

A NEW APPROACH FOR OPEN AIR INSULATOR TEST STATIONS: EXPERIENCE FROM TALOS AND THE POLYDIAGNO PROJECT

Dionisios PYLARINOS

Hellenic Electricity Distribution Network Operator S.A., Greece
dpylarinos@yahoo.com

Kiriakos SIDERAKIS

Assistant Professor, Technological Educational Institute of Crete, Greece
ksiderakis@staff.teicrete.gr

Emmanuel THALASSINAKIS

Assistant Director, Hellenic Electricity Distribution Network Operator S.A., Greece
E.Thalassinakis@deddie.gr

Nikolaos MAVRIKAKIS, Emmanouel KOUDOUMAS,
Emmanouel DRAKAKIS, Emmanouel KYMAKIS
Technological Educational Institute of Crete, Greece

Abstract: Insulator performance is strongly linked to local installation parameter such as the weather, induced stress, location, pollution etc. Therefore, insulator performance under actual service conditions is hard to be predicted based on laboratory tests, even though such tests may provide valuable hints and directions. Therefore, power utilities, especially these that have part of their network suffering from intense pollution problems, construct open air insulator testing stations in order to gain further insight on insulator performance. There, insulators are stressed under conditions that are as close as possible to the actual service conditions. The parameters usually monitored are the leakage current along with weather conditions. The Greek power, HEDNO, has gained significant experience from constructing and operating TALOS, its own open air test station in a heavily polluted location in the island of Crete. Recently, HEDNO and TALOS participated in a research project focused on the monitoring and diagnosis of polymer based outdoor insulators used in high voltage applications. This paper focuses mainly on the innovations implemented in the test station regarding to the monitoring scheme, set-up, hardware and software. These include adopting a variation of the usual leakage current monitoring set-up scheme, following a distributed approach for the DAS and using general purpose DAQs equipped with custom made Labview based software.

Key words: insulator, high voltage, test station, leakage current, weather, monitoring, DAQ, DAS, Labview

1. Introduction

The performance of high voltage insulators is a matter of great concern for power utilities as a single insulator fault may result to a major outage. Insulators' performance is strongly linked to local operating conditions including weather and climate [1-4]. In case

of polymer insulators, additional factors such as the chemical composition, handling and aging have to be considered [5-7]. Several power utilities construct and operate open air testing stations to gain a further insight on the insulators' performance. The significant experience gained from KIPTS (Koeberg Insulator Pollution Test Station) constructed and operated by the North African power utility Eskom, has even led to the publication of a CIGRE guide focused on the establishment of such test stations in 2007 [3].

The Greek power utility (HEDNO) faced severe pollution problems in the Greek island of Crete due to certain local conditions [8-9]. These have been dealt with rather successfully by employing extended RTV SIR coating in substations and by installing composite insulators in transmission lines [8-11]. HEDNO has also constructed and operates TALOS high voltage test station in the premise of Linoperamata power station in Iraklion, Crete [11-14]. TALOS is equipped with three bays for 21kV and 150kV post and suspension insulators. The activities of the test station were largely boosted through the participation in a large research project along with Greek academic and research institutions in 2013-2015. As several new approaches were adopted, mainly in relation to the basic monitoring scheme described in [3], the experience described in this paper should prove rather useful for the establishment and further development of such testing stations.

2. TALOS & POLYDIAGNO research project

POLYDIAGNO is a research project focused on the monitoring and diagnosis of polymer based outdoor insulators used in high voltage applications. The

research scheme includes HEDNO (TALOS), the Technological Educational Institute of Crete, the Foundation for Research and Technology-Hellas and ENTEC Green Economy Consultant. The project is focused on investigating the performance and aging of composite insulators [15-18]. The insulators considered for the project were chosen so as to portray a variety of induced stresses [12, 19-21]. Seven 150kV towers were selected and three insulators were removed from each tower. A photo of the insulators used for lab tests (one of each three) is shown in Figure 1, along with the basic data (tower, years in service, site pollution severity). The actual location of each tower along with the pollution severity of the site and the years in service is shown in Figure 2.

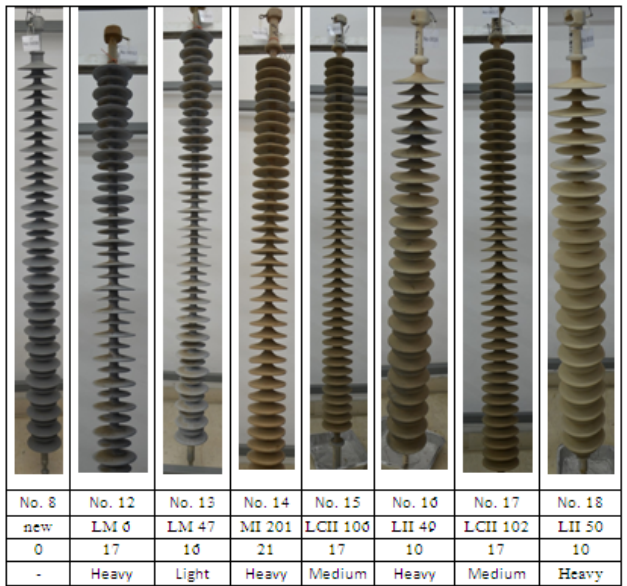


Fig. 1: The insulators removed from the network for POLYDIAGNO (No. 12-18) along with the respective tower, the years in service and the pollution severity of the site. A new insulator was also used for lab tests as control (No. 8)

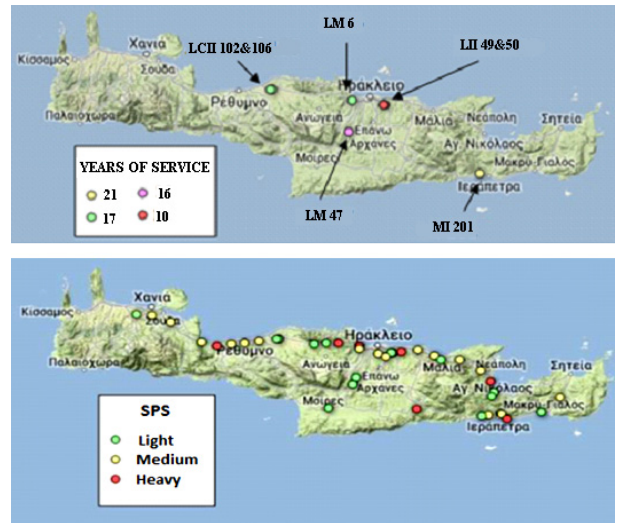


Fig. 2: The location of the selected towers along with the

years in service for the removed insulators and the site's pollution severity (SPS)
The location of TALOS, along with a 3D model and a photo from the POLYDIAGNO insulators installed in TALOS are shown in Figure 3.

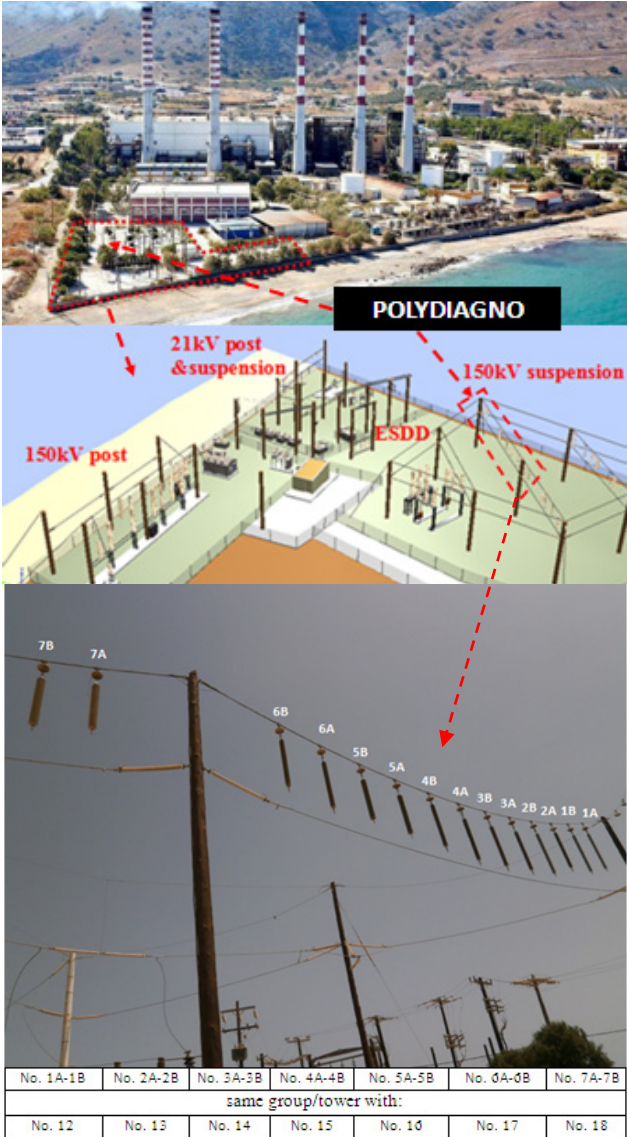


Fig. 3: The location of TALOS along with a 3D model and a photo from the POLYDIAGNO insulators installed in the 150kV suspension bay.

3. LC monitoring set up

The general scheme for leakage current monitoring as described in [3] and followed by various testing stations worldwide (e.g. most recently in [22]), includes the use of a stand-off insulator installed at ground side in order to guide the current through the LC sensor which is connected to a Data Acquisition System (DAS) and an expulsion fuselink connected to the HV side for protection and isolation purposes. This general approach is depicted in Figure 4. The initial approach in TALOS followed this exact scheme as shown in Figure 5.

However, it soon became obvious that such a scheme had a weak link: the mechanical strength (endurance) of the expulsion fuselinks part. Under the frequent strong winds that prevail in the island of Crete, the fuselinks and/or their connector wires tended to shatter and/or cut off as shown in Figure 6.

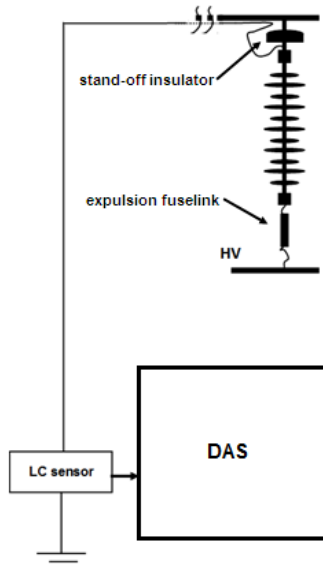


Fig. 4. Typical approach for a LC monitoring scheme at open air high voltage test station as proposed in [3]

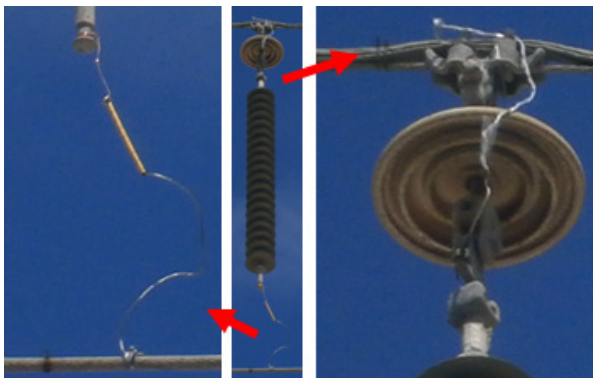


Fig. 5. The initial set-up at TALOS. Zoomed in for the stand-off insulator and the expulsion fuselink.



Fig. 6. A close-up photo from 150kV suspension insulators installed in TALOS following the initial scheme. The connecting wire of the far left fuselink has been cut off and the far right fuselinks has shattered.

This was proved to be a significant issue for the operation of the test station, as such faults could not be repaired online. As a first remedy, a non-conductive high strength net was installed, as shown in Figure 7, in order to not allow insulators to swing freely in all directions and to absorb the mechanical stress. The length of the net was obviously chosen to be shorter than the length of the fuselink/connector part. However, this did not seem to be able to solve the problem: the net was often found intact, however the fuselinks and their connecting wires continued to shatter, as shown in Figure 8.

This was attributed to the fuselink swinging, i.e. even though the net succeeded in stopping the insulator from swinging, the movement of the fuselink was enough to gradually overstress and shatter the connecting wires and/or the fuselinks. The next logical step was to mount the fuselink on the net. However, this also failed to solve the problem as shown in Figure 9.

The final approach was to fully remove the fuselinks. The obvious disadvantage of such an approach is that a flashed over insulator may require shutting off the whole bay or the test station. However, the fault free performance of composite insulators for a long time period in the Cretan network [10, 11] hinted that this should be considered a minor problem in this particular test station (and as long as composite or coated insulators were the ones tested). Photos of the final set up scheme are shown in Figure 10.



Fig. 7. Close ups from 150kV suspension insulators installed in TALOS with a non-conductive high strength net used to absorb the mechanical stress.

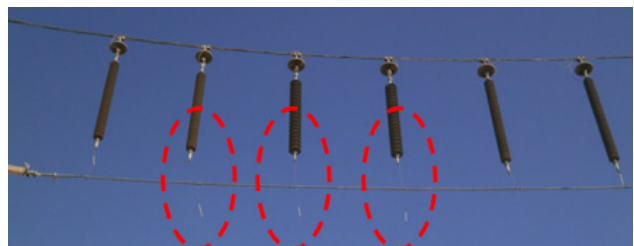


Fig. 8. A photo from Insulators installed in TALOS using a nonconductive net to absorb mechanical stress. The net was often found intact whereas the fuselinks and/or their connective wires were shattered.

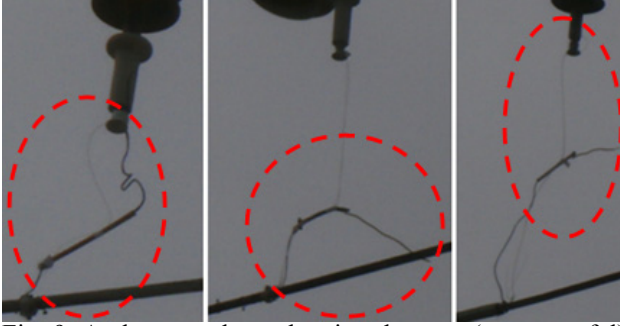


Fig. 9. A close up photo showing the next (unsuccessful) step: fuselinks mounted on the non-conductive net.



Fig. 10. The final set-up scheme followed in TALOS. The expulsive fuselinks have been fully removed.

An added variation from the basic scheme proposed in [3] is that sensors and DAQs were housed in a cabinet so as to be easily accessible and protected from the weather (Figure 11 and Figure 12).

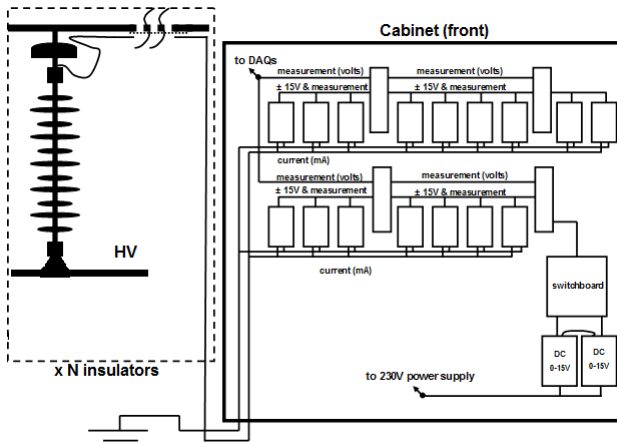


Fig. 11. The leakage current monitoring scheme now followed in TALOS High Voltage Test Station (150kV bay)

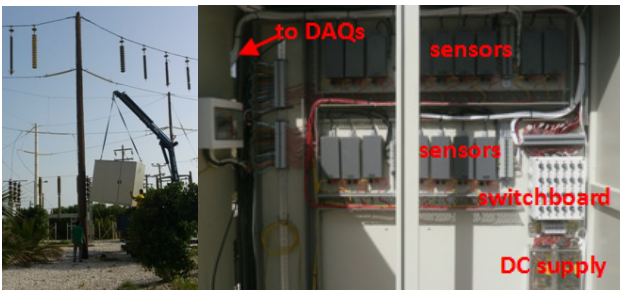


Fig. 12. Photos from the cabinet used top house sensors and DAQs

4. Proposing a new approach for the DAS

The DAS used in the CIGRE guide for the establishment of such testing stations [3] is an all-in-one system that has been widely used since in such applications worldwide (e.g. [22-28]). The Greek utility also purchased and operated such systems for a significant time period [29-32]. The all-in-one approach followed by this DAS has significant advantages (ease of use, compact operation etc) but also significant disadvantages (non configurable, total halt in case of fault, small market that lead to limited support and eventual abandonment by the manufacturer). Therefore, with the participation in POLYDIAGNO, it was decided to install new equipment and implement a distributed approach [33], i.e. the leakage current monitoring equipment should be independent from the weather monitoring system and increased stand-alone capabilities along with customizability should be available for both. General purpose equipment manufactured by major firms was to be selected in order to secure continuing support in the future and upgrade capabilities.

The choice was a National Instruments rugged and reconfigurable chassis (cRIO-9074 [34], Figure 13) equipped with 8 slots, a microprocessor and user-programmable FPGA. Several multiple hot-swappable I/O modules are available for this chassis. However, as leakage current Hall sensors from the previous DAS [3, 22-32] were already available and operational, the modules currently used are of NI 9229 type [35] that have 4 differential channels with an input range of $\pm 60V$ suitable for the $\pm 15V$ output of the sensors (Figure 13).

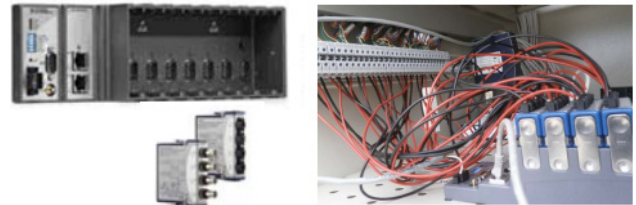


Fig. 13. The cRIO-9074 chassis, the NI 9229 modules and the system installed in the cabinet

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 (and losses). The time-windows used to calculate and save the values (i.e. the buffer size), are also user-defined. A txt file is created daily so that the recordings can be easily viewed and manipulated by other software. Instances of the software are shown in Figures 14-15.

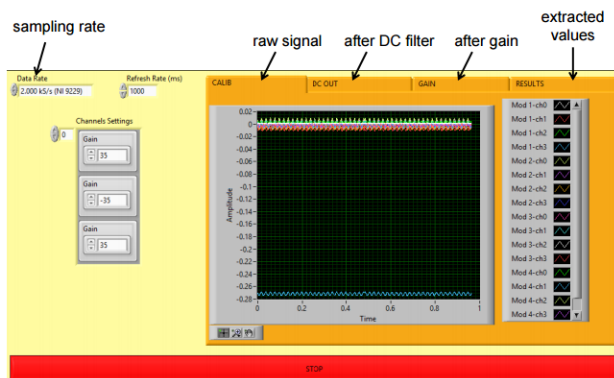


Fig. 14. The front-end of the software. The user can define the sampling and refresh rate (i.e. the buffer used) and see the raw signal, the filtered signal (without the DC offset, the signal acquired after the gain factor and the final results. Note the DC offset in one channel.

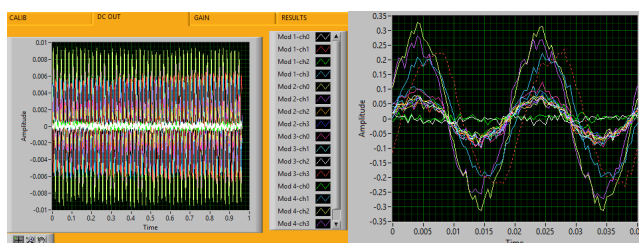


Fig. 15. The filtered signal (DC OUT tab) and a zoom-in on the waveforms after the gain application (GAIN tab)

A dedicated DAVIS VantagePro2 weather station [35] was installed for weather monitoring. This 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. An online report is publicly available at [14] and an instance in shown in Figure 16.

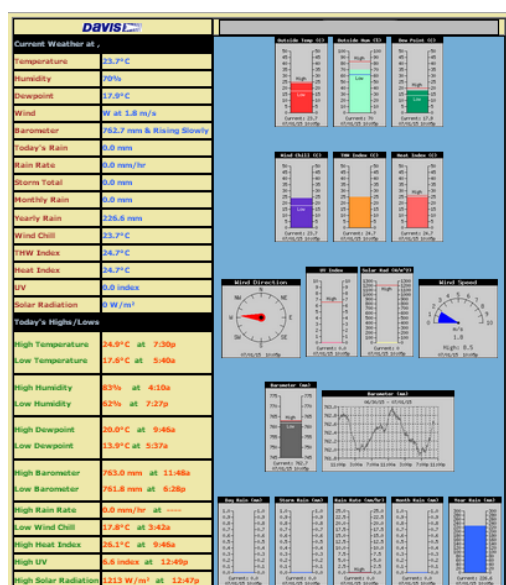


Fig. 16. A screenshot from the online report publicly available from TALOS [14]

5. Conclusion

Research on the performance of high voltage insulators is a rather interesting issue for both the industry and academia. Several power utilities, especially the ones facing severe pollution problems in parts of their network, have constructed and operate open air testing station in an attempt to gain further insight on insulators' performance. TALOS, the test station of the Greek utility, was able to significantly upgrade its operation through its participation in POLYDIAGNO, a research program focused on composite insulator diagnosis. The latest experience acquired is described in this paper. This includes adopting a variation of the basic set-up scheme for leakage current monitoring and a new approach for the Digital Acquisition System used for leakage current and weather monitoring that should prove useful to similar establishments worldwide.

6. Acknowledgment

This work was supported by the POLYDIAGNO research project (project code 11SYN-7-1503), implemented through the Operational Program "Competitiveness and Entrepreneurship", Action "Cooperation 2011" co-financed by the European Union (European Regional Development Fund) and Greek national funds (National Strategic Reference Framework 2007 - 2013).

References

1. IEC/TS 60815: *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions*, International Electrotechnical Commission, 2008
2. CIGRE WG C4.303: *Outdoor insulation in polluted conditions: Guidelines for selection and dimensioning*, CIGRE, 2008
3. CIGRE WG B2.03: *Guide for the establishment of naturally insulator testing stations*, CIGRE, 2007
4. CIGRE TF 33.04.07: *Natural and artificial ageing and pollution testing of polymeric insulators*, CIGRE Technical Brochure, No. 142, 1999
5. Hackam, R.: *Outdoor HV composite polymeric insulators*, In: IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 6, No. 5, pp. 557-585, 1999
6. Papailiou, K. O., Schmuck, F.: *Silicone Composite Insulators: Materials, Design, Applications*, Springer, 2013.
7. Vosloo, W. L., Macey, R. E., de Turreil, C.: *The practical guide to Outdoor High Voltage Insulators*, ESKOM, 2006.
8. Stefanakis, J., Thalassinakis, E., Siderakis, K., Agoris, D., Dialynas, E.: *Fighting pollution in the Cretan transmission system. 25 years experience*, In: Proceedings of Contamination Issues on High Voltage Installations, Iraklion, Greece, 2001
9. Siderakis, K., Pylarinos, D., Thalassinakis, E., Pyrgioti, E., Vitellas, I.: *Pollution maintenance techniques in coastal high voltage installations*, In: Engineering, Technology & Applied Science Research, Vol. 1, No. 1, pp. 1-7, 2011
10. Pylarinos, D., Siderakis, K., Koudoumas, E., Thalassinakis, E.: *Polymer Insulators and Coatings in the Cretan Power System. The Transmission Line Case*, In: Proceedings of the 9th Mediterranean Conference on Power

- Generation, Transmission Distribution and Energy Conversion, Athens, Greece, 2-5 November, 2014
11. Pylarinos, D., Siderakis, K., Thalassinakis, E.: *Comparative Investigation of Silicone Rubber Composite and RTV Coated Glass Insulators Installed in Coastal Overhead Transmission Lines*, In: IEEE Electrical Insulation Magazine, Vol. 31, No. 2, 2015
 12. Pylarinos, D., Siderakis, K., Thalassinakis, E.: *R&D in TALOS High Voltage Test Station-Assessing aging and performance of polymer insulators*, In: Proceedings of the 13th International Conference on Circuits, Systems, Electronics, Control & Signal Processing (CSECS '14), Lisbon, Portugal, October 30-November 1, 2014
 13. Dimitropoulou, M., Pylarinos, D., Siderakis, K., Thalassinakis, E., Danikas, M.: *Comparative Investigation of Pollution Accumulation and Natural Cleaning for Different HV Insulators*, In: Engineering, Technology & Applied Science Research, Vol. 5, No. 2, pp. 764-774, 2015
 14. TALOS High Voltage Test Station, www.talos-ts.com
 15. Mavrikakis, N., Siderakis, K., Pylarinos, D., Koudoumas, E.: *Assessment of Field Aged Composite Insulators Condition in Crete*, In: Proceedings of the 9th International Conference on Deregulated Electricity Market Issues in South Eastern Europe, Nicosia, Cyprus, 25-26 September, 2014
 16. Kokkinaki, O., Klini, A., Mavrikakis, N., Pylarinos, D., Siderakis, K., Koudoumas, E., Thalassinakis, E., Kalpouzios, C., Anglos, D.: *Assessing the type and operational quality of SIR HV insulators by remote LIBS analysis*, In: Proceedings of the 8th Euro-Mediterranean Symposium on Laser Induced Breakdown Spectroscopy, Johannes Kepler University Linz, Austria, September 14-18, 2015
 17. Znaidi, R.: *Expanded Test Station Helps Greek Power System Operator Assess Insulator Design & Performance*, In: INMR, Issue 107, Q1, pp. 54-67, 2015
 18. Znaidi, R.: *Co-operation with Local Academia Delivers Benefits for Greek Power Utility*, In: INMR, Issue 107, Q1, pp. 96-99, 2015
 19. Pylarinos, D., Siderakis, K., Thalassinakis, E.: *ESDD Measurements in the power system of Crete*, In: Journal of Electrical Engineering, Vol. 14, No. 4, pp. 172-177, 2014
 20. Pylarinos, D., Siderakis, K., Pellas, I., Thalassinakis, E.: *Assessing Pollution of Outdoor Insulators in the Cretan Power System*, In: Proceedings of the 18th International Conference on Circuits, Systems, Communications and Computers (CSCC 2014), Santorini, Greece, July 17-21, 2014.
 21. Dimitropoulou, M., Pylarinos, D., Siderakis, K., Thalassinakis, E., Danikas, M.: *Insulation coordination and pollution measurements in the island of Crete*, In: Proceedings of the International Conference on the Properties and Applications of Dielectric Materials (ICPADM), 19-22 July, 2015 Sydney, Australia
 22. Znaidi, R.: *Algerian HV Grid Operator Combats Harsh Pollution Environment*, In: INMR, May, 2015, available at: <http://www.inmr.com/algerian-hv-grid-operator-combats-harsh-pollution-part-2-2/>
 23. Chrzan, K. L., Vosloo, W. L., Holtzhausen, J. P.: *Leakage Current on Porcelain and Silicone Insulators Under Sea or Light Industrial Pollution*, In: IEEE Transactions on Power Delivery, Vol. 26, No. 3, pp. 2051-2052, 2011
 24. Bologna, F. F., Britten, A. C., Watridge, G., Stevens, D. J., Grigorakis, G.: *Leakage currents on lightly polluted 275 kV glass disc insulator strings in conditions of light wetting*, In: Proceedings of the IEEE Africon Conference, Vol. 2, pp. 739 – 742, South Africa, 1999
 25. Vosloo, W. L., Gutman, I., Hartings, R.: *Long-term service testing of insulators at a test tower in South Africa*, In: Proceedings of the CIGRE Regional Conference, Somerset West, 2001
 26. Vosloo, W. L., Engelbrecht, F., Heger, N., Holtzhausen, J. P.: *Implementation of 220 kV In-Service Insulator Performance Test Tower in Namibia*, In: Proceedings of the 2007 Africon Conference, pp. 1-6, 2007
 27. Natan, E., Munteanu, R., Rabinovici, R.: *Prediction of Insulator Flashover Based on Leakage Current and Humidity Measurements*, In: Proceedings of the IEEE 24th Convention of Electrical and Electronics Engineers in Israel, pp. 260-264, 2006
 28. Kazemi, A., Hassanzadeh, M. T., Gholami, A.: *Artificial Neural Network for Insulator Leakage Currents Prediction from Environmental Data*, In: Proceedings of the 2nd IEEE International Conference on Power and Energy (PECon 08), Malaysia, pp. 13-17, 2008
 29. Pylarinos, D., Theofilatos, K., Siderakis, K., Thalassinakis, E., Vitellas, I., Alexandridis, A. T., Pyrgioti, E.: *Investigation and classification of field leakage current waveforms*, In: IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 19, No. 6, pp. 2111-2118, 2012
 30. Pylarinos, D., Siderakis, K., Thalassinakis, E., Pyrgioti, E., Vitellas, I., David, S. L.: *Online applicable techniques to evaluate field leakage current waveforms*, In: Electric Power Systems Research, Vol. 84, No. 1, pp. 65-71, 2012
 31. Pylarinos, D., Siderakis, K., Pyrgioti, E., Thalassinakis, E., Vitellas, I.: *Impact of noise related waveforms on long term field leakage current measurements*, In: IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 18, No. 1, pp. 122-129, 2011
 32. Pylarinos, D., Siderakis, K., Thalassinakis, E., Pyrgioti, E., Vitellas, I.: *Investigation of leakage current waveforms recorded in a coastal high voltage substation*, In: Engineering, Technology & Applied Science Research, Vol. 1, No. 3, pp. 63-69, 2011
 32. Pylarinos, D., Siderakis, K., Thalassinakis, E., Vitellas, I., Pyrgioti, E.: *Recording and managing field leakage current waveforms in Crete. Installation, measurement, software development and signal processing*, In: Proceedings of the ISAP 16th International Conference on Intelligent System Applications to Power Systems, Hersonissos, Crete, Greece, September 25-28, 2011
 33. Pylarinos, D., Mavrikakis, N., Siderakis, K., Thalassinakis, E.: *R&D in TALOS High Voltage Test Station: A Distributed Approach on Insulator Monitoring Systems*, In: Proceedings of the 3rd Panhellenic Conference on Electronics and Telecommunications, Ioannina, Greece, May 8-9, 2015
 34. National Instruments, cRIO9074, <http://sine.ni.com/nips/cds/view/p/lang/en/nid/203964>
 35. National Instruments, NI 9229, <http://sine.ni.com/nips/cds/view/p/lang/en/nid/208796>
 36. Davis Vantage Pro 2 plus, cabled version, http://www.davisnet.com/weather/products/weather_product.asp?pnun=06162