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Optimization of distribution networks supplied by photovoltaic sources, using a new optimal loads distribution center method

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ABSTRACT

This paper shows a new method for optimization of the general investment cost in a distribution network supplied by solar photovoltaic (PV) source. This method consists of first, determining, the optimal cross sections for electrical cables used between solar generator and loads and second, find the optimal placement of loads distribution center such that the cost sum of installation and exploitation, of the investment, are considerably reduced to its optimal value. Particular method has been presented in previous study, where the optimization of the solar generator placement, is based on network having identical cables cross sections. However, our work was performed on the general case in view of the influence of technical and economical cable cross sections, operating hours or time periods of loads and the possibility to use more than one solar generator with several separated networks. The supply point that corresponds to the lowest general investment cost is referred as the Optimal Loads Distribution Centre "OLDC" which can also be referred to the Optimal Volume Center "OVC" if the exploitation details are not known. The OLDC method was applied on several examples, one of the most general and difficult case is presented in this article. The results of the analysis are found satisfactory since the adoption of the optimal number of loads distribution centers in their optimal places, taking into account the operating hours of loads with time periods, helped reducing drastically the general cost of the investment.

Contents

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1. Introduction

Nowadays, when energy becomes a major issue, both from the perspective economic and ecological, it is imperative to make every effort for holiest energy production systems [1]. Indeed, the oil and gas resources are expected to be exhausted, even though at present they are a real benefit for our country [2]. Nevertheless, in the long term, Algeria should use solar sources of energy; especially since it has the largest solar field in the Mediterranean basin [3,4].

In spite of its simplicity of implementation, its weak environmental impact and the low maintenance, which it requires, a PV system is not competing any more when energy request increases, thus a rigorous study is necessary to make the best choice with the lowest possible costs [5].

As from the moment when it is possible to implement solar collectors on a site, the choice of PV generator is essential, in order to create a suitable topology of a distribution network, so it is important to be able to optimize the three parts of the system: loads, generators, and networks.

The purpose of this paper is the optimization of the solar distribution network and its loads distribution center for rural or tertiary zone by proposing the new general method "OLDC" for determining the optimal sections of electrical cables and the optimal position of the loads distribution center that corresponds to the lowest general cost (installation cost+exploitation cost).

The solar distribution network in these zones is large with many and long electrical cables; which causes an important energy loss, moreover lines losses imply a significant increase in the number of modules to be used, and thus will result in an increase in the general cost. This situation will force the designer to imperatively reduce these losses [4].

In the literature, there is a method to reduce these energy losses for a particular case of network with identical cables cross sections. It is achieved using the technique of load distribution center "LDC" that involves the method of determining the center of electrical gravity of all the loads [6,7]. However, the OLDC method was performed on a general case, to find the optimal cross sections for the electrical cables used between solar generator and loads and to locate the position of the OLDC that corresponds to the lowest general cost. For this reason, the technical and economical choice of cable cross sections, the operating hours of loads (time periods) and the utility of using several separated solar networks have taken into account for the sake of a better analysis.

2. Technical cross sections choice (S_{tec})

Based on the network topology, for a given position of loads distribution center, the cables cross sections were determined according to loads current using the well-known engineering method. Indeed the standards of an electrical installation require that the cable must support [8]: the design current (operating current (I_b)) [9,10], the short circuit current (I_{sc}) until the protection intervention [11] and the cable must also verify the authorized voltage drop [12].

There is respectively for each of these three cases, a permanent section (S_p) [9,10,13], a short-circuit section (S_{sc}) [14] and a voltage drop section ($S_{\Delta v}$) [14,15]. The technical cross section (S_{tec}) will be selected as the maximum value among S_p, S_{sc}, and $S_{\Delta V}$ [8].

If the cable is not sized properly, the small cross section will cause an overheating and a loss of power, the excessive cross section may cause a cost problem. Therefore, it is important to select the technical cross section that covers the three installation conditions. This technical section will be normalized by choosing a standard section, larger and closer than it.

3. Optimization of cables installation cost

The optimization of the installation cost of cable (purchase and placing up) is carried out by the optimization of the copper quantity [15]. Indeed, there is a direct relationship between the installation cost and lengths and sections of cables.

For every loads distribution center position, starting from an origin, covering the entire surface limited by loads, we calculate: the lengths of the cables (L), the technical cross sections (S_{tec}) and then the copper volume of all cables ($\sum_{i=1}^{n} L_i \times S_{teci}$). The load distribution center position which corresponds to the minimum copper quantity is called optimal volume center "OVC". This position can be the electrical gravity center if the technical cross sections are calculated according to cables voltage drop sections only [6,7,15].

The minimum of copper quantity means the least cables installation cost. Then one can say that the OVC allows us to optimize the cost of cables for the complete installation, by optimizing the quantity of copper by taking into account the adequate technical cross sections.

The determined technical cross sections for each cable in this position are the smallest technically acceptable. However, the losses have maximum value means that the exploitation cost is also high [16]. In case, the exploitation details are not known (the loads curve, the load operating hours…..etc.), we should stop in this step, then the general cost optimization will be linked with the installation cost optimization, and the OLDC will therefore be the OVC.

4. Optimization of exploitation cost

In this step, where the loads distribution center is placed in the O.V.C. and the cross section of each cable is the minimum technically acceptable; the cable resistance is then maximum as shown in Eq. (1) [17,18].

$$R = \frac{\rho L}{S} \tag{1}$$

R. conductor resistance, Ω.
ρ. electrical resistivity, Ω mm²/km.
L. cable length, km.
S. cable section (technical cross section, mm²).

Thus, for a given intensity I, the energy losses ($R \times I^2$) [19] are at their maximum, however the reduction of these losses is carried out by an increase in the cross sections of the electrical cables, which can lead to decrease the cables resistances and then decrease the exploitation cost. Indeed, by increasing the cross sections of electrical cables, the electric losses decrease, whereas