International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

Optimal Location of Investors in Large-Scale Photovoltaic Generators using Clustering Techniques

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Abstract: ***This article presents the state of the art of an unapplied investigation for an optimized deployment in investment units, to decrease the number of elements implemented, elements that allow changing the characteristics of the currents from Dc to Ac, assuming scenarios of 3000, 5000 and 6000 photovoltaic modules. We assume an arbitrarily georeferenced scenario to determine the distances between the elements that are part of this system and locate an optimal centroid, so that the location of these does not depend solely on the panel layout, voltage or power, but also varies depending on the distance; therefore, through this research, a location model is proposed that has not yet been implemented...***

Keywords: Location, inverter, clustering.

1. Introduction

Throughout history and thanks to the constant development of humanity, electric power has become as one of the most important resources & necessary for trade, comfort and well-being of the population, because it is one of the most versatile forms of energy and best adapted to each need, that's why the electric energy plays a fundamental role for the advancement and sustainable development, of the different nations[1], making that the continuous and reliable supply to users wherever they are is of great importance[2].

Some of the widely used and common systems for the production of electrical energy have an associated problem, for example, in hydroelectric power plants there are problems thanks to the greenhouse effect and climate change, because they make droughts more and more prolonged due to stable production cannot always be guaranteed[3]. In thermal power plants they use fossil fuels, which are a time-limited resource, in addition to producing large amounts of greenhouse gases[4] and nuclear power plants have the problem of eliminating the waste generated, in addition to the potential risk of a nuclear accident. The production of energy leaves a great ecological impact and for that in the world there has been a great effort to diversify the sources that make up the energy matrix, giving great clean alternative photovoltaic energy[5], [6] the solar cell behaves like a diode, the part exposed to solar radiation is N and the part located in the dark zone is P[7] and the set of these cells form the photovoltaic panel.

Systems which are composed of the main element that is the generator, which is also called as solar cell, it is characterized by directly converting photons from sunlight into electricity, effect that was discovered by Albert Einstein and published in one of his articles 'A heuristic point of view on the production and transformation of light'[8]
The proposed location technique should not affect the observability criteria of the photovoltaic generator, to achieve an observable system it is necessary to implement heuristic optimization algorithms, which can be genetic algorithms (GA), taboo search (TS), but the one selected for the development of this research is graph theory(GT)[9] and its most common grouping techniques are the k-means and k-medoids algorithms. In this document, an analysis of the optimum of the photovoltaic inverters has been carried out, which have been implemented by each panel, in small systems or according to the parallel series arrangements, this document of optimal realization of the location of these inverters for reduce the number of inverters to enable the installation of fewer of them, in order to improve investment criteria. In order to apply these distance-dependent algorithms, an arbitrary georeferencing of them is taken to locate the best possible center, centroids or nodes in the characteristics of the phasor voltage and current are the same. Hereinafter this document is made up as follows. Section 2 is an introduction to graph theory and grouping techniques, section III describes the formulation of the problem and results.

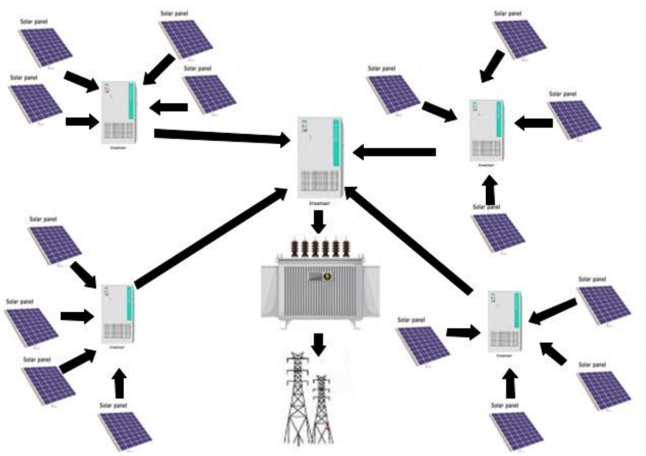

Figure 1: Representation of the model proposed

2. Clustering Techniques

Graph theory is a branch of mathematics that has been used in different ways to study various electrical systems[10] which has many applications, among the most outstanding are the adequate grouping of articles with similar characteristics and optimization of resources. The techniques based on distances that are of interest and that have been chosen to implement in the present investigation are in the present investigation are k-means and k-medoids[11].

2.1 K-means algorithm

This is a technique in which the variables are quantitative and the Euclidean square distance is different between each of its elements. The elements that are part of the system have a minimum Euclidean distance and have similar characteristics, given by

$$d(x_i, x'_i) = \sum_{j=1}^{p} \left\| x_i, x'_i \right\|^2 \quad (1)$$

Where:

$d(x_i, x'_i)$; it represents the Euclidean square distance.

x_i ; it represents the starting point.

x'_i ; it represents the starting point.

p ; it represents the number of elements in the universe to study.

Then the k-means algorithm is detailed:

Table 1: K-means algorithm

Step 1	Initialization center clusters u_i = some value; i = 1, 2, …, k
Step 2	Selection centroid closer to each element $c_i = \left\{ j : d\left(x_j, u_l\right) \le d\left(x_j, u_i\right), l \ne i, j = 1, \dots, n \right\}$
Step 3	Establish the elements of each cluster $u_i = \frac{1}{\lvert c_i \rvert} \sum_{j \in c_i} x_j, \forall i$
Step 4	Repeat from step 2 and 3 to converge

When the algorithm converges, it is not the case that the selected point has been minimized, because the algorithm is a heuristic of a non-convex node, this ends when the values do not change value between one iteration and another[9].

2.2 K-medoids algorithm

This clustering technique is similar to the previous view, but instead of observing the centroids, they are medoids, which are no more than an element of the cluster being spread, the central object[9] highly related to the aforementioned algorithm k-means and medoidshift, both try to minimize the distance between the points that would be added to a group and another point designated as the center of that group,
In this technique, not only can the Euclidean square distance be used, but also the circular distance can be used using the Haversine formula, that is, not only the application of plane universes is possible, but also the application of spherical universes that in the same way must be geo-referenced distances, finally it's given by

$$a = \sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos(\varphi_1) * \cos(\varphi 2) * \sin^2\left(\frac{\Delta\gamma}{2}\right) \quad (2)$$

$$c_i = 2 * \mathrm{a}\tan\theta\left(\sqrt{a}, \sqrt{1-a}\right) \quad (3)$$

$$d\left(\varphi, \gamma_1; \varphi, \gamma_2\right) = R * c \quad (4)$$

Where

$\Delta\varphi$; Represents the change in latitude between two locations.

Δy; Represents the change in longitude between two locations

φ; Represents de latitude

y; Represents the longitude

R; the radius of the earth

$d\left(\varphi, \gamma_1; \varphi, \gamma_2\right)$; is the distance between two georeferenced

Table 2: K-medoid algorithm

Step 1	Initialization center clusters u_i = some value; i = 1, 2, …, k
Step 2	Selection centroid closer to each element $c_i = \left\{ j : d\left(\varphi, \gamma_j; u_l\right) \le d\left(\varphi, \gamma_j; u_i\right), l \ne i, j = 1, \dots, n \right\}$
Step 3	Establish the elements of each cluster $u_i = \frac{1}{\lvert c_i \rvert} \sum_{j \in c_i} \varphi, \gamma_j, \forall i$
Step 4	Repeat from step 2 and 3 to converge

The main difference between these two grouping algorithms means that k is its centroid located at the center of mass in the universe of elements that belong to the group and the center does not necessarily have to be one of the elements, instead the medoid is one of the cluster elements[9].

3. Formulation of the Problem and Results

In the formulation of the problem, it is assumed that all the nodes found in the system are feasible for the installation of fewer inverters, once each of the centroids has been verified, the observability of our system is verified so that it has not been affected using the following criteria

It is feasible to place the inverter after the voltage values of all the nodes have been verified, and that they comply with the voltage drop requirements, since the installation of this equipment normally depends on variables, such as voltage, power and current. , but it can be seen that when dealing with very large systems the distance plays an important role, by reducing the number of nodes we have optimized the number of elements to be installed, meeting investment criteria referring to the number of installed inverters. When entering the variable distance, the different sections of the conductors can change and different measurements of the conductor cable and section will be used, if the voltage is affected it means that it is not observable, a case that was not presented in the present investigation.

3.1 Comparison

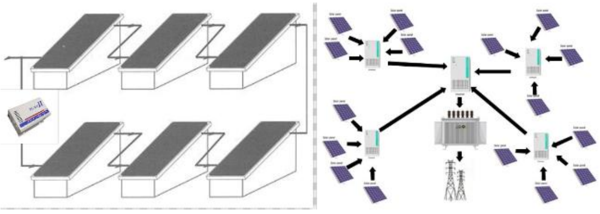

Figure 2: Comparison of traditional vs proposed model

If we compare the traditional implemented model that depends on the type of arrangement or arrangement of panels[12], for very large systems, the implementation system of inverters by arrangements, for the proposed scenarios of 3,000, 5,000 and 6,000 photovoltaic modules, we should install a number of investors, making the proposed model optimal in terms of the number of elements installed, which in cost criteria will be optimal the proposed model.

3.2 Centroid failure or abnormality

Due to unforeseen changes in the topology of the centroid, that is, if said inverter should fail, the backup one should be together, since changes in the position of the centroid will not meet the criteria of optimal location, this article endorses said criteria since for the observability analysis, this document is carried out using only analytical methods.

4. Conclusions

The implemented algorithms responded very well, giving an optimal solution regarding the number of investors, which was the objective of this investigation. Furthermore, the complexity of these extremely large systems means that electrical parameters need to be measured in real time to verify their observability.

It has been shown that grouping techniques can be used to optimally locate photovoltaic inverters, reducing the number of elements installed giving a possible cost optimization.

In the event of contingencies, a backup inverter will be located in the same determined position, since a change in position or georeferencing will probably not meet the parameters of an optimal centroid.

When comparing the scenarios, from the traditional installation of the photovoltaic inverters, between the installation by series-parallel arrangement, it could be determined that the proposed model considerably reduces the number of elements installed.

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Author Profile

Kevin Villacis, born in the city of Quito, Ecuador, in 1997, is also a recently graduated student of the electrical engineering career at the Salesian Polytechnic University, hopes to complete his degree soon, in addition to hoping to contribute with research

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