Examination and Estimation of the Losses due to Molten Connections in Electricity Distribution Networks Using Thermography Method

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Abstract: **One of the most significant aims of electricity distribution companies is supplying electric energy to the consumers, having the highest quality and having the least power outage time. However, the mentioned companies are always faced with some problems while utilizing distribution networks. Weakening of the applied connections in these networks which is due to incorrect installation or passage of short connection currents and even unfavorable atmospheric conditions are among the flaws which will make problems in power supply trend for the consumers. This problem can be identified from the beginning using thermography or thermo-vision tests. Thermography test is done via thermal-sensitive cameras, known as infrared cameras. It can be applied to the lines, with no power outage. In this test, the connections having abnormal thermal increase are detected easily and can be solved in proper time. The molten spots which are not detected or are detected lately due to the large span of distribution networks can engender some losses by the consumption of part of the electric power in thermal mode. In this paper, first we will examine the method to detect molten connection by means of infrared cameras. Then, the engendered losses in electricity distribution network of Masjed-soleiman city (southwest of Iran) will be estimated. Finally, some alternatives are recommended to decrease such problems.**

Keywords: Electricity Distribution Companies, Weakening of Connections, Thermography, Losses, Masjed-soleiman City (Southwest of Iran)

I. INTRODUCTION

In the middle of 19th century, William Hershel could bring about the first thermogram (thermal picture). However, this phenomenon did not advance for a while. It was until 1880 and later in 1892 when significant advances were made regarding the measurement of thermal degree using camerawork. The usage of thermographic knowledge during the first and second world wars was restricted to military and weaponry applications. Finally, in 1960 and after two decades of continuous research and examination, the applied and economical application of thermal camerawork was manifested but taking a thermal picture took more than ten minutes; furthermore, the taken pictures were not accurate enough which led to the difficulty in analyzing the pictures. For the first time, in 1965, a Swedish Company, Power Board, applied thermography or infrared examination method on 150 pieces of the electric equipment of the industries in the country. After a decade, the first thermal camerawork was invented which used liquid Nitrogen to cool its sensors. This system which was made relatively big, weighted about 40 to 50 kilograms [1]. In 1975, thermal camerawork entered a new phase regarding production technology and application technique. By this time, the weight of the camera and all belongings decreased and reached 15 kilograms. In 1976, an England-based Company, EGB, started thermography in power lines. Baltimore Gas & Electric Company also undertook experiments on 40000 miles of distributing networks and 175 electrical stations of Baltimore Electricity Company [2]. In 80 and 90s, application of highly sensitive detectors and sensors and also using computer and saving pictures brought about extraordinary advances in this method. The current cameras are continuation of those advances. In 1991 an article was published in T7D journal in which application of infrared equipment made the possibility of immediate examination without the need to power outage in electrical industry. The method was such effective, by means of which 150 thousand hours of disorders in giving services to the clients of Baltimore Company was avoided.

Nowadays, infrared cameras are used in a more modern way, such that the equipment is produced and used in smaller sizes than the old ones. The application of this useful equipment is not just confined to electric industry and when necessary, it will be used in other fields. As an example, in 2010 an article, entitled Investigation of Temperature Effect on Pulsation Range Using Thermography and Pulsation Analyze was published in the second conference on rotary equipment [3]. In the next year, Vlastimil Moni and Frantisek Helebrant showed the application of infrared cameras in detection of hot spots in protractors and electro-motors [4]. Troubleshooting of Electric Equipment Using Thermal camera was the title of an article, authored by Milan Sebok et al. at Zilina University in Slovakia. The authors of this article mentioned the weaknesses of infrared camerawork and proposed a new method for the detection of molten spots [5]-[6]. In 2013, some studies were made regarding the economical aspect of this plan in electricity distributing networks. As an example, the studies conducted in electricity distributing company of Julfa city (northwest of Iran) indicated that usage of infrared cameras can help avoiding more than 105 thousand dollar damage to the equipment of distribution companies [7]. In this regard, thermo-vision test is one of the effective and well-known methods which has always been used to detect molten spots.

II. THEORY OF THERMAL CAMERAWORK

According to fig. 2 infrared waves compose parts of electromagnetic wave spectrum and their wavelengths are broadened in the two areas of short infrared wave (2 to 5 Microns) and long infrared wave (7 to 14 Microns).

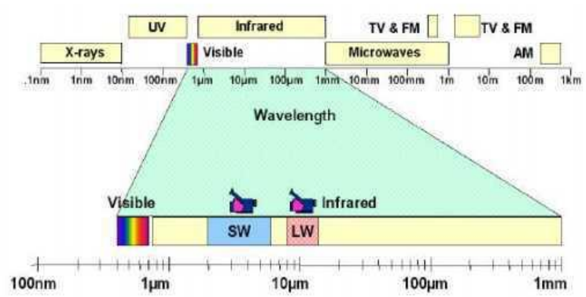

Fig. 1 A view of electromagnetic wave spectrum

On one hand, infrared waves or thermal waves are scintillated from all creatures and things having a temperature above absolute zero (-273.15 centigrade) and all surfaces have a certain amount of infrared area, depending on their temperature. (Of course, such scintillation is invisible to human sight) but based on the forming structure of thermal camerawork, it can receive thermal energy scintillated from things, have it focused on the detector and can transfer it to electric signals. After amplification, these signals are transferred to camera part and after needed examination are sent to the screen and are seen in picture form.

3. THERMAL CAMERAWORK IN ELECTRIC INDUSTRY

The life span of equipment used in electric industry depends on their thermal degree. In case their thermal temperature exceeds the proper level, their life span decreases and results in replacing the defective piece. Table 1 indicates the maximum temperature for the application of electricity network equipment [8]-[9]-[10]-[11].

Table 1 Maximum temperature for the application of electricity network equipment

Name of the Equipment	Maximum Increase Extent from Environment Temperature (C ○)	Maximum Allowed Temperature for the Application (C ○)
Cables used in low electric voltage	30	70
Cables used in high electric voltage	50	90
Line wires	50	90
Copper busbar transmissions together	25	65
Transmission of insulated cables to busbars or keys	25	65
Contacts of power key	85	125
Blades of fuse keys, fuse bases and isolating switch	35	75
Distribution transformers	70	110

Application of infrared cameras for thermal camerawork has nowadays broadened in electric industry, as in other industries. Electricity distribution companies and even regional electric companies use this method to detect molten spots which cannot be seen by naked eye. Because of the weakness of the connections or infrequent conductor level, by the pass of time and as the result of the increase in temperature, the equipment gradually becomes hot and after a short while grow molten and in case of no investigation, will be totally wasted. Thermal examination or thermovision test is one of the anti-destructive methods for detecting these problems. In this method, the application form of which is identified depending on the instructions given by the manufacturing company of the camera, the molten equipment can be detected, day and night, without any power outage and in the problem can be resolved in the proper time. The following list, in detail explains the equipment which are normally molten in electric industry, especially in distribution network.

A. Bushing insulators

Some problems such as the explosion of insulators which leads to leakage of the current or their slight flashovers, brings about a temperature difference of about 1 to 2 degrees which are detectable by adjusting the sensitivity of infrared camera. Fig. 2 shows thermal picture of abnormal increase inside the bushing of a transformer and an insulator.

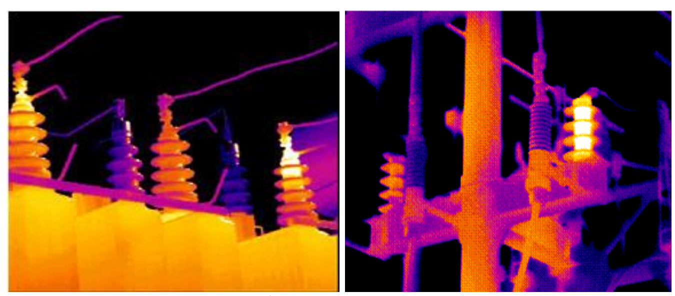

Fig. 2 right Thermal picture of the abnormal increase in insulator temperature
Fig. 2 left Thermal picture of the abnormal increase in transformer bushing.

B. Connections

Weak connections are of the main problems which are frequently seen in electric networks. Based on the experiments, one can claim that normal services on connections are not enough solutions for their troubleshooting and there is a possibility that some problems may raise again. Weak connections may be made during their assembly or installation. Also it should not be neglected that the power due to the passage of high short connection currents are also effective in this regard.

Not using Belleville washers in moving connections (air networks), loosening of the bullets and not using proper clamps may lead to the increase in their temperature degree, due to connection resistance increase in loosening moment. This increase in thermal degree leads to more oxidization in the connection place and consequently thermal increase. Temperature increase continues to the extent that reaches melting point of the composing components of the equipment and leads to total destruction of the equipment. Fig. 3 is indicative of this issue.

Fig. 3 Normal and thermal picture of weak connection in electricity distribution network

C. Conductors and Cables

The increase in thermal degree of conductors and cables is mainly caused by the slightness of their surface and the increase in the consumed load current. Existence of molten in one of the phases of three-phase system can be indicative of the unbalanced load which can be detected using ampere realization of three-phase. High temperature of a cable near which there are no connections may be due to leakage current which can be detected and solved using High Pot tests. Fig. 4 shows a conductor of distribution network which has been molten because of the slightness of the surface and passage of consumed overload.

Fig. 4 Normal and thermal picture of molten in parts of the conductor in distribution lines

D. Transformers

Transformers are regarded as one of the most important and expensive equipment in distribution networks. As this equipment can be applied even in cold seasons, its temperature is remarkable. Transformers use oil and radiator to decrease their temperature and even in their power mode oil pump and strong coolers are used in addition to other methods. The reason behind extreme increase of the transformer temperature can be related to dysfunction of each of the above-mentioned instruments or might be caused because of the weakness of the holder connections of the transformer core. Such increase in temperature not only destroys the applied insulators inside the transformer but also leads to the explosion of the whole equipment. Fig. 5 indicates thermal picture of temperature increase inside distribution transformers.

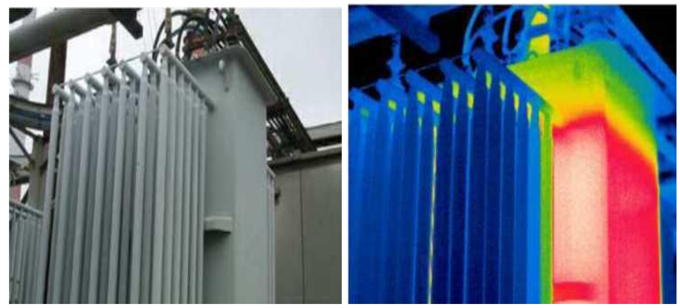

Fig. 5 Thermal picture of the temperature increase inside distribution transformer

E. Sectionners and breakers

Not tuning the sectionners and weakness of the bushing connectors are the most important reasons behind the formation of molten spots on these two equipment. Figure 6 displays the increase in thermal degree on breaker bushing connector and sectionner blades.

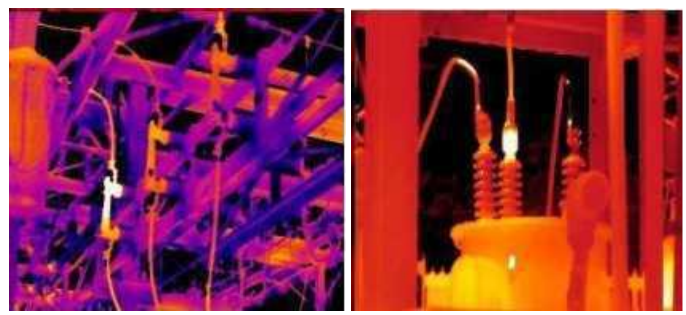

Fig. 6 right Increase in thermal degree on breaker bushing connector
Fig. 6 left Increase in thermal degree on one of the **Sectionners** blades

IV. METHOD OF ESTIMATING LOSSES DUE TO FLUX TRANSMISSION

Flux transmission wastes some losses in thermal mode (joule loss). Therm and heat of the energy are exchanged due to the temperature difference between a system and the surrounding environment. This heat leads to the increase in exhaustion, oxidization and electric resistance in the transmission spot which is wasted in RI^2 Mode.

For more explanation, consider an electric heater which is heating a water vessel, like Fig. 7. As all energy forms are equivalent and are not wasted but may appear in other forms, it can be concluded that the consumed electric bar of the heater can ideally be considered as equivalent to the saved thermal energy in the water vessel.

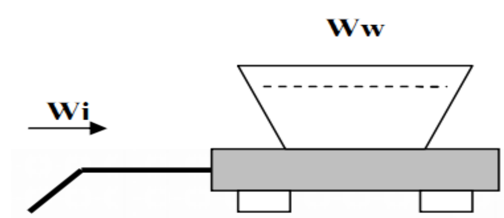

Fig. 7 Saved heat produced from the heater in water vessel

W_i : Consumed electric energy in the heater

W_w : Saved electric energy in water vessel (output heat from the heater to the water vessel)

$$P \times t = W_i$$

$$= 1\ m \times c \times \Delta\theta \quad \rightarrow \quad if \quad \eta = Q = W_w$$

$$W_w = W_i$$

Therefore, it can be concluded that when the water inside the vessel reaches its maximum temperature, each moment consumes a power equal to Q. therefore:

$$m \times c \times \Delta\theta = Q \rightarrow \quad P = P$$

The abovementioned points can be explained so in flux transmissions.

In above relations we will have:

M: Mass of the flux transmission in grams

C: Special thermal capacity in $J/g.c^{\circ}$ (the needed heat to increase mass temperature). For some of the metals used in electric network equipment will be according to table 2. [12].

$\Delta\theta$: Temperature difference between flux transmissions and safe transmissions in centigrade

Table 2 Characteristics of some of the metals used in electricity network equipment

Metal	Melting point (C°)	Special thermal capacity ($J/g.c^{\circ}$)
Aluminum	660	0.9
Copper	1083.4	0.385
Brass	920	0.38
Iron	1535	0.447
Steel	1510	0.502
Cobalt	1495	0.423
Nickel	1453	0.444

For example, in a weak aluminum transmission, the mass of which is 200 grams and had 85 centigrade degree increase more than the similar safe transmission, its wasted power can be calculated according to the following formula, even though the amount of thermal exchange with the environment is not considered.

$$\text{P} = = 15300\ \text{W}\ 200 \times 0/9 \times 85 = m \times c \times \Delta\theta$$

The above lost power has been estimated for a second. In case we want to calculate it for 24 hours, we will have:

$$= 367/2\ \text{KWh}\ \frac{(15300 \times 60 \times 60 \times 24)}{(1000 \times 3600)}\ \text{P} =$$

In case the duration of the detection of fluxed spot until the time when the problem is solved will be multiplied by the calculated energy, the whole energy losses of that piece will be calculated. In case the mentioned problems are solved late, the losses due to flux of that piece will increase.

V. ESTIMATION OF THE LOSSES DUE TO MOLTEN CONNECTIONS IN ELECTRICITY DISTRIBUTION NETWORK OF MASJED-SOLEIMAN CITY

A. Electricity Distribution Network o f Masjed-Soleiman City

Masjed-soleiman city, having a population of about 300 thousand dwellers, is located in 125 kilometers to Ahvaz city, center of Khuzestan province. Due to oil discovery, this province which is located in southwest of Iran has been one of the first cities of Iran enjoying electric industry. The existence of two dams and powerhouses, namely Giodar Masjed-soleiman and Shahid Abbaspoor, each having 3000 megawatt power indicates potential capacities of the area in electric power generation. Unfortunately because of the special geographical situation of this area and existence of several gas and oil wells inside the city, the distribution network is old and complicated. Existing corrosive gases in the atmosphere of the city led to oxidization of the surface of the conductors used in the distribution networks and will be accompanied by slightness of the surface and immediate erosion. Fortunately, attempts of the personnel of Masjed-soleiman Electricity Distribution Company could help collecting worn-out wires and replacing self-supporting cables. This action not only decreases the problems due to the erosions of distribution network, but also significantly decreases maintenance costs.

Masjed-soleiman city has 7 electricity ultra-distribution stations, namely Fajr, Havanirooz, Malkarim, Tembi, Enghelab, Mohamad Abad and Cham Asiab, having the voltage level of 132 to 33 and 11 kilovolt. The stations have consumers with different usages.

As utilization operator was present in just 6 of the stations among the mentioned 7 stations, the data of just 6 stations are available and Cham Asiab station which is the newest ultra-distribution station of Masjed-soleiman is not equipped with registered data related to output feeders.

Information related to the reason behind breaker outage of each feeder is saved both in each station and in the up-to-date system of distribution network of the mentioned city.

Based on the given information, breakers of the electric ultra-distribution stations of the city have automatically gone outage 519 times, annually. Based on fig. 8 which shows the reason of their outage, weakness of the connections which leads to molten have caused outage of the city feeders for 43 times. Based on this figure, this problem ranks fourth in the reasons behind power outage which might be ranked upper in case of more heedlessness.

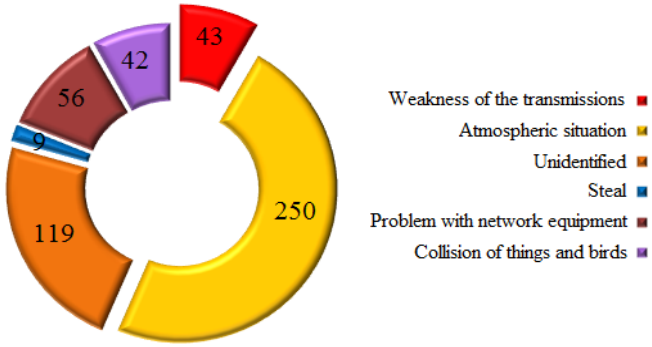

Fig. 8 Examination of outage reason for feeders related to electric ultra-distribution stations of Masjed-soleiman city

In this diagram, atmospheric situation is ranked first and the ranks afterwards are respectively as follows: unidentified, problem with network equipment, weakness of connections, collision of things and birds and thief. Fig. 9 indicates electric ultra-distribution stations of Masjed-soleiman, the breaker feeders of which have gone outage as the result of weakness of the applied molten connections.

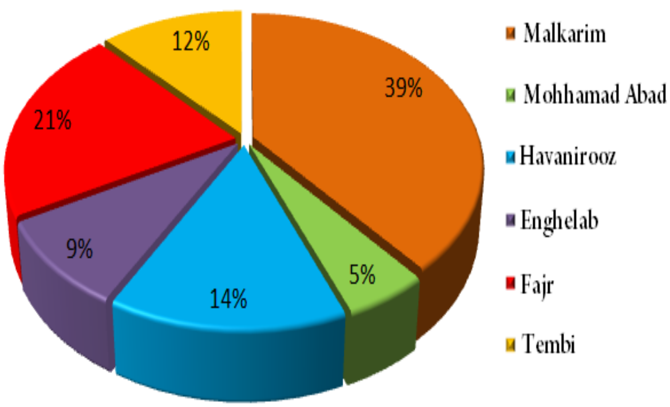

Fig. 9 Outage of feeder breakers related to electric ultra-distribution stations of Masjed-soleiman city as the result of the weakness of molten connections

In the mentioned diagram, Malkarim electric station, having 39 percent feeder outage, has ranked first because of having a broad and complicated distribution network and Mohamad Abad station, having 5 percent feeder outage, had the least loss due to molten connections.

B. Detection and estimation of losses due to weak connections in distribution network of Masjed-soleiman

Weak connections which may cause temperature increase and finally molten connection can be detected and resolved from the beginning through infrared cameras. Troubleshooting of these connections is dependent on their temperature and is prioritized based on table 3. Totally, 3 priorities will be defined. In the third priority the problem of the increase in connection temperature due to its weakness is still in the primary stages and in case it is not resolved, it will reach upper priorities. In the second priority which happens after the third priority, the equipment temperature is more than the previous priority. In this priority, problems with connection increases and the problem shall be resolved soon. But in the first priority, which is the most critical one, connection temperature reaches molten stage and by paying a little attention, it can be seen with naked eyes. In this stage the problematic connection shall be immediately replaced, by imposing outage power.

Table 3 Priority of problematic equipment temperature

Priority	Equipment temperature	Necessity of servicing (percentage)
1	Environment temperature: above 19 centigrade	80 to 100
2	Environment temperature: up to 19 centigrade	50 to 80
3	Environment temperature: up to 9 centigrade	10 to 50

In three days, more than 650 thermal pictures in middle and weak voltage levels were taken of Masjed-soleiman electric network by means of an infrared camera of Hot Find LXS model, by the employees of Masjed-soleiman Electricity Distribution Company, the picture of which is shown in fig. 10.

Fig. 10 infrared camerawork using Hot Find LXS camera model

In the pictures, it was revealed that just 33 spots, the specifications of which are given in table 4, have priority and the rest were in the lower priorities. It shall be reminded that losses due to weak and molten connections in Masjed-soleiman electricity distribution network will be estimated based on these 33 spots.

After estimation of the losses due to molten connection it was indicated that the loss average of each phase will be between minimum 0.53 percent and maximum 15.9 percent. Fig. 11 to 14 are indicative of this issue. Most of the losses have been caused by 6 molten connection related to phase B of line 303 in Tembi electricity station and the least one belongs to phase C of line 503 in Malkarim electricity station, having 1 connection. In the meanwhile, it shall be mentioned that there is a possibility that the losses may be made in just one phase and will not be observed in other phases. In case these losses are made in just one phase, the amount will be equivalent to one-third in all three phases.

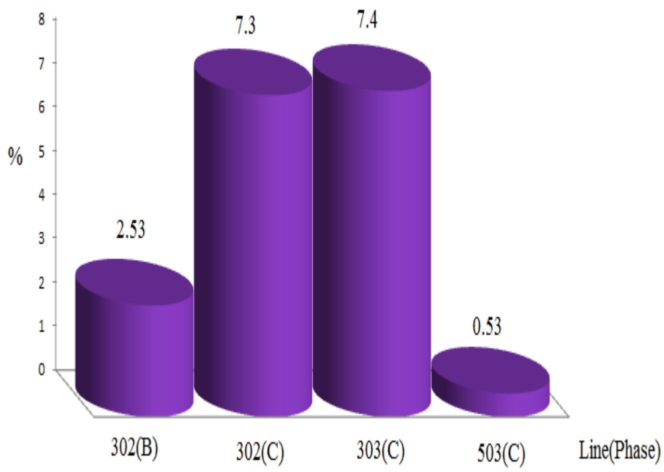

Fig. 11 Average losses due to molten connection in feeders of Malkarim electricity station

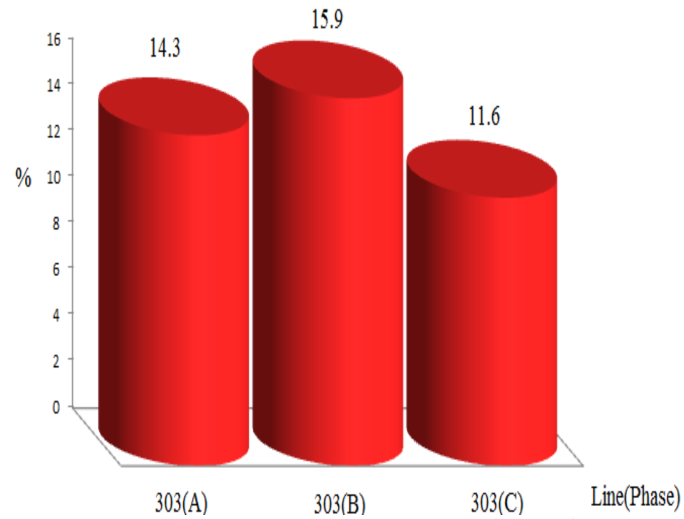

Fig. 13 Average losses due to molten connection in feeders of Tembi electricity station

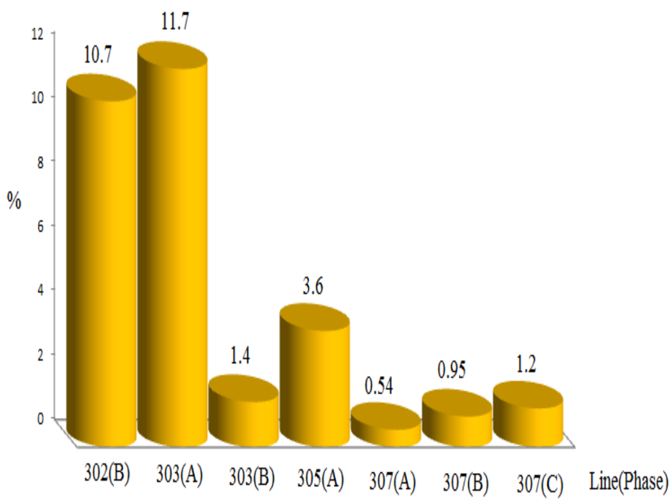

Fig. 12 Average losses due to molten connection in feeders of Havanirooz electricity station

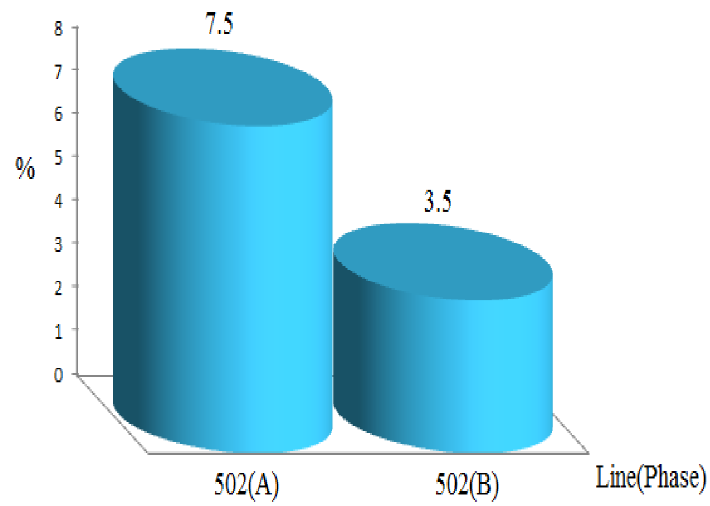

Fig. 14 Average losses due to molten connection in feeders of Fajr electricity station

Table 4 Specifications of 33 detected prior spots in thermal camerawork of electricity distribution network in Masjed-soleiman city

No.	Line No.	Phase	Station	Kind of molten equipment	Equipment temp	Equipment weight	Equipment type	Detection date	Resolve date
1	302	B	Malkarim	Clevis pin	104.3	80	Copper	27/09/2012	16/10/2012
2		C		Bolted joint	450	400	Brass	27/09/2012	
3		C		Terminal	85.8	350	Brass	27/09/2012	
4		B		Terminal	94.9	350	Brass	27/09/2012	
5		B		Terminal	107.7	350	Brass	27/09/2012	
6		B		Clevis pin	93.6	80	Copper	27/09/2012	
7	303	C		Brake shoe	81.4	1500	Aluminum	25/09/2012	16/10/2012
8		C		Terminal	108.6	350	Brass	27/09/2012	
9	503	C		Terminal	84.7	350	Brass	25/09/2012	07/12/2012
1	302	B	Havanirooz	Brake shoe	119	1500	Aluminum	25/09/2012	07/11/2012
2	303	A		Brake shoe	97.3	1500	Aluminum	25/09/2012	15/11/2012
3		A		Middle clamp	113.6	550	Aluminum	26/09/2012	
4		B		Terminal	152.8	350	Brass	26/09/2012	
5	305	B		Middle clamp	120.2	550	Aluminum	26/09/2012	27/10/2012
6	307	A		Fuse connector	90.4	150	Copper	27/09/2012	21/5/2013
7		B		Fuse connector	133.9	150	Copper	27/09/2012	
8		C		Fuse connector	199.7	150	Copper	27/09/2012	
1	303	B	Tembi	Middle clamp	95.4	550	Aluminum	25/09/2012	2/10/2012
2		B		Middle clamp	90.1	550	Aluminum	26/09/2012	
3		B		Middle clamp	99.1	550	Aluminum	26/09/2012	
4		C		U- bolt	90	350	Iron	26/09/2012	
5		A		Middle clamp	198	550	Aluminum	26/09/2012	
6		B		Middle clamp	142.4	550	Aluminum	26/09/2012	
7		B		Middle clamp	124.6	550	Aluminum	26/09/2012	
8		A		Middle clamp	226.2	550	Aluminum	26/09/2012	
9		C		Brake shoe	137.6	1500	Aluminum	26/09/2012	
10		A		Fuse	193.7	150	Copper	27/09/2012	
11		B		Terminal	153.2	350	Brass	27/09/2012	
12		A		Terminal	85.6	350	Brass	27/09/2012	
1	502	A	Fajr	Hot and saddle	167.1	950	Aluminum	26/09/2012	18/10/2012
2		B		Bolted joint	186.1	400	Brass	27/09/2012	
3		B		Terminal	116.9	350	Brass	27/09/2012	
4		B		Terminal	171.3	350	Brass	27/09/2012	

VI. ESTIMATION OF ECONOMIC DAMAGES

All the time losses lead to economic damages to electricity industry companies and losses due to molten connection are not exception. These losses can both damage the equipment and impose long power outages.

Generally, losses due to molten connection can lead to economic damage in three ways:

1. Cost of purchasing safe connections, man power and needed machineries to replace the problematic connections
2. Cost due to the imposition of power outage to feeder to replace the problematic connections
3. The power which the problematic connection loses as heat

A. Cost of purchasing safe connections, man power and machinery

In order to replace a problematic connection, the distribution companies need to pay for purchasing safe connection, employing expertise man power and needed machinery. Table 5 is indicative of the costs due to the replacement of problematic connections which has been referred to in table 4. Also, in this table, the costs related to expertise man power and needed machinery to replace 33 molten connections will be shown.

Table 5 Cost of purchasing safe connections, man power and machinery to replace problematic connections (1$= 2470 IRR)

Type of the problematic transmission	Quantity	Price of each safe transmission ($)	Approximate cost of man-power and machinery ($)	Total cost ($)
Clevis pin	2	1.81	81	84.62
Load connector	2	3.38	81	87.76
Terminal	10	3.81	141.7	179.8
Brake shoe	4	6.47	101.2	127
Middle clamp	9	1.9	141.7	158.8
Fuse connector	4	1.11	81	85.44
U-bolt	1	0.85	32.3	33.15
Hot and saddle	1	14.42	32.3	46.72
			Total cost ($): 803.29	

B. Cost of power outage imposition to feeder for the replacement of problematic connections

In order to replace the problematic connections, the station needs to outage the feeder on which molten connection had happened. From the time the feeder is interrupted till resolving the molten connections and reapplying the feeder, the consumer will gone outage. It is true for Masjed-soleiman electricity distribution network which is radial and the consumer will go outage during line services. The undistributed power which has not reached the consumer and for which some expenses have been devoted may cause damages to the company. Table 6 indicates the costs due to outage imposition for the replacement of problematic connections. The average cost due to one kilowatt hour power in Iran has been assumed as 50 Tomans.

Table 6 Costs due to outage imposition to feeder for the replacement of problematic connection (1$=2470 IRR)

Name of the line and station	Quantity of problematic transmissions	Needed time for troubleshooting	Average undistributed power	Cost ($)
302 Malkarim	6	120	2.4	97.16
303 Malkarim	2	60	3.2	64.77
503 Malkarim	1	20	3.2	21.86
302 Havanirooz	1	30	2.6	26.31
303 Havanirooz	3	75	2.8	70.85
305 Havanirooz	1	20	3.3	22.26
307 Havanirooz	3	30	1.6	16.19
303 Tembi	12	240	3.4	275.3
502 Fajr	4	120	4	161.94
			Total cost ($): 756.64	

C. Cost due to the losses of molten connections

The energy of molten connections are wasted as heat from the time of detection until the time solved by service teams. In order to estimate the losses made in molten connections, the average wasted power in 24 hours shall be multiplied by the duration of the detection of problematic connection till the problem is resolved. It shall be mentioned that the sooner the problems are resolved, the less would be the cost. Figure 7 shows the costs due to molten connection losses.

Table 7 Cost due to molten connection losses (1$= 2470 IRR)

Station name	Specification of the feeder	Average duration from detection till resolve	Average wasted energy in hours (KW)	Cost ($)
Malkarim	Phase B- Line 302	456	20.55	189.23
	Phase C- Line 302		68.9	636
	Phase C- Line 303	480	67.9	659.75
	Phase C- Line 503	1752	6.21	220.24
Havanirooz	Phase B- Line 302	1032	109.3	2263.43
	Phase A- line 303	1224	117.4	2908.85
	Phase B- Line 303		15.2	376.61
	Phase B- line 305	744	40.6	611.46
	Phase A- line 307	4944	3	300.24
	Phase B- Line 307		5.5	550.44
	Phase C- Line 307		9.3	930.75
Tembi	Phase A- Line 303	144	187.6	546.85
	Phase B- Line 303		194.2	566.08
	Phase C- Line 303		142.5	415.38
Fajr	Phase A- line 502	528	110.3	1178.91
	Phase B- Line 502		55.1	588.92
			Total cost ($): 12943.14	

In contrast with other losses in electricity networks, one can claim that losses due to molten connection are among the few losses which not only waste network power, but also impose severe damages on its equipment so that for the compensation of these damages, electricity distribution companies or even regional electricity companies are obliged to devote certain amounts of their budget to such damages.

Total sum of the damages due to molten connections to Masjed-soleiman Electricity Distribution Network is 14503.07$, annually. Based on tables 5 to 7 it can be found out that the lion share of these damages belong to connection losses. By accurate investigations and on-time detection and services of these connections, such damages can be minimalized.

CONCLUSION AND SUGGESTIONS

Some of the connections used in distribution networks will be weakened as time passes and after the passage of severe short connection currents or by the movements due to environmental conditions. In this mode, the temperature which in the safe mode shall be equal to that of the environment gradually increases. As the environment temperature and consumed load increases, the temperature of these equipment reaches molten point till it leads to its abscission. At the same time, the molten connection wastes the power which should have reached the consumers which is regarded as the losses due to the weakness of connections and reaches around 0.53 to 15.9 percent in each phase, annually. Such losses can be detected and solved immediately and cost-friendly using infrared cameras. In case weak connections are not replaced with safe ones, long-term power outages will take place in the network.

Molten connections not only lead to losses and imposition of costs on the network, but because of engendering unequal losses in the three-phase network will lead to unbalanced consumption which in turn leads to losses. Based on such findings, losses due to weakness of the connections shall be named hidden losses as they have not yet been estimated and have been easily dealt with. To prevent such losses, some suggestions are given which are the results of expertise studies:

1. Utilizing technical technicians in service departments.
2. Utilizing modern equipment such as thermal cameras and other troubleshooting equipment during service visits.
3. Using colors which will be changed upon temperature increase so as to be able to detect high-temperature connections without using thermal devices.
4. Providing data sources for planning and services.
5. Analyzing network problems and providing user manuals on how to use the equipment.
6. Providing operation manual for correct installation of the equipment and wrenching the connections before installation, especially in the boards.
7. Periodical services and wrenching the equipment and electricity of the network.
8. More technical accuracy and purchasing high-quality equipment for the network.
9. Utilizing Sectionners, separating keys, clamps and hotline stirrups while maneuvering in the network.
10. Utilizing Belleville washers in network connections.
11. Decreasing connection numbers by accuracy in choosing wire length.
12. Applying proper and modern plans to decrease base numbers and consequently decreasing the applied number of connections.

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