning about the critical situation coming up and the load may be switched to other lines if such alternatives exist.

Leakage current monitoring on an insulator for the purpose of avoiding flashover or to determine the relative performance of one insulator type versus another, can be accomplished by registering the actual current pulses amplitude over a period of time and either saving these values to a memory device inside the monitor or to a hard disk of a computer permanently attached to it which is generally hard to do in substations and almost impossible in case of transmission lines.

Alternatively, the same valuable information can be obtained and derived from saving the statistical distribution of the actual current pulses during the same period and saving the distribution information rather than the actual pulse data. The advantage is an extended periods of data acquisition, smaller, more economical and easier to handle current monitor.

4) ILMOS–5: The Insulator Leakage Current Monitoring System

Introducing ILMOS-5. A new leakage current monitoring system that is easy to use and easy to maintain. ILMOS-5 is small in size and is battery operated. ILMOS-5 monitoring system is composed of three parts, the acquisition unit, the transducer box, which includes protection circuitry and a user-friendly software to retrieve and analyze the data. A properly terminated coaxial cable picks up the leakage current signal from the insulator base and delivers it to the transducer box. The acquisition unit and the transducer box are connected via another coaxial cable. A microprocessor controls data collection and processing. The housing is weather proof. Figure 2 shows ILMOS-1 acquisition unit.

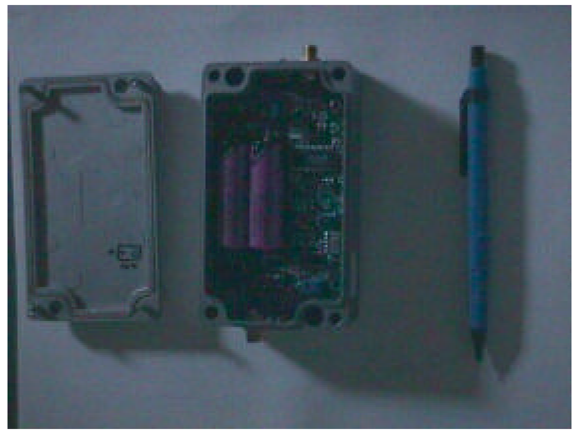

Figure 2: Logic control and data storage unit.

5) ILMOS Operation

ILMOS-5 acquisition parameters are set using a personal computer away from the field prior to the installation. The following describes the sequence of setting up the system.

a) The acquisition unit is connected to the PC using the RS-232 serial port.

b) Using the ILMOS software, the histogram bin boundaries are set and the bin contents are reset to zero using the appropriate soft dials and buttons on the screen (Figure 3).

c) Finally, the system is started.

Special care should be taken when the voltages ranges are defined. The maximum voltage allowed across the acquisition unit is 4 Volts. The histogram bins should be adjusted based on the expected leakage current and the resistance of the transducer box. Please refer to chart 1 for some guidance on the leakage current indications on external insulation.

The system is then installed at the desired location and the acquisition starts. In this mode, the system detects the leakage current peak values every positive half cycle. These values are then analyzed by the processor unit, which creates the histogram of the current pulses. The system stamps the data with the time and date after a predetermined interval, saves the data to a nonvolatile memory chip and then resets histogram bins contents and restart another acquisition batch. The acquisition interval and the histogram bins are all fully adjustable. The unit can store 1000 histograms having an adjustable period from 3 hours to a week.

When desired, the acquisition box can be removed from service and sent back to the responsible person to retrieve the data using the computer and interpret it. The control unit housing is 4x2.5x4.5 inch box, which makes it very easy to transport it by regular mail service. Figure 3 shows the user-friendly interface of ILMOS-5.

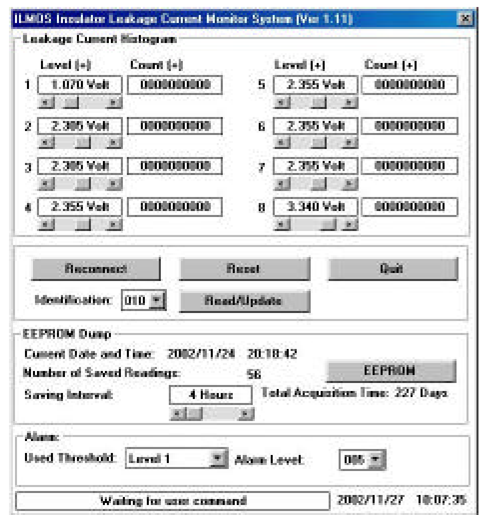

Figure 3: The user friendly interface of ILMOS-5.

6) ILMOS-1 Applications

ILMOS-1 is an extremely compact and easy to use. It is designed for the following applications:

1) Determination of insulator looses, in fact one of the field in the output report is stating the power losses in KWH,

monitored during the duration of that time.

2) Determination of site pollution severity. ILMOS-5 can be used to establish the pollution zones in the local areas. This provides a dynamic mapping of the pollution severity at a particular site irrespective of the individual insulator design or type. When the study involves special weather or atmospheric conditions, the acquisition period per histogram can be limited to a relatively short period (e.g. 4 hours) after which ILMOS-5 will reset itself and restart another batch every four hours, a total of 6 histograms per day, for over 160 days.

3) Insulator design validation and comparative study of the performance of various insulators at the same site under the same pollution conditions.

4) Establishing status based maintenance schedules to replace time-based schedules. This insures that maintenance is performed when it is actually needed and rationalizes expenses and reduces cost.

7) Conclusions

Industrial related contamination and salt storms in costal areas cause flashovers on overhead lines and station insulators resulting in serious disturbances of the electric power supply at a high cost. In some areas, artificial washing of the insulators becomes the only means available to prevent such outages although it is very costly.

To rationalize the expenditure when washing is deemed necessary, pollution monitoring becomes an interesting option. One way to monitor the pollution level is to determine the ESDD. A tedious and time consuming process which reveal information pertinent only to the particular insulator type where the measurement was taken. A better option is to monitor the leakage current on the insulators, which can be related directly to how close this insulator is to flashover under different operating conditions.

The three main applications for monitoring of pollution of stations' and lines' insulators are:

- Maintenance planning or “on demand” insulation washing.

- Site pollution severity mapping to identify the most critical locations in the network.
- Design validation, comparative performance study of insulators and lines design.

ILMOS-5 provides the user with such valuable information at a very competitive cost and with high level of reliability.

ILMOS-5 can be easily mounted at the insulators base for transmission lines, circuit breakers, transformers, capacitors banks and others and because it is battery operated there is no need to provide a low voltage AC supply to energize the system. This makes it viable to monitor long transmission lines, where there is no access to low voltage power. The battery lasts for more than a year and hence there is no need for frequent battery replacements.

ILMOS-5 is small in size, which allows easy installation and data retrieving. The unit is initiated with a personal computer running Windows 3.1 or higher, and the software provided with the equipment Kit, which is easy to install and use.

ILMOS-5 does not require any maintenance. However, if an extreme leakage current is to circulate, or a flashover takes place, a severe damage may be inflicted on the transducer box and possibly the acquisition unit too. This condition is not covered by the warranty of the unit.