EUROPEAN ACADEMIC RESEARCH
Vol. III, Issue 3/ June 2015

ISSN 2286-4822
www.euacademic.org

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

Analysis and Calculation of Thermal Losses Resulting from the Junction Fusions in Electrical Networks

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Abstract:

One of the most significant aims of electricity 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 thermo-vision tests. thermo-vision 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, instead of analyzing how fused connections detecting by infrared cameras, also the heat transfer equations of geometric shapes, which is contributed to the geometric form of fused joints, were examined to calculate thermal losses. At the end, resulting losses of them was calculated in power stations, so the results of which showed that greatest losses of the fused connections at this station, is about 175.125 kW per year.

Key words: Power Companies, Connections, Thermo Vision Testing, Heat Equations, Losses.

1. Introduction

In the middle of 19^{th} 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 (Farahani, 2009). 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 (Firoozban, 2009). 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 (Moavenian, 2010). 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 (Vlastimil, 2011). 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 (Sebok, 2010)(Sebok, 2011). 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 (Tiv, 2013). In newest research work done in this field, a project entitled as analysis and calculation of losses resulting of connections fusion in electrical distribution networks were done simply that results indicate losses between 0.53 to 15.3 percent (salehi, 2014). In this regard, thermo-vision test is one of the effective and well-known methods which has always been used to detect molten spots. In this paper, assuming that wind speed is zero, heat transfer equations in fused joints were done by free convection method. Geometric shapes that heat transfer equation was calculated for them, was selected according to the geometry of these connections. Horizontal cylindrical usually used in screws and measuring transformers terminal, and flat plates or sheets in Disconnect Switches and Circuit Breakers, and heat transfer equations of irregular geometric shapes that many connections and fittings are made by this way. In the following, in addition to investigate the losses of fused connections or fittings in a sample power station, some solutions to reduce this problem will be proposed.

2. Theory of thermal camerawork

According to Fig. 1. 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).

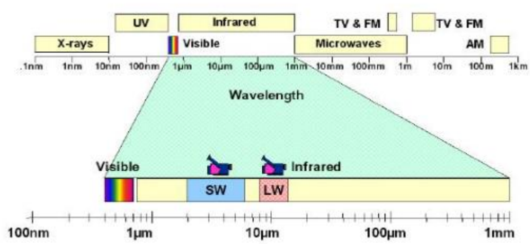

Fig. 1. A view of electromagnetic wave spectrum

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 (salehi, 2014).

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 Disconnect Switch	35	75
Distribution transformers	70	110

Today, the use of infrared cameras to capture thermal of power industry, has found wide popularity like other industries. Also regional electricity distribution companies and power companies use this technique to identify hot spots are not visible by the unaided eye. Because of low conductor cross section or loosening of connections, over time with the passing of their consumer-flow And rising up the ambient temperature, equip start to heat up and melt after a very short time and would deteriorate if not addressed. Thermo Vision test or thermal inspection or testing is of a non-destructive method for the detection of these imperfections. In this way, which the way it works determine in accordance with the manufacturer's instructions of the camera, in day or night without electricity outages of consumers can be identified equipment that work at unusual temperature, and within the stipulated time, decided to fix it. Including equipment, mainly in the electricity industry are involved in fusion may be named connectors, disconnect switches, conductors, transformers and etc. Fig. 2. shows thermal image taken from equipment that is fused due to loosening.

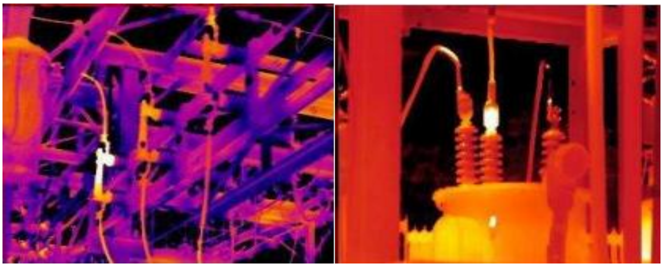

Fig. 2. right Increase in thermal degree on Circuit Breaker bushing connector
Fig. 2. left Increase in thermal degree on one of the Disconnect Switch blades

4. The methods of heat transfer

Heat transfer happens in three ways described below:
Conductivity
Displacement
Radiation

A) The heat transfer by conduction method

when there is a temperature gradient in the object, the energy is transmitted of the higher temperature region to lower temperature region. In this case we say that energy is transferred by conduction.

B) The heat transferring by displacement method

This method, which occurs in both compulsory and free state, happens while for example, if hot object is to let in air, so hot object heat is then transferred to the air. This method named heat transfer by free convection method. If the object is affected by the weather, so their heat transfer named free convection and if the wind speed is to be cooled, it named forced displacement method.

C) The heat transfer of radiation method

In contrast with the recent mechanisms by which energy is transferred through a material medium, but in this method transition is as electromagnetic energy. For example, heat receives of a black color object compared to its bright color. Since the work temperature of the fittings and electrical equipment in power networks due to loose connections and flow of current reaches its highest level and some of the energy is dissipated as heat in the medium, it can be concluded based on the above mentioned topics that the heat transfer occurs by displacement method in this case. To calculate the losses of the molten or fused connections, we first examine the heat transfer by free convection method (assuming zero wind speed) on the objects with different geometrical shapes described above. Considering that the Electrical Fittings and power network connections are made in various geometric shapes And their behavior vary in heat transferring, this review is necessary.

4.1 Heat transfer by free convection on a vertical flat plate

Consider vertical flat plate in fig. 3. When the plate is heated, free convection boundary layer is formed in the manner shown. Velocity profile in this free boundary layer is quite different with velocity profile in the boundary layer of displacement forced. On the wall, velocity is zero since the lack of slip; velocity increased to a maximum value and then decreases to zero at the edge of the boundary layer. Because free flow at free transport (free convection) system is stasis. Expansion of the early boundary layer is laminar, but at distance from the front edge, Depending on the properties of the fluid and the temperature difference between the wall and the surrounding environment, turbulent vortex is formed and transition to turbulent boundary layer begins. At longer distances, Boundary layer becomes completely turbulent. (Holman, 2010).

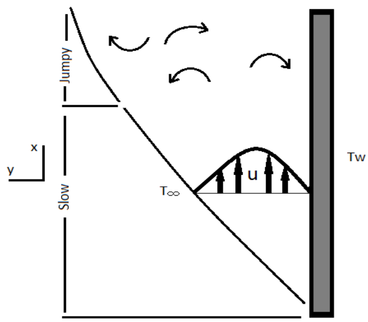

Fig. 3. The boundary layer on a vertical flat plate

To analyze the problem of heat transfer, Must obtain the differential equation of motion for the boundary layer. For this purpose, we consider the x component in direct of (across) sheet or plate and y component perpendicular to the sheet. Only new force that must be considered at this analysis is weight of the fluid element. We put equal the Total foreign forces in the x direction by changing in momentum of flow through control volume dx dy. So the result, according to equation (1) will be.

$$\rho(u\frac{\partial u}{\partial x}+\upsilon\frac{\partial u}{\partial y})=-\frac{\partial p}{\partial x}-\rho g+\mu\frac{\partial^2 u}{\partial y^2} \quad (1)$$

In which $-\rho g$ represents the force of gravity acting on the fluid element. The pressure gradient in the x direction arises of changing in height on the plate.

So we have:

$$\frac{\partial p}{\partial x}=-\rho\infty g \quad (2)$$

In the other words, Pressure change in height dx is equal to unit weight of Fluid element. Substituting the equation number (2) in equation (1) we have:

$$\rho(u\frac{\partial u}{\partial x}+\upsilon\frac{\partial u}{\partial y})=g(\rho\infty-\rho)+\mu\frac{\partial^2 u}{\partial y^2} \qquad (3)$$

The density difference, $\rho\infty-\rho$ can be expressed in terms of volume expansion coefficient β.

$$\beta=\frac{1}{v}(\frac{\partial v}{\partial T})_p=\frac{1}{v}\frac{v-v\infty}{T-T\infty}=\frac{\rho\infty-\rho}{\rho(T-T\infty)} \qquad (4)$$

So then:

$$\rho(u\frac{\partial u}{\partial x}+\upsilon\frac{\partial u}{\partial y})=g\rho\beta(T-T\infty)+\mu\frac{\partial^2 u}{\partial y^2} \qquad (5)$$

Volume expansion coefficient β for perfect gases, That it can be achieved from equation (6) is.

$$\beta=\frac{1}{T} \qquad (6)$$

Where T is the absolute temperature of the gas.

If the fluid motion is because of the density variations, these changes are very small, and assuming that the flow is incompressible, i.e. ρ = Constant, We can obtain an acceptable solution. To find solution of Equation of motion for free convection system, we proceed as follows.

$$\frac{d}{dx}(\int_0^\delta \rho u^2 dy)=-\tau w+\int_0^\delta \rho g\beta(T-T\infty)dy=-\mu\frac{\partial u}{\partial y}]_{y=0}+\int_0^\delta \rho g\beta(T-T\infty)dy \qquad (7)$$

The following terms are used to calculate the temperature distribution:

$$T=Tw \qquad y=0$$

$$T=T\infty \qquad y=\delta$$

$$\frac{\partial T}{\partial y}=0 \qquad y=\delta$$

So the temperature distribution is obtained as follows.

$$\frac{T - T\infty}{Tw - T\infty} = (1 - \frac{y}{\delta})^2 \quad (8)$$

Three conditions for the velocity profile are:

$u = 0 \qquad y = 0$

$u = 0 \qquad y = \delta$

$\frac{\partial u}{\partial y} = 0 \qquad y = \delta$

An additional condition can be achieved from equation (5).

$$\frac{\partial^2 u}{\partial y^2} = -g\beta \frac{Tw - T\infty}{v} \qquad y = 0$$

Assuming that the velocity profile at distance x along the sheet has the same geometric shape. For free convection mode, we consider Speed function as a polynomial in terms of y that multiplied by an arbitrary function of x. So then:

$$\frac{u}{ux} = a + by + cy^2 + dy^3 \quad (9)$$

Where ux is a virtual velocity as a function of x. Since the four conditions must be met, we choose a third order polynomial, and this is the simplest type of function that can be used. Applying these four conditions for above velocity profile, we have:

$$\frac{u}{ux} = \frac{\beta\delta^2 g(Tw - T\infty)}{4u_x v} \frac{y}{\delta}(1 - \frac{y}{\delta})^2 \quad (10)$$

You can combine the term including temperature difference, δ^2 and ux in to the ux function, And finally The final equation for the velocity profile is obtained as follows.

$$\frac{u}{ux} = \frac{y}{\delta}(1 - \frac{y}{\delta})^2 \quad (11)$$

Putting equations (8) and (11) in equation (7) And calculating the exist integrals and differentials, We have:

$$\frac{1}{105}\frac{d}{dx}(u^2 x\delta) = \frac{1}{3} g\beta(Tw - T\infty)\delta - v\frac{ux}{\delta} \quad (12)$$

The integral energy equation for the free movement system is According to equation(13).

$$\frac{d}{dx}[\int_0^\delta u(T - T\infty)dy] = -\alpha \frac{dT}{dy}]_{y=0} \quad (13)$$

Putting the temperature distributions and velocity in this equation And some algebraic operations, the equation (14) is obtained.

$$\frac{1}{30}(Tw - T\infty)\frac{d}{dx}(ux\delta) = 2\alpha \frac{Tw - T\infty}{\delta} \quad (14)$$

From the reasons related to equation (11), it is clear that:

$$ux \approx \delta^2$$

To put this relation in equation (12), it is result that:

$$\delta \approx x^{1/4}$$

Thus we consider below exponential functions for ux and δ changes:

$$ux = C1x^{1/2}$$

$$\delta = C2x^{1/4}$$

Substituting above relations in equations (12) and (14), we will have equations (15) and (16):

$$\frac{5}{420}C1^2 C2x^{1/4} = g\beta(Tw - T\infty)\frac{C2}{3}x^{1/4} - \frac{C1}{C2}vx^{1/4} \quad (15)$$

And

$$\frac{1}{40}C1C2x^{-1/4} = \frac{2\alpha}{C2}x^{-1/4} \quad (16)$$

These two equations can be solved in terms of constant coefficients C1 and C2, And obtain:

$$C1 = 5.17v(\frac{20}{21} + \frac{v}{\alpha})^{-1/2}[\frac{g\beta(Tw - T\infty)}{v^2}]^{1/2} \quad (17)$$

$$C2 = 3.93(\frac{20}{21} + \frac{v}{\alpha})^{1/4}[\frac{g\beta(Tw - T\infty)}{v^2}]^{-1/4}(\frac{v}{\alpha})^{-1/2} \quad (18)$$

The resulting expression for thickness of boundary layer is equivalent to:

$$\frac{\delta}{x} = 3.93 \Pr^{-1/2}(0.952 + \Pr)^{1/4} Gr_x^{-1/4} \quad (19)$$

In which used the Prandtl number $\Pr = \frac{v}{\alpha}$ with a new dimensionless group called Grashof number, Grx .

$$Gr = \frac{g \times \beta \times (T\omega - T\infty) \times x^3}{(v)^2} \quad (20)$$

Required coefficients of Grashof Number are shown in Table 2 (Holman, 2010).

Table 2: Coefficients of $(K), (v), (\Pr)$

$Tf\,(k)$	$v \times 10^6 (\frac{m^2}{s})$	$K(\frac{w}{m.c\circ})$	Pr
100	1.923	0.009246	0.77
150	4.343	0.013735	0.753
200	7.49	0.01809	0.739
250	11.31	0.02227	0.722
300	15.69	0.02624	0.708
350	20.76	0.03003	0.697
400	25.9	0.03365	0.689
450	31.71	0.03707	0.683

Heat transfer coefficient can be calculated from the following equation.

$$qw = -kA\frac{dt}{dy}]_w = h \times A \times (T\omega - T\alpha) \quad (21)$$

Using the temperature distribution of equation (8) we have:

$$h = \frac{2K}{\delta}$$

Or

$$\frac{hx}{k} = Nux = 2\frac{x}{\delta}$$

So the dimensionless equation of heat transfer coefficient in equation (22) becomes the following equation:

$$Nux = 0.508 \Pr^{1/2} (0.952 + \Pr)^{-1/4} Grx^{1/4} \qquad (22)$$

Equation (22) resulting changes in local heat transfer coefficient along the vertical plate.

Average heat transfer coefficient can be calculated by integration.

$$\bar{h} = \frac{1}{L}\int_0^L hx dx \qquad (23)$$

For changes given in equation (22) the average coefficient is equal to:

$$\bar{h} = \frac{4}{3} hx = L \qquad (24)$$

Grashof number can be interpreted as dimensionless groups that display ratio of float forces to the viscosity force in free convection system. This number has the same rule as the Reynolds number in forced displacement system. And it is used to as a criterion for transition from laminar boundary layer to turbulent (Holman, 2010).

4.2 Empirical free movement relations

Over the years it has been shown that mean coefficients of Free convection heat transfer can be provided as The following function for different environments:

$$\overline{Nuf} = C(Grf \Pr f)^m \qquad (25)$$

In which low index f shows that Fluid properties is set in dimensionless groups at film temperature.

$$Tf(k) = \frac{T\infty + T\omega}{2} \qquad (26)$$

Product of Prandtl and Grashof numbers, is called Rayleigh number: (Holman, 2010).

$$Ra = Gr \times \Pr \tag{27}$$

Rayleigh number is given in Table 3 depends on the geometry of the problem (McAdams, 1954)(Eckert, 1951)(Morgan, 1975)(Lienhard, 1973).

This characteristic dimension for a vertical flat plate is the plate height (L) and for horizontal cylinders are their diameters (d).

Table 3: Constant coefficients of C and m

Geometry	$Gr \Pr$	C	m
Vertical planes and cylinders	$10^4 - 10^9$	0.59	$1/4$
	$10^9 - 10^{13}$	0.021	$2/5$
Horizontal cylinders	$0 - 10^{-5}$	0.4	0
	$10^4 - 10^9$	0.53	$1/4$
	$10^9 - 10^{12}$	0.13	$1/3$
	$10^{-10} - 10^{-2}$	0.675	0.058
	$10^{-2} - 10^2$	1.02	0.148
	$10^2 - 10^4$	0.85	0.188
	$10^4 - 10^7$	0.48	$1/4$
	$10^7 - 10^{12}$	0.125	$1/3$
Irregular solids	$10^4 - 10^9$	0.52	$1/4$

4.3 Heat transfer by free convection method on horizontal cylinders

Each of the references has been expressed different Constant values of c and m for horizontal cylinders(McAdams, 1954)(Morgan, 1975). Mr. Churchill and Chu, offered a larger complex Definition for widespread use of GrPr (Churchill, 1975).

$$\bar{NU}^{\frac{1}{2}} = 0.6 + 0.387\{\frac{Gr\Pr}{[1+(0.559/\Pr)^{\frac{9}{16}}]^{\frac{16}{9}}}\}^{\frac{1}{6}} \quad for \quad 10^{-5}\langle Gr\Pr\langle 10^{12} \tag{28}$$

Equation (28) is calculated at the film temperature, But for heat transferred from a horizontal cylinders to the molten metals, equation (29) can be used (Hyman, 1953).

$$Nud = 0.53 \times (Grd\Pr^2)^{\frac{1}{4}} \tag{29}$$

4.4 Heat transfer by free convection on the objects with irregular shapes

For irregular objects there is no overall relationship. But Reference (Sparrow, 1983) shows that equation (25) with c=0.775 and m=0.208 can be used for a vertical cylinder with a diameter equal to its height. Nusselt and Grashof numbers can be estimated Using the Diameter As a characteristic length. Reference (Lienhard, 1973) suggests that Values of c=0.52 and m=0.25 in equation (25) and also characteristic length to be considered as well as the distance that fluid particles passed inside the boundary layer.

Example) the temperature of the wire with a diameter of 5 mm on an electric base Due to excessive flow of consumers is reached To 205 C° and inflamed. If the ambient temperature is about 49 degrees and inflamed wire length is 0.5m then calculate the power dissipated by the wire.

$$T\infty = 49 + 273 = 322$$

$$T\omega = 205 + 273 = 478$$

$$Tf = \frac{478 + 322}{2} = 400$$

$$v = 25.9(\frac{m^2}{S}) \qquad k = 0.03365(\frac{w}{m.c\circ}) \qquad \Pr = 0.689$$

$$\beta = \frac{1}{400} = 2.5 \times 10^{-3}$$

$$Gr = 4.9 \times 10^{-10}$$

$$NU = 0.675 \times (4.9 \times 10^{-10})^{0.058} = 0.194$$

$$h = 0.194(\frac{0.03365}{5 \times 10^{-3}}) = 1.305 \frac{w}{m^2.c^\circ}$$

$$qw = 1.305 \times 5 \times 10^{-3} \times \pi \times 0.5 \times (205 - 49) = 1.59w$$

5. Calculation of losses Resulting from the fusion joints in Power stations

To calculate the losses of the fusion joints In power stations For example, A power station in Khuzestan province (South-West of Iran) was selected. This Chosen is because Power stations in the province can be attributed High temperatures to other provinces of Iran. Since high air temperature can be related into the increased load and even increase in the equipment working temperature Which Will lead to the creation of fused joints in power stations. The Power station, that want to examine Annual losses resulting from the fusion connections, has Three transformer with dispatching code T1, T2, T3 Each have a capacity of 27 mega volt amperes and transform ratio of about 132/11 kV. All equipment of this station will be tested Thermal Vision (or thermo vision) Twice a year by the thermal camera Hot Find LXS model such As in Fig. 4. Thermo Vision test results of this station in a year, has been shown in Table 4.

Fig. 4. Infrared Photography by Hot Find LXS model camera from equipments of sample power stations

Table 4: Test results of Thermo Vision in Sample power station

Row	Equipment name	Code dispatching equipment	Defective phase			Temperature equipment	Ambient temperature	Join identification	Date Troubleshooting
			A	B	C	(C°)	(C°)		
1	Current Transformer	CT-3433		*	*	50	20	24 March	23 May
2	Current Transformer	CT-3052	*			95	20	24 March	23 May
3	Disconnect Switch	3051	*			37	20	24 March	23 May
4	Current Transformer	CT-3412	*	*	*	60	20	24 March	23 May
5	Disconnect Switch	3416			*	100	20	24 March	23 May
6	Current Transformer	CT-3032		*		65	20	24 March	23 May
7	Current Transformer	CT-342	*	*	*	220	40	23 June	17 November
8	Disconnect Switch	3421	*	*	*	95	40	23 June	17 November
9	Disconnect Switch	3041			*	65	40	23 June	17 November
10	Disconnect Switch	3051	*	*	*	90	40	23 June	17 November
11	Current Transformer	CT-305	*	*	*	90	40	23 June	17 November
12	Disconnect Switch	3061	*	*	*	98	40	23 June	17 November
13	Bus	33			*	80	40	23 June	18 September
14	Disconnect Switch	3071			*	250	40	23 June	18 September
15	Transformer	SS3	*	*	*	85	40	23 June	18 September

16	Current Transformer	CT-T3	*	*	*	100	40	23 June	18 September
17	Transformer	T3	*	*	*	90	40	23 June	18 September
18	Transformer	T1	*	*	*	73	40	23 June	15 November
19	Current Transformer	CT-341	*	*	*	140	40	23 June	15 November
20	Disconnect Switch	3416	*	*	*	140	40	23 June	15 November
21	Circuit Breaker	3412	*	*	*	55	40	23 June	15 November
22	Disconnect Switch	3411	*	*	*	70	40	23 June	15 November
23	Current Transformer	CT-303	*	*	*	80	40	23 June	15 November
24	Circuit Breaker	3031			*	85	40	23 June	15 November
25	Current Transformer	CT-302	*	*	*	98	40	23 June	15 November
26	Circuit Breaker	3012	*			98	40	23 June	15 November
27	Circuit Breaker	3522	*	*	*	142	40	23 June	30 July
28	Shunt Capacitors	SC1		*		80	40	23 June	30 July
29	Transformer	T1	*			70	40	23 June	7 November
30	Shunt Capacitors	SC2	*	*	*	250	40	23 June	30 July
31	Circuit Breaker	3522	*	*	*	121	40	23 June	30 July
32	Disconnect Switch	3426	*	*	*	250	40	23 June	7 November

Results of losses of 32 fused connections In Fig. 5. related to 3 power transformers of power station are shown.

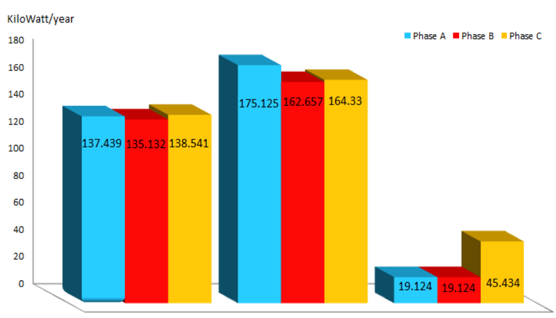

Fig. 5. Losses of the connections fused in the power station

6. Conclusion and Suggestions

Some connections used in power networks, passing with time or with severe short-circuit current or shock caused by environmental conditions become weak And their temperature of work which in normal mode, was roughly equal to the ambient temperature, Will begin to rise. If the ambient temperature gets warmer, and load consumption gets too high, temperature of these equipments reach their fusion temperature So that it will lead to get damaged. In this case, these fused connection are wasted Amount of power which should lead to consumers As heat. The most losses estimated resulting from 32 fused junctions who were identified in a power station Indicated that About 175.125 kW per year Energy is wasted as heat in these connections. These types of losses at an early stage can be identified and remedied with Low cost Using infrared cameras. In the event that Loose connections are not replaced with healthy connections Can lead to long-term power outages apply to their power 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 Circuit Breaker, 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.

7. Symbols

$T\omega$: temperature of the object (K)
$T\infty$: Fluid temperature (K)
Gr : Grashof Numbers
$\Pr$: Prandtl numbers
x: Characteristics dimension of the object (m) (for vertical flat plate is considered plate height, And for horizontal cylinder is considered its diameter)
NU: Nusselt numbers
A: Lateral surface of the object (m^2)
qw : Heat transmission coefficient (w)
g: the local acceleration of gravity (m/s^2)
ρ : Density of the fluid (kg/m^3)
v and u: Speed in direction of y & x (m/s)
δ : Thickness of the boundary layer
∞ : Out from the boundary layer
μ : Dynamic viscosity
P: pressure fluid (pa)

V: volume of fluid (m^3/mol)

h: Heat transmission coefficient (w/ m^2 .°C)

α : thermal coefficient (m^2/s)

L: vertical height of the object (m)

d: diameter of the object (m)

Acknowledgements

The author of this article appreciate the Electricity Distribution Company Khuzestan Province for their cooperation in providing the required information.

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