R&D in TALOS High Voltage Test Station: A Distributed Approach on Insulator Monitoring Systems

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Abstract

In this paper, the R&D activities in TALOS High Voltage Test Station, and especially the distributed approach followed for insulator monitoring, are presented. TALOS is a High Voltage Test Station constructed by PPC/HEDNO in Iraklion, Crete. The isolated power network of Crete faces intense pollution problems due to coastal development, the high voltage level used and local weather conditions. TALOS High Voltage Test Station is constructed at a minimum distance from the coast in order to provide a worst-case scenario for the insulators used throughout the network. The Greek power utility (originally PPC and now HEDNO), has issued several remedies to cope with the problem and has participated in several research projects. This paper focuses on the currently running project (POLYDIAGNO) and the distributed insulator monitoring scheme now followed.

Keywords: insulator, monitoring, leakage current, test station, HTV SIR, pollution, high voltage, long term, field

1. Introduction

The performance of high voltage insulators is a matter of great importance for power utilities as insulators essentially represent weak links in the chain of power systems. Their performance is strongly linked to local operating conditions including weather and climate [1-4]. With new polymer materials, additional factors such as the chemical composition, fillers, proper handling and especially aging have to be considered [5-7]. Even electrical stress has a different effect on such materials [4]. Therefore, utilities are always interested in R&D programs aiming to further investigate the performance of HV insulators in relation to certain operation conditions and especially pollution. The Greek power utility (PPC at the past, and now HEDNO) has employed several remedies over the years to cope with the intense insulator pollution problems in the island of Crete [8-9]. The latest development is the replacement of traditional ceramic insulators with HTV SIR composites in the vast majority of transmission lines [10]. This has increased HEDNO's interest in the behavior of such insulators and has lead to HEDNO participating in a large research project along with Greek academic and research institutions.

2. TALOS High Voltage Test Station

HEDNO has issued the construction of a High Voltage Test Station in Iraklion, Crete aiming to provide a research and testing center primarily to satisfy HEDNO's needs but also to cooperate with academia, other utilities and manufacturers in larger R&D programs [11-16]. TALOS High Voltage Test Station is equipped with three bays for testing and monitoring 21kV and 150kV post and suspension insulators [11-15]. It is constructed right next to the sea in the premise of the Linoperamata substation in order to be subjected to the maximum possible pollution [11-15]. A 2D and a 3D representation of TALOS is shown in Fig. 1. A pollution measurement arch is installed in the center of TALOS for ESDD and NSDD measurements [15-16].

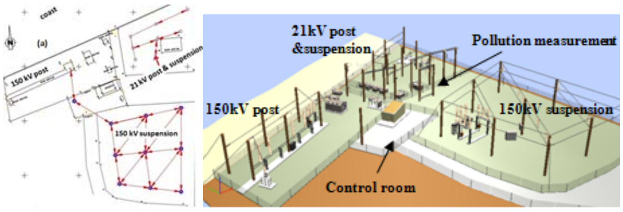

Fig. 1. A 2D and a 3D model of TALOS

3. POLYDIAGNO research project

POLYDIAGNO, is a research project focused on the monitoring and diagnosis of polymer based outdoor insulators used in high voltage applications [12, 17-18]. It is focused on investigating the performance and aging of HTV SIR insulators using advanced techniques (contact angle, FTIR, SEM, LIBS etc [19-21]). The insulators considered for this project have been removed from the network and an effort was made to select insulators that have operated for different years and under a variety of stresses [18, 20, 22-23]. Three insulators were removed from each selected tower. One of each three was sent to the cooperating labs [19-21, 23] where as the remaining two were installed in TALOS [10, 18]. A detailed list of the published results up to now can be found in [11, 17].

4. Insulator Monitoring System

Leakage current monitoring is a well-established and widely applied technique to monitor and investigate the performance of high voltage insulators [25] that should be combined with weather data monitoring [1-4]. The Greek power utility has issued large monitoring projects during the past years mostly based on a widely used at the time but no-longer commercially available device able to monitor current, voltage and weather data [14-15]. As demands grew, upgrading the monitoring system became a necessity. Highly specialized equipment proved to bear the unavoidable disadvantages of any product targeting a small market: high cost, poor support and limited (if any) upgrades. Therefore, it was decided to move towards general purpose DAQs. However, this meant that additional work had to be invested in market research and in designing a reliable low cost system that could monitor leakage current waveforms along with extracted values [25] and weather data [1-4]. Currently, a three-level distributed approach is followed: a dedicated PC-based DAQ records the full waveform using its standard software with slight modifications, stand-alone Labview based DAQs are employed for monitoring extracted values through custom-made VIs and a stand-alone weather station is used to monitor weather data. The proposed approach provides an interesting low-cost alternative to specially designed equipment.

4.1 Weather station

A dedicated weather station [26] has been installed in TALOS that provides a publicly available live weather report [27] and also detailed data (currently set to one recording per minute) (Fig. 2). The weather station is stand-alone, equipped with an internal memory and software able to update a cloud data base at regular intervals, without requiring any action or PC connection. It measures rain, temperature, humidity, solar radiation, UV radiation and wind. It has been mounted on top of the pollution measurement arch installed in TALOS in order to acquire ESDD and NSDD measurements [15-16].

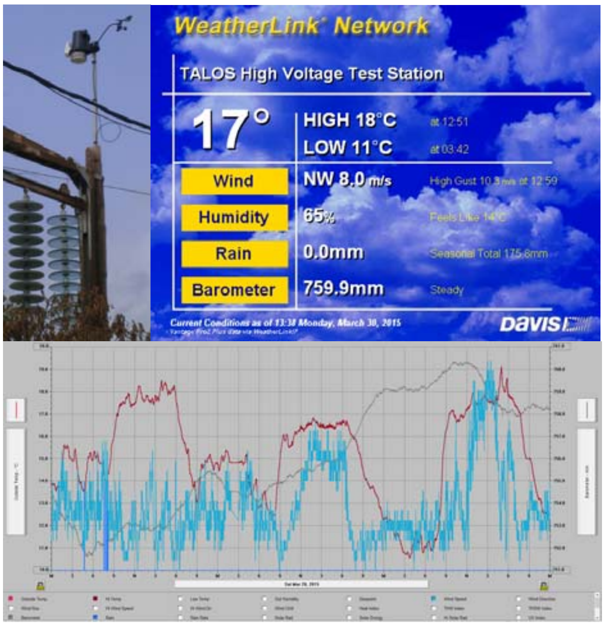

Fig. 2. Weather station photo, online report and detailed chart

4.2 Leakage Current monitoring

4.2.1. General scheme

The leakage current measurement is acquired by using a stand-off insulator to lead the current to a current sensor (Fig. 3). Expulsion fuselinks [28] are used to protect the leakage current monitoring equipment and to disconnect a particular insulator in case of a flashover, without interrupting the supply to the other insulators. The sensors purchased with the initial monitoring device [29] were powered with ±15V DC from the device. A single wire was used to carry the ±15V DC power and the measurement signal, but this wire consisted of two parts: a short part near the sensor and a longer near the device. The main disadvantage of these sensors is their input (500mA) and output range (±15V). Leakage current is indeed usually under 500mA, however it may reach larger values without a flashover being imminent. The ±15V range means that these sensors can not be used with most low-cost general purpose DAQs as these usually have a ±10V input. It should also be noted that each sensor has a different offset and is to be independently calibrated [29]. For all these reasons, research is also focused on designing new sensors [30]. Meanwhile, the ones currently available are used in TALOS.

Considering the installations in TALOS, it was decided to house the sensors and measuring devices in metal cabinets installed in the center of each bay (see Fig. 1 and Fig. 3). Sensors are powered from two 0-15V DC power supplies properly connected in order to acquire a ±15V DC supply. An added electric board (panel) is installed, equipped with a switch, fuse and indication light for each sensor (Fig. 3). The short part of the original wire (the one near the sensor) is kept in use in order to avoid any connection problems at the sensor's end. The signals are separated using a connection table at the end of these wires and the measurement signal is sent to the back side of the cabinet where the DAQs are stationed. An online UPS is used to provide the power to the DAQ's power converters and underground LAN cables connect the DAQs to the control room.

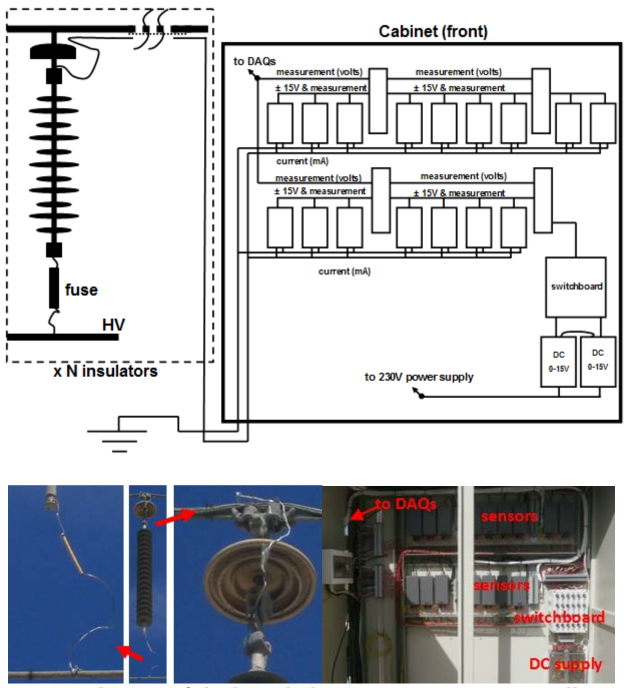

Fig. 3. A drawing of the basic leakage current measuring installation and photos from the actual installation in TALOS High Voltage Test Station

4.2.2. PC-based DAQ

As the original recording systems started to become obsolete, the first demand was for a low cost solution able to monitor as much insulators as possible and use the already available sensors. It was decided to purchase a DATAQ DI-

722-32 device which is capable of monitoring 32 different channels (±20V input), with a satisfying sampling rate (50kHz for all channels) [31]. The device has many advantages (low cost, easy to use) but also a main disadvantage: the limitations of the original software. As research advances, new approaches on the processing of the signal may arise and fully customized software could be needed. Further, certain extracted values and filtering that was not provided by the original software are already desired (e.g. incorporating a DC filter in the software eliminates the sensor offset issue). Therefore, it was decided to keep this device as a waveform recorder and move to other equipment for the calculation and recording of extracted values.

Fig. 4. DATAQ DI-722-32

4.2.3. Labview based DAQ

Following the issues mentioned in the previous paragraph, it was soon decided to move to NI Labview based systems that could be fully customized at any time. Stand-alone capability was also a desired characteristic as a loss of power to the control room (and the PC) should not mean a data recording loss. The scheme followed employs the use of rugged and reconfigurable chassis (cRIO-9074 [32]) equipped with 8 slots, a microprocessor, user-programmable FPGA and the separate purchase of multiple hot-swappable I/O modules. Two different types of modules were purchased: NI 9229 [33] and NI 9205 [34]. Each NI 9229 has 4 differential channels with an input range of ±60V that allows the use of the currently available sensors. Each NI 9205 has 16 differential channels with an input range of ±10V and these modules are scheduled to be used with new sensors that will provide a ±10V range output. The Labview software along with the Labview Application Builder and the Labview Real Time Module were also purchased to allow the stand alone operation of the DAQ. A custom made software was developed capable of removing the DC offset and then calculating certain values (positive and negative peak, RMS, harmonic ratios, THD, positive and negative charge). A user-defined gain was available for each channel in order to incorporate each sensor's transfer function. The time-windows used to calculate and save the values, are also user-defined. A txt file is created daily so that the recordings can be easily viewed and manipulated by other software.

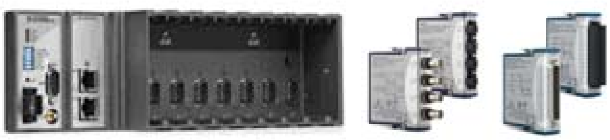

Fig. 5. cRIO-9074, NI 9229 and NI 92005 modules

5. Overall scheme and future expansion

Currently a total of 16 insulators are monitored. A cRIO-9074 equipped with 4 NI 9229 modules is used to monitor extracted values and the DATAQ DI-722-32 is employed to record the full leakage current waveform. The set-up of the DAQs during a test run-up and the latest set-up are shown in Fig. 6. In the future, added cRIO-9074 equipped with 9205 modules will be added to monitor more insulators, as shown in Fig. 7

Fig. 6. The DAQs installation during a test run-up and a picture from the latest set up

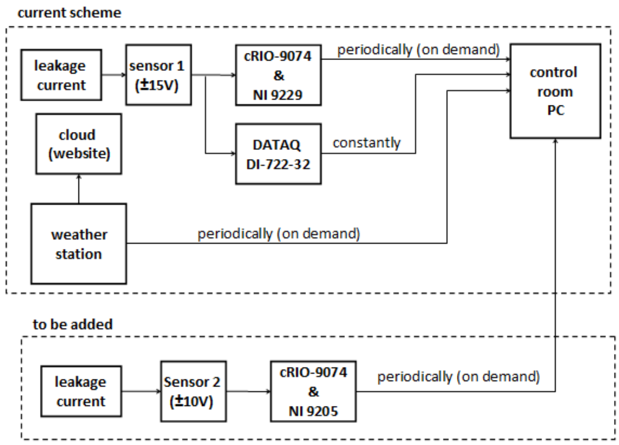

Fig. 7. The leakage current monitor scheme in TALOS

6. Conclusion

Proper insulation selection, design and maintenance is a matter of significant importance to power utilities as insulators are scattered throughout the network and a single insulator fault can lead to an excessive outage. Further, the behavior of such insulators is strongly linked to local operating conditions that can not be simulated in the lab. Therefore, open air high voltage test stations are constructed where insulators are subjected to the actual conditions met in the network (or, if possible, in a worst case scenario regarding the network). The Greek power utility has issued the construction of such a testing station named TALOS High Voltage Test Station in Iraklion, Crete. TALOS is currently participating in the research project POLYDIAGNO in cooperation with academic and research institutions. Leakage current monitoring is a well established and widely employed tool to monitor and investigate the behavior of leakage current insulators. However, although it is easy to employ such a tool under lab conditions, several problems arise when applied to long term field monitoring (data managing, storage, filtering etc). Further, weather data should be recorded as the insulators' performance (and leakage current recordings) is strongly linked to the experienced weather. This paper describes a distributed approach to insulator monitoring as followed in TALOS High Voltage Test Station. This approach delivers a low-cost system able to monitor full leakage current waveforms, extracted values per user defined intervals and weather recordings. Different parts are used for each type of monitoring (and even different modules installed in the same parts) in order to avoid a total breakdown of the system in case of a faulty or malfunctioning part. Further, with slight modifications, the system can operate without the need of a constant PC connection (however, data should be downloaded in regular intervals to avoid allowing the onboard memory to full). The system currently monitors the 16 insulators installed in TALOS for the POLYDIAGNO research project. However, it can be expanded to monitor a larger number of insulators. The described system provides a customizable, flexible, low-cost alternative to specially designed equipment.

ACKNOWLEDGMENT

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