

Optimization of copper in a renewable source based network

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Abstract The objective of this work is to find the optimal location for installing the generator to allow minimizes cable prices by optimizing the volume of used copper. One approach to solving the problem presented here is to determine the point where we need to insert the generator, such that the volume of copper is reduced. This position is called the gravity center of the charges "GCC".

The method used in this paper is comparable to the determination of the gravity center of a system made up of points weighted with the power ratings of the various electrical loads. [1]In order to show that the gravity center gives us a minimum volume of copper, it is required:

- First, a change in the position of generator from a point O (0, 0) and
- Second a load position scanning across the surface.

The use of MATLAB software has helped us to verify and confirm the result.

Key words

Electrical gravity center, photovoltaic grid, distribution grid optimization, grid topology.

1. Introduction

Increased electrification needs, in the world, have created a new market for the industry. And solar energy has been a very important development that has allowed it to be an essential component of the modern economy.

Solar photovoltaic installations provide power to the isolated electrical grid systems. There are two types of PV system:

-Installations connected to the network.

-Autonomous installations.

Design, optimization and implementation of photovoltaic systems are topical problems. They surely lead to a better use of solar energy.[2]

One of these problems is the point where must be placed the photovoltaic generator relative to the loads.

The network should be optimized to minimize operating costs of installation. For that we will try to answer questions that arise and which are:

How to build and maintain the network at a lower cost?

The position of the PV generator minimizes the installation cost. How can we get this position? And what is its influence on the minimization of the cost?

The determination of the gravity center is very widespread in the calculations and dimensioning of electrical grid, but its physical meaning and its influence on the network topology is not very well known.

The aim of our work is to find the physical explanation of the electrical gravity center and to use it in the optimization of an electrical grid supplied by solar generators.

2. Mechanical gravity center

A. The mechanical moment[3]

1) Physical definition

The moment of a force is a physical phenomenon which causes the rotation or stopping of the rotation or twisting of a piece.

2) Calculation of the moment

- Using the lever arm

$$\|\overrightarrow{M_A}(\overrightarrow{F})\| = \|\overrightarrow{F}\| \cdot d \quad (1)$$

$\|\overrightarrow{M_A}(\overrightarrow{F})\|$: The moment's module (N.m),

$\|\overrightarrow{F}\|$: The module of the force (N),

d : Distance(m).

Recall that for a solid balance:

$$\sum_{i=1}^n \vec{M}_A(\vec{F}_i) = \vec{0} \quad (2)$$

B. The mechanic gravity center

In physics, the gravity center is the application of the resultant force of gravity or gravity points. Thus, it is clearly dependent on the gravitational field in which the body is subjected. [4]

In Static, the gravity center is the application's point of weight.

Calculating the position of gravity center

$$p_{tot} = \sum_i^n p_i \quad (3)$$

p : Weight (kg)

$$M_{tot}^o = \sum_i^n x_i p_i^o \quad (4)$$

M_{tot}^o : Total moment from the point O.

The sum of moments at GC is zero.

$$x_{CG} = \frac{\sum_i^n x_i p_i^o}{\sum_i^n p_i} \quad (5)$$

x_{CG} : Position of gravity center.

The gravity center position in space: [5]

$$\mathbf{x}_{CG} = \frac{\sum_i^n x_i p_i^o}{\sum_i^n p_i}; \quad \mathbf{y}_{CG} = \frac{\sum_i^n y_i p_i^o}{\sum_i^n p_i}; \quad \mathbf{z}_{CG} = \frac{\sum_i^n z_i p_i^o}{\sum_i^n p_i} \quad (6), (7), (8)$$

3. Electrical gravity Center

In the case of electrical moment, we replaced the weight by the electrical power and found:

$$M_{e.tot} = \sum_i^n x_i \cdot p_i \quad (9)$$

Where:

M_e being the electric moment (m.A) for a group of charges in which the Cartesian coordinates of each load are known.

At The gravity center, we have:

$$\sum_i^n \vec{M}_e = \vec{0} \quad (10)$$

The Calculation and design of the electrical network in the plane(x, y) is given by:

$$\Leftrightarrow \begin{cases} \sum_i^n (x_i - x_{CG}) p_i = 0 \\ \sum_i^n (y_i - y_{CG}) p_i = 0 \end{cases} \quad (11)$$

We will therefore have

$$x_{CG} = \frac{\sum_i^n x_i p_i}{\sum_i^n p_i} \quad (12)$$

$$y_{CG} = \frac{\sum_i^n y_i p_i}{\sum_i^n p_i} \quad (13)$$

(X_{CG}, Y_{CG}) electrical gravity's center position, (X_i, Y_i): the position of i^{th} charge in the site, n the number of loads established on the site and P represents the consumption by the i^{th} charge.

If we consider that the voltage is constant and all charges have the same number of phases, we can write:

$$M_e = l \cdot p \rightarrow M_e \approx l \cdot u \cdot I \quad (14)$$

I: the current value (A), u:the voltage (V).

$$M_{e.tot} = \sum_i^n l_i I_i \quad (15)$$

4. Physical meaning of gravity center

To understand the physical meaning of the gravity center and show its importance, we have performed several calculations of many examples using MATLAB, to see the influence of generator's position on the volume of copper and electrical losses in the cables, because these two parameters are needed to optimize the cost of a network.

The volume of copper used can be calculated by the following equation:

$$V_i = s_i \cdot l_i \quad (16)$$

Where V_i represent the volume of copper used in the i^{th} cable.

Joule losses in the cables are calculated using the equation (17) [7]:

$$P_i = R_i I_i^2 = \frac{l_i \cdot \rho \cdot I_i^2}{s_i} \quad (17)$$

Where P_i represent joule losses of the i^{th} cable (Watt). R_i being the electrical cable's resistance.

The equation (18) is used to calculate the length of the cables connecting the load with the supply power:

$$l_i = ((x_i - x_{CG})^2 + (y_i - y_{CG})^2)^{1/2} \quad (18)$$

For a maximum voltage drop authorized, the cross section of each cable connected to the solar generator is given by the equation (19) [6]:

$$s_i = \frac{\sqrt{3}}{\Delta u} \rho \cdot \cos \varphi \cdot I_i \cdot l_i \quad (19)$$

Where:

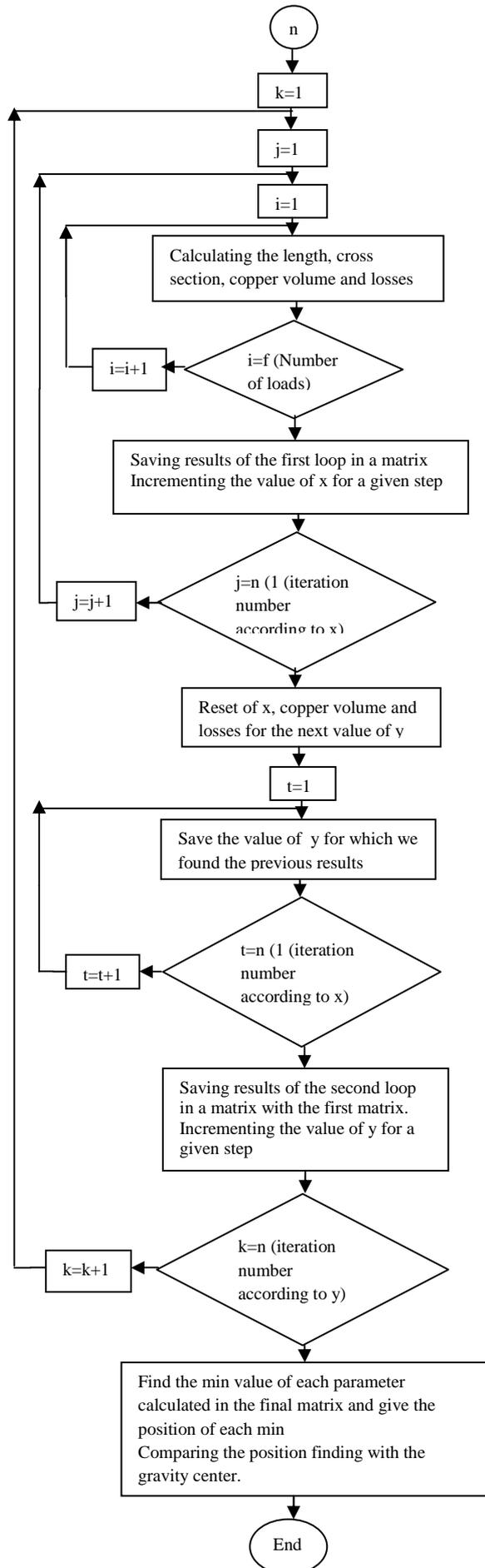
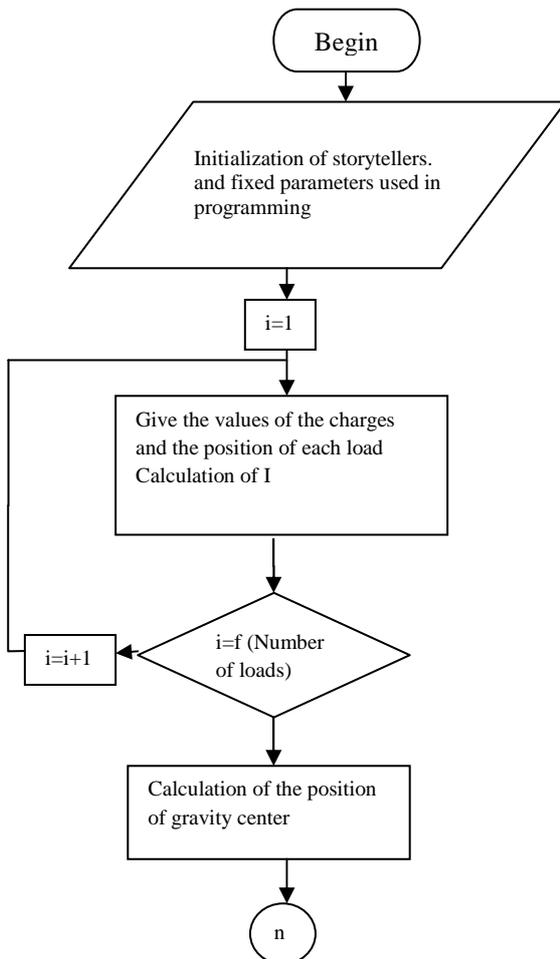
Δu is the maximum voltage drop authorized.

Regarding copper material where $\rho = 22.5\Omega \cdot m$,

A- The calculation method

We have calculated the length, cross section, volume of copper and losses, using all the generator's positions covering the entire surface limited by the electrical loads, to demonstrate that the smallest volume of copper is at the gravity center. We found that the gravity center position corresponds to the minimum copper volume.

The calculation method is presented in the following flowchart:



The Examples treated using MATLAB programming, confirm that the quantity of copper is optimal at the gravity center.

B- Example of calculation

Among the treated examples, we present a site of five loads.

Tab.1.Calculated lengths, cross sections, volume of copper after optimization of solar generator position

P(w)	I(A)	X(km)	Y(km)	X0(km)	Y0(km)	L(km)	s(mm ²)	V _{min} (10 ⁴ cm ³)	V _{max} (10 ⁴ cm ³)	X _{max} (km)	Y _{max} (km)	cos
32000	46.243	0.055	0.55	0.317	0.297	0.364	49.53	3.5615	13.2239	0.000	0.000	0.8
37000	53.468	0.505	0.055			0.306	47.912					
18000	26.012	0.505	0.505			0.279	19.868					
24000	34.682	0.305	0.285			0.017	1.612					
25000	36.127	0.255	0.195			0.12	11.61					

Table 1 contains: the power of each load is represented in the first column, the x and y position's loads in columns 3 and 4, the position of gravity center in column 5 and 6, the minimum volume of copper in column 9, the value of the maximum volume in column 10 and its position in the column 11 and 12.

In this example, we found that at the center of gravity, the volume of copper was minimum, and the maximum volume was in the position (0,0), a reduction of approximately 26% of copper volume, used in cables, is then estimated.

5. Conclusion

- The results show that the gravity center position is optimal from the standpoint copper volume that minimizes the fixed cost of network. The position of the solar generator is therefore found.
- In this position, a very significant reduction of copper used is found which allows to reduce the price of cables
- But to win on the economy savings and energy efficiency, we must balance the costs of joule losses and copper used in cables, while the gravity center does not meet to minimum losses, because the cross sections calculated are a minimum for each cable that gives us very great losses. The sections can be increased to optimize losses, but in order to keep the copper volume reasonable. It is the study of our group that may be presented at the same conference.

So we must look for the most optimized total cost of copper volume and the losses, keeping the position of generator in the gravity center.

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