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Applications of Drones in Power system

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Abstract: Electricity is proven to be the most important and reliable source of energy in major fields like domestic, industrial, agricultural, commercial. Etc. the upcoming transition towards electrical vehicle just adds on to this. As important these systems are (electrical power systems) it is equally important to have a check on its maintenance in order to have a hassle or interruption free supply of power. Unlike other systems Maintenance of electrical system poses a high risk to lives of human workers In India, a total of 9606 person died due to electrocution, in 2016 alone [2]. In order to reduce the human interaction with this system there is a high need of newer approaches to carry out maintenance in a safe environment. The main aim of this paper is to explore the various area in electrical power system maintenance that can be optimized with the employment of drones. This paper contains the different approaches for finding thermal hot spots and sag of electrical conductors with the help of image processing and other methodology assisted by drones.

Key words – Sag, temperature, Expansion, Span, Hotspots, Transmission line, Maintenance.

I. INTRODUCTION:

Maintenance of electrical equipment's is one of those process where in safety is considered at higher most priority. Conventional methodologies that exist for inspection or maintenance of electrical equipment's or transmission lines require a very high human interaction with the equipment's of transmission lines which operates at voltages well surpassed safety limits for workers. While dealing with electrical equipment's of transmission lines even a silly mistake or negligence from the workers may result in serious injury or death of workers / employees. So, in order to eliminate such unwanted dilemma Drones can be utilized in some fields of energy operation (i.e., Thermography sag calculation of transmission line) where human involvement can be reduced to greater extinct.

Thermograph- It is a method of inspecting electrical and mechanical equipment's by obtaining heat distribution pictures. This inspection method is based on the facts that most component of a system show an increase in temperature when malfunctioning.

Thermography plays a vital role in determining the health of transmission line and electrical equipment's, but when it comes to performing thermography and analyzing the obtained thermal images there is a Very high chance that due to some human error, some hot spots can be over looked which may lead to failure / breakdown of equipment or poor efficiency in transmission line, so there is high need of method that can detect the hot spots from thermal image.

Sag-calculation – It is very difference in level between points of support and the lowest point of conductors.

Sag is effect of rise in temperature on transmission line conductors. It is a very important part of transmission line which has a direct effect of power handling capacity of transmission system.

II. Methodology:

Thermal imaging:

Analysis of thermal images is done by finding out the hot spots in the system. For this thermal camera is used to obtain the thermographic view of the equipment which is to be evaluated, further the different colour patterns in the image are studied to obtain the hot spots, the image fig (1.0) shows the view of hot spots in a thermal image. Usually, hot spots are the regions with highest temperature in a thermal image.

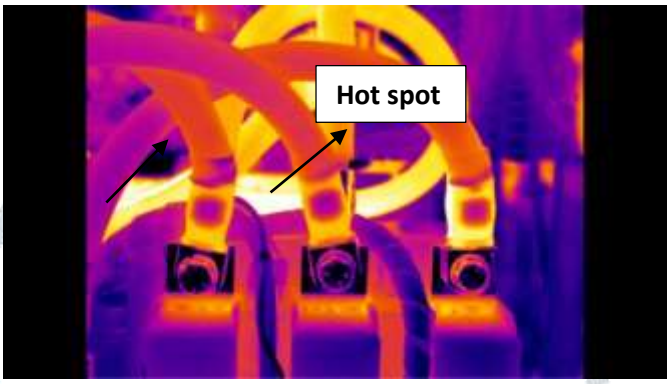

fig 1.0 – thermographic image of electrical contacts

Conventionally the study of Hot spots is done manually which leaves a very high room for error. But with assistance of Image Processing the same task can be done more effectively and efficiently.

The IP (image processing) adapted in this paper is known as image segmentation [1]. fig (1.1) shows the MATLAB code for performing image segmentation and fig (1.2) shows the results obtained by this method.

```
img1=imread('maxresdefault.jpg'); % input image
subplot(2,2,1);
imshow(img1);

%initialization of input RGB
red=img1(:,:,1);
blue=img1(:,:,2);
green=img1(:,:,3);

%taking samples of hotspot form input image
d=impixel(img1);

%initialization of threshold RGB values of hotspot
out=red>250 & blue<250 & blue>158 &  green<240 & green>8;
subplot(2,2,2);
imshow(out);

%processing of image
out2=imfill(out,'holes');
out3=bwmorph(out2, 'dilate',3);
out3=imfill(out3,'holes');
subplot(2,2,3);
imshow(out3);

%detected hotspots output
imgBoth = imoverlay(img1,out3,'green');
subplot(2,2,4);
imshow(imgBoth);

```

fig 1.1 – MATLAB code for detection of hotspots

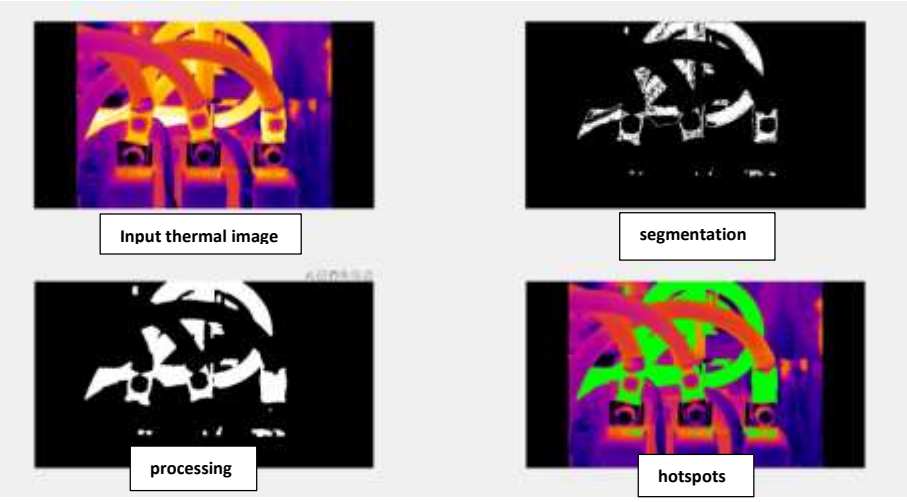

fig 1.2 – output of the hotspot detection system

In the obtained results in fig (1.2) the regions with green marking are the hot spots.

2.1 Flowchart:

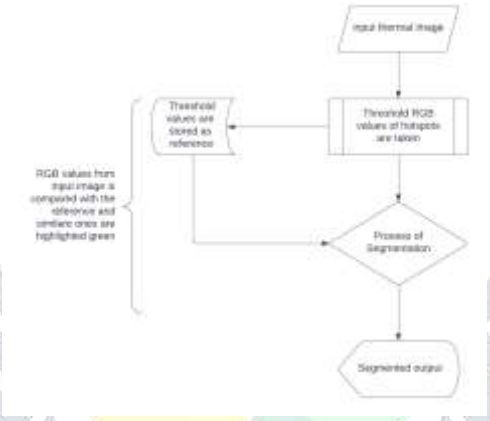

fig 1.2.1 – flowchart of hotspot detection system

2.2 Algorithm:

Step-1: The thermal image is fed to system.

Step-2: The RGB values of hotspots regions are obtained from the input image.

Step-3: The values of RGB that need to be segmented out is then set as the thrush hold values.

Step-4: Then portion of images that meet the RGB values that are specified will be segmented out.

Step-5: Mark the segmented-out regions with green else black.

2.3 Sag- Calculation:

Sag is the effect of rise in temperature in transmission lines that result in the expansion of transmission line conductors, which then effect to various ill effects like, reduced power transfer capability, reduced efficiency, uneven loading of conductors reduces life of transmission line.

Some of the main causes of sag in transmission lines are listed below:

- Average temperature of environment around the conductor.
- Heat produced in the conductors due to internal resistance.

- Selection of material for making of conductors.

2.4 Available method for calculating of Sags:

1. When the conductor supports are at equal level [3].

   The following fig (1.3) shows the sag at equal level supports.

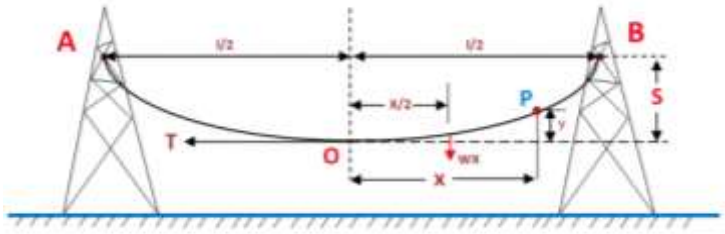

fig 1.3 – sag at equal level supports

$$\text{Sag} = \frac{WL^2}{8T}$$

The above equation is used for the calculation of sag when conductor supports are at equal level.

L= Horizontal distance between the towers (i.e., Span)
W= weight per unit length of conductor
T= Tension of the conductor

2. When conductor supports are at unequal levels [3].

   The following fig (1.4) shows the sag at unequal level supports.

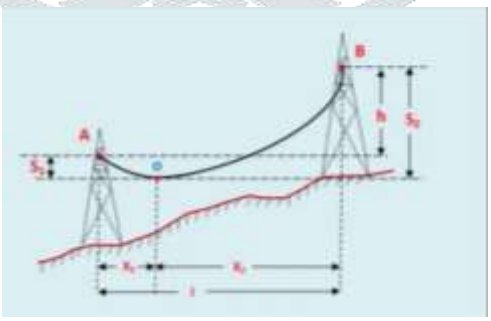

fig 1.4 – sag at unequal level supports

$$\text{Sag S1} = \frac{WX_1^2}{2T}$$

$$\text{Sag S2} = \frac{WX_2^2}{2T}$$

The above equations are used for the calculation of sag when conductor supports are at unequal levels.

From the above equation:
X_1 = Distance of support at lower level
X_2= Distance of support at higher level
T = Tension of the conductor
W = weight/unit length of conductor

III. **PROPOSED METHODOLOGY:**

The main aim of this methodology is to calculate the sag by making use of as little information as possible, in conventional way of calculating sag it requires many parameters such as span, weight of conductor, tension on conductors etc. But in the methodology proposed it only needs any one of the parameters such as span or conductor length or height of the support.

3.1 CALCULATIONS:

In the proposed method a drone is utilized for capturing a picture of the transmission line from an elevation. Then the captured picture is analyzed by mapping any one of the above-mentioned required parameters (span or conductor length or height of the support) as the distance between the pixel [4][5].

Example: consider in a picture of size 100 × 100 (i.e., 100 pixels on X-axis and 100 pixels on Y-axis) now if we know any one of the distances with in the image, we can calibrate our system to map that distance on per pixel bases. Like if we know the distance between 10 pixels in the 100 × 100 pixels image as 100 meters then we can relatively calculate the distance between any one pixel to other, as the size of the pixels in an image remains constant.

The following image fig (1.5) shows the MATLAB code for calculation of sag with the help of image of transmission line.

Note: For the following calculation in this paper "Blender" is used with front up view of the model for creation of transmission line and it's surrounding environment.

3.2 MATLAB code[5]:

```
%input image
A = imread("pic 2.PNG");
imshow(A);

%measuring
h=imdistline(gca);
api=iptgetapi(h);
%
pause();
%
%conversion of distances between pixels to distances of different units
dist=api.getDistance();
u=menu('Choose Measuring unit','Pixels','Centimeters','Meters');
if(u==1)
    fprintf('The length of sag is: %0.2f Pixels \n',dist)
elseif(u==2)
    dist_cm=dist*0.0264583333;
    fprintf('The length of sag is: %0.2f Cms \n',dist_cm)
else
    dist_m=dist*0.500813198534526;
    fprintf('The length of sag is: %0.2f m \n',dist_m)
end
```

fig 1.5 – MATLAB code for calculation of sag from images

Fig (1.6) shows the input image from blender with actual accurate sag and relative distances.

Input:

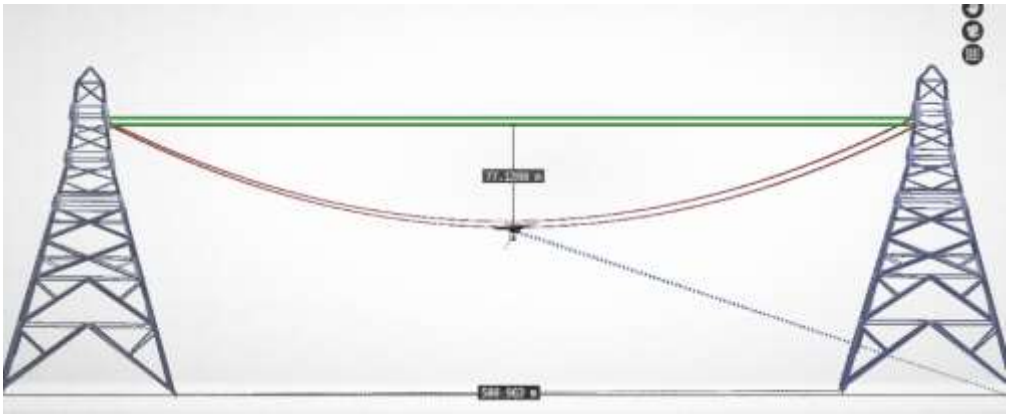

fig 1.6 – Input image

Fig (1.7) shows the results of calculation.

Output:

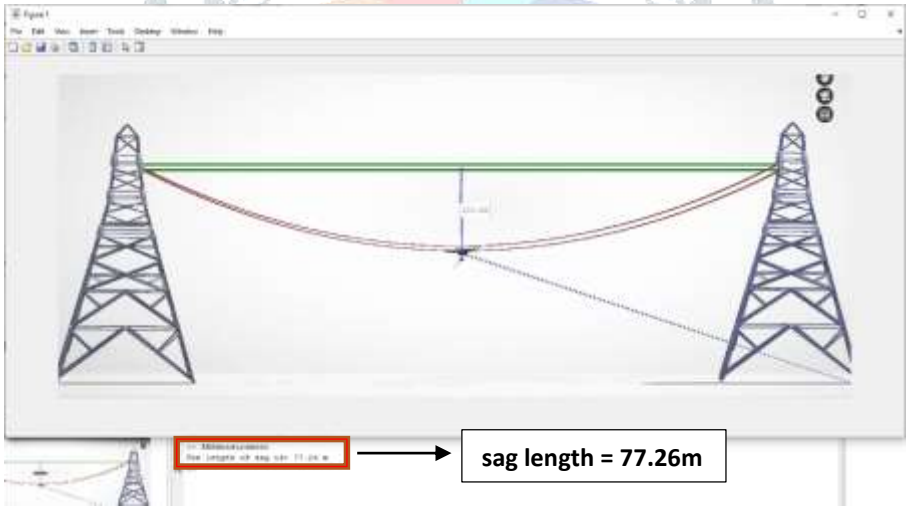

fig 1.7 – result of sag calculation

From fig (1.7) the Calculated sag length = 77.26m which is very close to the original value in fig (1.6) i.e., 77.12m.

From the above obtained output (sag) further the length of the sagged conductor and the rise in temperature which caused the sag can be calculated.

3.3 Calculating the length of the sagged conductor:

The sag is caused due to rise in temperature and this effect takes place due to property of metal known as thermal expansion. Thermal expansion is the property of metals due to which metals increase in size when subjected to rise in temperature.

Thermal expansion of a metals/substance is given by [6][7][8]:

$$\Delta L = \propto L\Delta T$$

In the above equation:

$\propto$ = thermal expansion co-efficient of materials.

L = original length of material.

ΔT = change in temperature.

ΔL = change in length (in our case the expansion that causes the conductor to sag).

ΔL can be calculated by converting the output sag calculating system into graph I.e., map the known distance like span, height of line support and sag onto a graph.

The following image fig (1.80) shows graphical mapping of the sag calculation output.

fig 1.80 – initial picture with reference values

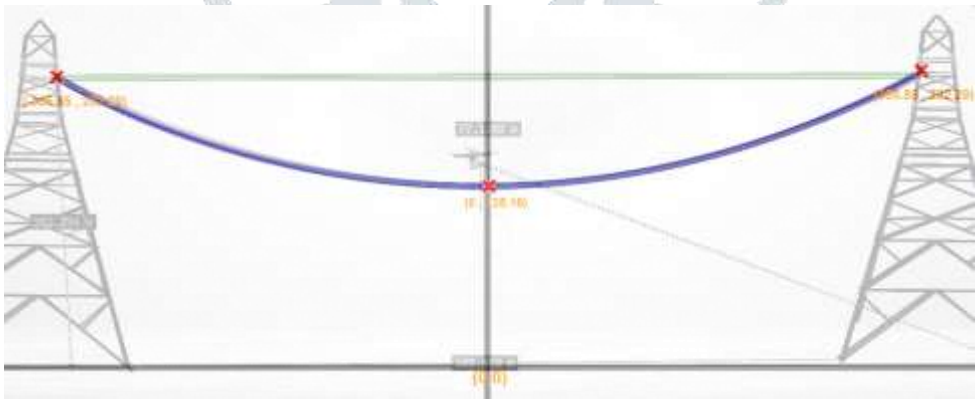

fig 1.81 – initial picture getting mapped as graph

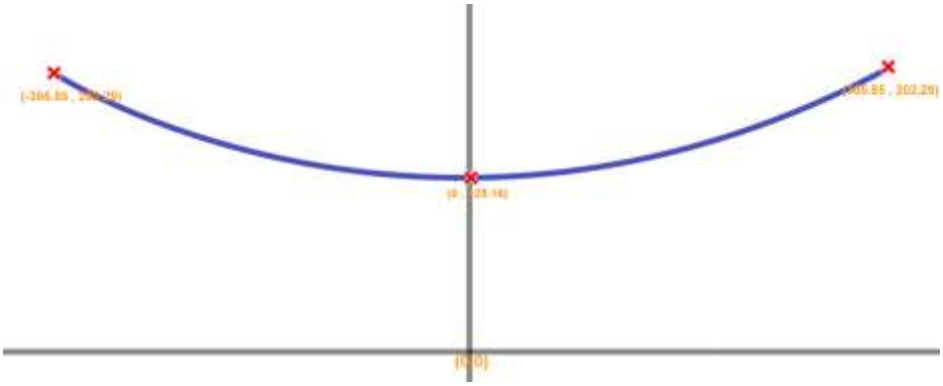

fig 1.82 – initial mapped as graph

Then the mathematical methods can be used to obtain the arc length of the expanded / sagged conductor (blue arc in the fig (1.82)).

3.4 CALCULATION OF ΔL:

After converting the sag calculation output in to graph the co-ordinates of the graph can be used to get the equation of the curve (curve is the blue arc in the fig (1.82)).

Equation of the curve can be obtained by plugging the co-ordinates shown in fig (1.82) onto the following equation.

$$y = a(x - h)^2 + k$$

From the above equation:

h = value of X co-ordinate at the lowest sag point / lowest point on the conductor.

k = value of Y co-ordinate at the lowest sag point / lowest point on the conductor.

x = value of X co-ordinate at any one of the line supports.

y = value of Y co-ordinate at any one of the line supports.

Then the following equation of the curve can be used to integrate along the x and y axis co-ordinate to obtain ΔL (sagged conductor length).

Rise in temperature ΔT can be further calculated by plugging the values of ΔL, L, $\propto$ onto the thermal expansion equation I.e.,

$$\Delta L = \propto L \Delta T$$

$$\Delta T = \frac{\Delta L}{\propto L}$$

The following gives the calculation of ΔL and ΔT for the above considered blender transmission line model based on above-described method.

Calculation of ΔL :

Note: refer above image fig (1.82) for the calculations.

$y = a(x - h)^2 + k$ → equation 1

from fig (1.82) we get:

$y = a(x - h)^2 + k$ → $202.29 = a(305.85 - 0)^2 + 125.16$

$202.29 = a(93544.22) + 125.16$

$202.29 = a(93669.382)$

Solving for 'a' we get:

$a = 0.0021596$

substituting 'a' in equation 1 we get:

$y = 0.0021596x^2 + 0.2702$

now finding arc length by integrating:

arc length = $2\int_{x1}^{x2} \sqrt{1 + (\frac{dy}{dx})^2}\ dx$ → equation 2

$\frac{dy}{dx} = 0.0021596x^2 + 0.2702$

$\frac{dy}{dx} = 2(0.0021596x)$ → put in equation 2

arc length = $2\int_{x1}^{x2} \sqrt{1 + (0.0043192x)^2}\ dx$

x1 = -305.85, x2 = 0;

arc length = $2\int_{-305.85}^{0} \sqrt{1 + 0.000018655x}\ dx$

$= 2\left[\frac{(1+0.000018655x)^{\frac{3}{2}}}{\frac{3}{2}\times 0.000018655}\right]_{-305.85}^{0} + c$

After applying limit we get:

$=2\times \frac{1}{0.0000279825}((1 + 0.000018688 \times 0)^{\frac{3}{2}} - (1 + 0.000018688 \times -305.85)^{\frac{3}{2}})$

Solving above equation we get

Arc length = 610.8266 m

L = 604.34

$\Delta L = 610.8266 - 604.34$ =6.4866m

Now using ΔL we can find ΔT :

$\Delta T = \frac{\Delta L}{\propto L}$

Considering the conductor is made up of aluminum we are taking $\propto = 24 \times 10^{-6}$

$\Delta T = \frac{6.4866}{24\times 10^{-6}\times 604.34} = +447.223\ C^0$

According to above results a temperature rise of +447.223 C^0 has caused the conductor to sag.

3.5 Algorithm of Calculation:

Step-1: Image of tower and sagged conductor from certain elevation is taken by the Drone.

Step-2: The Image taken by the Drone is fed in to Sag calculation system.

Step-3: Pixels in the input image is mapped as distances with the help of predefined reference distances.

Step-4: Sag is calculated and given as output.

Step-5: The calculated sag distance is used to calculate the expanded length of conductor ΔL.

Step-6: Once ΔL is Calculated, with the help of expanded length of conductor the rise in temperature ΔT which has caused the sag is Calculated.

IV. Conclusion:

The main aim of the conducting maintenance is to prevent the break down or failure of the system, at the same time making sure the safety of workers. This is achieved by utilizing the drones in the maintenance operation the methods mentioned in this paper are just some of many applications of drones in power systems. Power of drones combined with modern techniques can yield many more life and time saving applications of drones in this sector.

V. References:

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