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Thermograpic Inspection in a Modern Distribution Network: Case Study of Fokida

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Abstract

Infrared thermography is a powerful tool for predictive and preventive maintenance of electrical failures. Using as case study the area of Fokida in this work we present the application of the thermal camera tool in the Greek distribution network. The article analyzes the general principles of conducting measurements and chosen results with the use of a modern thermographic system as thermal images. Weak and critical points and their analysis from the aspect of the electrical power supply quality in selected equipment of a distribution power system are also demonstrated. Owing to thermographic examination it is possible to assessment potential problems before they become dangerous, prevent expensive equipment failures and breakdowns and finally enhance the reliability of the network. SAIDI and SAIFI indices reveal the progress in the field of the reliability of the medium and low voltage network in the prefecture of Fokida, with values improved by more than 62%.

Keywords: thermography; distribution network; monitoring; faults.

1. Introduction

Electrical installations need careful attention because play a vital role in our daily life for the modern human. Today life without electricity is just impossible. If we are disconnect from the electricity grid for an extended time this could cost more than money. With hospitals and other critical locations depending on electricity an extended power failure might cost lives. For these reasons distribution operators like HEDNO in Greece uses thermal imaging cameras to perform preventive inspections of electrical networks [1-4].

Thermal cameras capture the infrared emission in order to visualize the temperature variations on the examined component surface. In electrical networks the temperature is considered an outstanding indicator of the condition of operating network because the majority of electrical faults are illustrated as overheating of the components and characterized finally by the emission of infrared radiations. The infrared radiation is proportional of the surface temperature of the checked object. Overheated parts in the electricity grid usually are not visible with the human eye and could be a forerunner to serious matters [5-6].

Thermography is a nondestructive, noninvasive, high speed test method operates without damaging or destroying the inspected objects and will not require power shut down. Loose or dirty electrical connections, deteriorated insulation, unbalanced loads, defective equipment and other electrical anomalies can be identified before they become critical preventing the electrical networks from posing hazardous threats to facilities and persons. For these reasons infrared thermography is a useful electrical monitoring preventive maintenance procedure [7].

The primary goal of this work is to depict the electrical equipment which inspected by the Greek distribution network operator and present how thermography combine with other enhancements in the network improves the service quality of a power system in Greece. A case study for the Fokida area is presented using the FLIR T 640 thermographic system.

2. Method and data

Reliability of an electric power system is the ability to insure adequate electricity delivery and can be measured in several different ways. In order to help the electrical distribution companies to quantify and report the reliability of its network the Institute of Electrical and Electronics Engineers (IEEE) has developed and standardized 13 metrics which are generally accepted as reliability indices.

The most common measurement indices which distribution operator's measure are those defined by the System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI). SAIFI gives the information about the average frequency of sustained interruptions per customer over a predefined area. SAIDI provides the information about the total duration in minutes on average that a customer is without supply in a certain period, normally a year. Mathematical expression of SAIFI and SAIDI are

$$SAIFI = \frac{Total\ number\ of\ customer\ interruptions}{Total\ number\ of\ customers\ served} = \frac{\sum N_i}{\sum N_T} \quad (1)$$

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$$SAIDI = \frac{Total\ duration\ of\ customer\ interruptions}{Total\ number\ of\ customers\ served} = \frac{\sum r_i N_i}{\sum N_T} \quad (2)$$

where r_i is the restoration time in minutes, N_i is the total number of customers interrupted and N_T is the total number of customers served [8].

Distribution companies use thermographic cameras with intention to survey the electric distribution system for finding hotspots on a huge number of components such as non tension sleeves, transformers, transformer bushings, capacitor buss connections, relays and breakers, generators, circuit breakers, power switches, fuse clips, switches, moving and rotating equipment, all control connections, insulators, panel boards, lightning arrestors, crossarms, etc.. For this purpose is necessary a fast and reliable evaluation of the inspected object.

Experienced thermographers in electricity companies know well both the critical components and the common problems of the networks, but except from the experience use also and international standards. HEDNO the Greek distribution network operator commonly use the inter-National Electrical Testing Association (NETA's) standards Delta T (temperature difference) criteria in order to indicate the maintenance priority of the suspected electrical equipments. The Delta-T criteria is based on the temperature different between the ambient temperature and the observed equipment temperature or between the temperature different of a similar object operating under the same condition as the target object. The temperature difference between the target and the reference are usually divided into four categories as given in table 1 [9].

Table 1. NETA Maintenance Testing Specifications for electrical equipment.

Priority	Temperature difference (ΔT) based on comparisons between similar components under similar loading	Temperature difference (ΔT) based upon comparisons between component and ambient air temperatures	Recommended action
4	1ºC −3ºC	1ºC −10ºC	Possible deficiency, monitor and repair when possible
3	4ºC −15ºC	11ºC − 20ºC	Probable deficiency, investigate further and repair when possible
2	-------------------	21ºC − 40ºC	Deficiency repair at next opportunity
1	> 15ºC	> 40ºC	Major deficiency, repair immediately

3. Case study Fokida

The prefecture of Fokida or Phocis lies in the centre of Central Greece and in 2011 its population was 40,343. It is an almost entirely mountainous area, in the largest of the few valleys of Fokida, stands the town of Amphissa, the capital of the prefecture. Although Amphissa is situated near mountains many other small but important towns have sprung out by the coast of Fokida. Galaxidi is a small town with a great cultural and historical importance while Itea is the most important port in the area. Without doubt the attraction of the area is the ancient town of Delphi, the centre of the world according to the ancients Greeks. Delphi is the second most popular ancient site in Greece with hundreds of visitors, from all over the world, coming daily on day trips from the Greek capital due to both its stunning setting and its inspiring ruins. Fokida is one of Greece's least populous regional units, however, in the summer months; the population nearly doubles owing to the influx of tourists (fig. 1).

The whole prefecture is powered by one High Voltage / Medium Voltage (HV/MV) substation with two transformers each of which has rating 25 MVA. The transformers operate permanently in parallel with total installed renewable energy sources capacity 11.55 MW. The substation has 8 MV 20kV distribution lines; the main specifications of the presented substation are listed in Table 2. The whole area is powered by 823 Medium Voltage / Low Voltage (MV/LV) substations, has more than 31,000 consumers, 856 km length of medium voltage lines while the total length of low voltage network lines reaches 623 km. The statistics of the distribution network of the area are show in Table 3.

Fig 1. Fokida map.

Table 2. Lines and load in area of Fokida.

Line	Maximum load (season)	Normal load
210	160 A (winter)	110 A
220	220 A (winter)	140 A
230	200 A (summer)	150 A
240	160 A (summer)	80 A
250	120 A (summer)	60 A
260	blank	
380	190 A (summer)	160 A
390	10 A	5 A

Table 3. Key figures of the electricity network in Fokida.

- 856 km of Medium Voltage Network (MV)
- 623 km of Low Voltage Network (LV)
- 823 (772 in air and 51 underground) Substations of MV/LV with 138,140 MVA
- 31,323 Customers (38 MV & 31,285 LV)
- 118,611 MWH Customers' consumptions (14,970 in MV & 103,641 in LV)

4. Results and discussion

HV/MV substations are the points in the power system where power can be pooled from generating sources, transformed, distributed, and delivered to the consumers. With intention to increase the reliability of the power supply system the HV/MV substations are interconnected with each other providing alternate paths for flow of power, creating a meshed network. Hence, the HV/MV substation is a very critical component in the power system, and the reliability of the power system depends upon the substation. For these reasons the HV/MV substation is the heart of the electric network in Fokida and their equipment inspected in detail at least two times a year [10].

Fig. 2 shows a thermal image of a HV/MV transformer during the June midday heat when the transformer works nearly with the maximum load. With the thermograph we can find faults which are invisible with the SCADA system or with the human eyes such as loose, dirty or high resistance connections, problems in the bushings, improper oil levels and the cooling pattern of the transformer oil. There are numerous potential root causes for abnormal cooling pattern, such as low oil level, a closed valve or flow obstruction.

Disconnectors are basically mechanical switching devices; their main goal is to protect the staff working in the substations, providing an isolating distance and a visual separation gap in the open position. Fig. 3 shows a picture of the three single phase busbar disconnectors while the fig. 4 presents a three single phase feeder disconnectors in this case usually examine the hinged joint of the knife in the disconnectors.

Busbars or buses are the backbone of the substation. Busbars are metallic tubes which used in order to carry large current and distribute it to multiple circuits within switchgear or equipment. With a thermal camera search mainly for strange objects or animals, usually snakes or ferrets (fig. 5). Load breaker switches, tele controlled load breaker switch and switch disconnectors inspected principally for poor or dirty connections (fig. 6).

A sectionalizer is a self-contained, circuit-opening device that automatically isolates a faulted section of line from the rest of the distribution system. Both for single and three phase sectionalizers the most common problem is located on the connection between the top side of the bushing and end cap or in internal connections on the top side and the bottom side of the bushings (fig. 7).

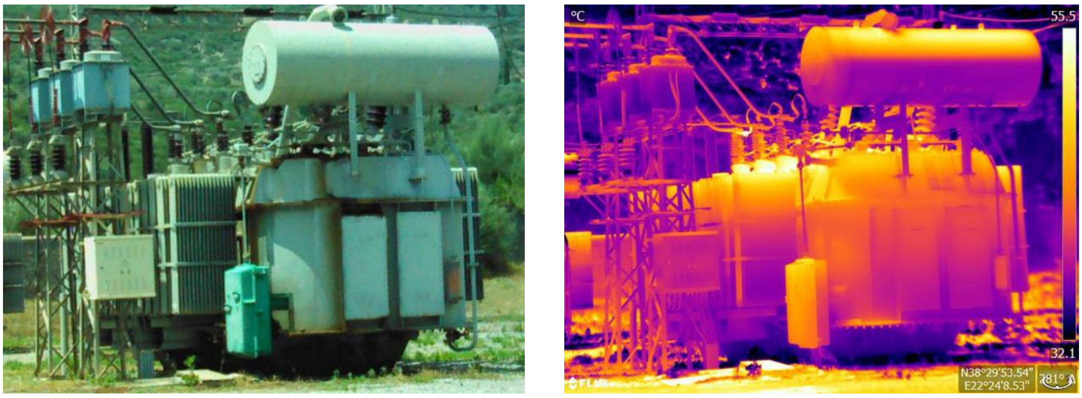

Fig 2. The visual photo and (left) the thermal photo of a HV/MV transformer (right).

Fig 3. The visual photo (left) and the thermal photo of a three single phase busbar disconnectors (right)

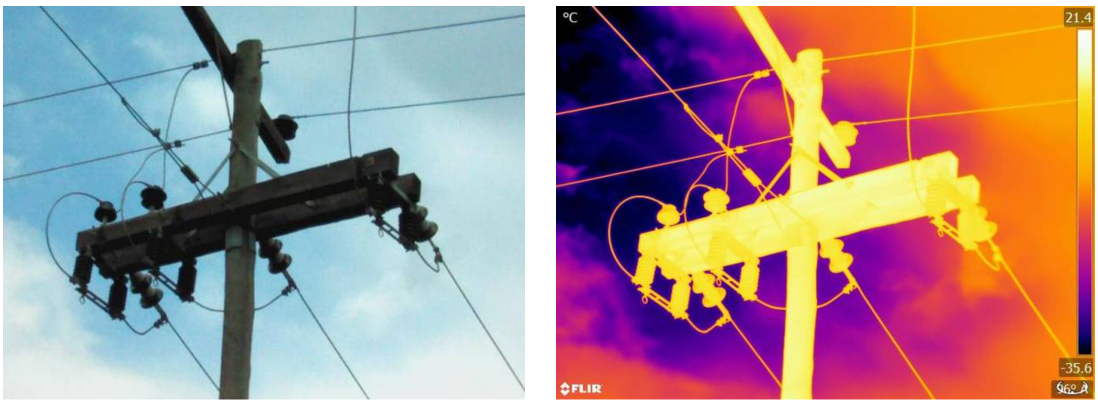

Fig 4. The optical photo (left) and the thermal photo of a three single phase feeder disconnectors (right).

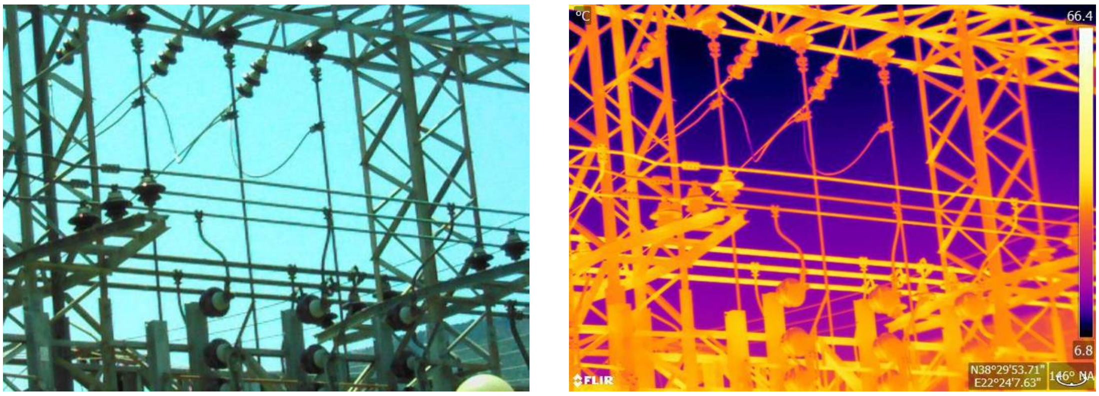

Fig 5. The visual photo (left) and the thermal photo of a part of busbars in the Fokidas' HV/MV substation (right).

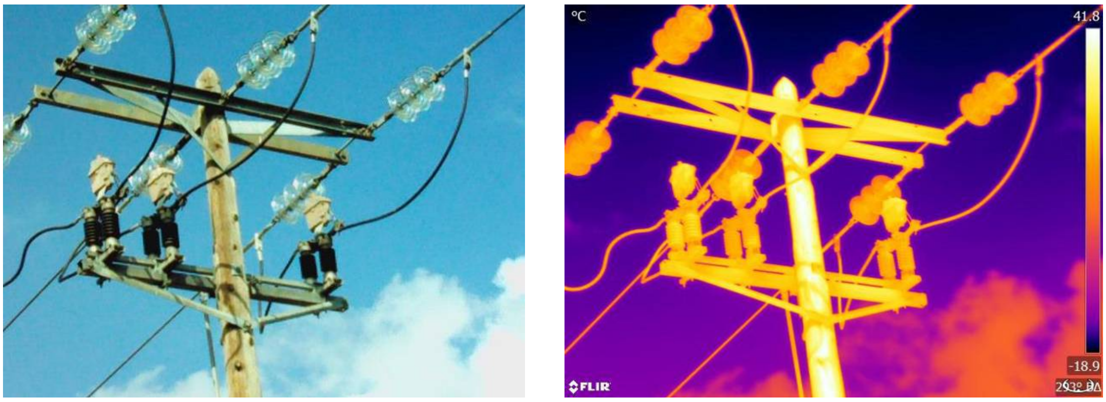

Fig 6. The optical photo (left) and the thermal photo of three Load breaker switches (right).

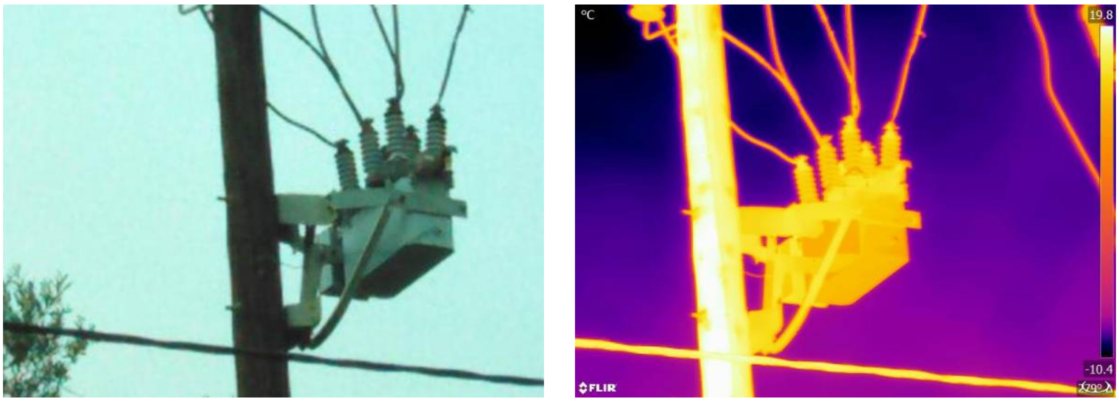

Fig 7. The visual photo of a sectionalizer (left) the thermal photo of the same part (right).

Surge arresters are devices which protect electrical equipment from over-voltage or surges caused by external (lightning) or internal (switching) events. Surge arresters can frequently be installed at the end of an overhead line or a cable. Fig. 8 shows the thermal and the visual image of three surge arresters above in a MV/LV substation. Similar to a HV/MV power transformer in the case of MV/LV power transformer thermographer of the HEDNO inspect all the critical points of the transformer namely surge arresters, cooling system, tap changer tank and bushings.

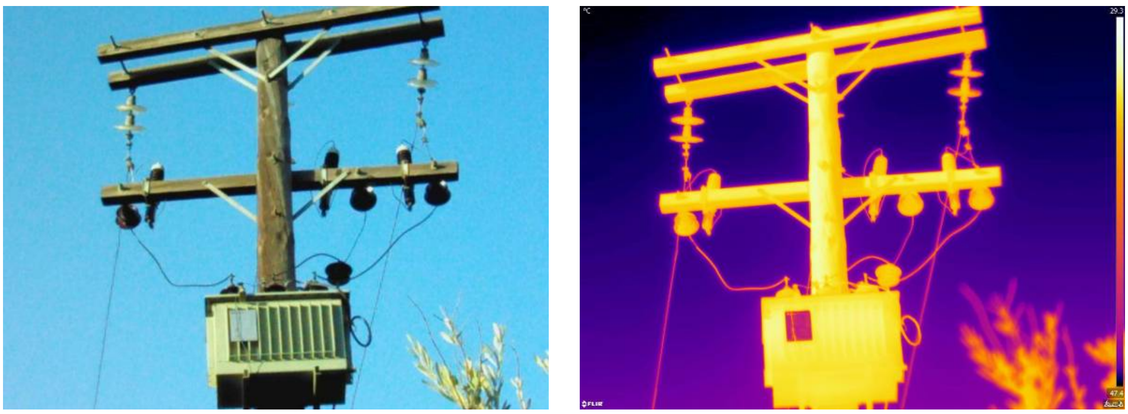

Fig 8. The visual photo of 3 surge arresters in a MV/LV substation (left) and the correspondingly thermal photo (right).

Bushings are critical components in all electrical networks. Generally speaking if any bushing has high temperature when compared to a similar unit under similar loading, there are usually two possible faults, a loose connection or problem in the seal of the bushing. The second failure has as results oil from the conservator to push the transformer oil up the bushing. A further reason a bushing can display high oil level is the top seal leaking, allowing water to enter and moved towards the bottom shifting the oil upward. However the most revealed problem in the inspection of a distribution network is a poor or dirty connection. Fig. 9 shows a poor connection in the second phase of a load breaker switch with priority 1 according to NETA Maintenance Testing Specifications.

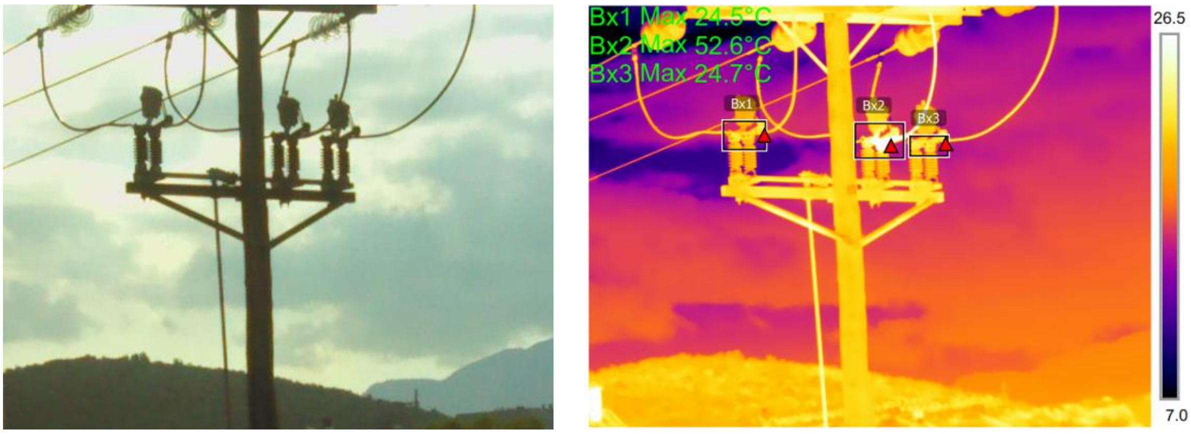

Fig 9. A visual image of a load breaker switch (left) and the thermal photo which reveals a poor connection in the second phase (right).

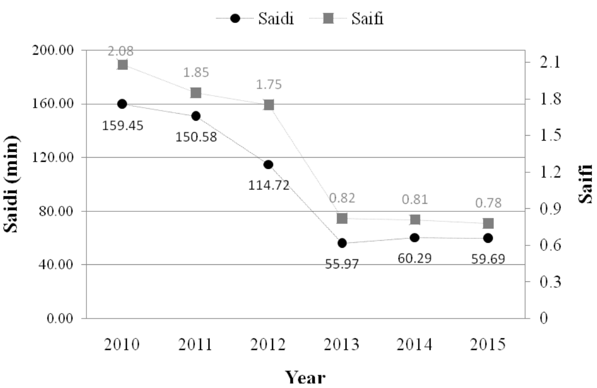

Fig 10. SAIDI and SAIFI indices during 2010 - 2015 in Fokida area.

However, the critical question is how the SCADA system, the tele controlled switches and the thermographical inspections meliorate the reliability of a distribution network. In the case of Amfissa the fig. 10 shows that two most common indices SAIDI and SAIFI improved by 62.6% and 62.5% respectively (during 2010 - 2015).

5. Conclusions

Infrared thermography has used for many years as a condition monitoring tool in the field of electrical system. The Greek distribution operator has established the use of a portable thermographic system and now uses modern thermal cameras to maintain the electrical network. The article presents the equipment which inspected usually and the critical points in the grid in order to increase reliability and decrease electric losses, or downtime. The case study of Fokida is used as example with intention to explicate all the weak points of the electrical equipment and gives the answer of how the modern networks using monitoring systems such as a thermal camera provide more reliability to the consumers.

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