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Selection and configuration of inverters and modules for a photovoltaic system to minimize costs

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A B S T R A C T

The photovoltaic (PV) systems have become an option to reduce utilities costs for many social sectors. For a PV system design, the correct selection of the inverters and PV module could reduce the initial investment. The designer of these systems runs up against the difficult dilemma of selecting an adequate components combination. With many challenging restrictions, the purchasing costs of the system could be last priority. The suggested selection of these components with the objective of minimizing costs is established as a linear programing problem. The model that is formulated minimizes the purchasing costs of inverters and PV modules for a required capacity by selecting the appropriate combination of them given a list of models with its specifications. Also, it provides an array configuration of the proposed solution in order to meet all the design requirements. Results obtained show that using this model the purchasing costs can be reduced by 16.45% of a 10 kW PV systems kit available in the market on April 2013.

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1. Introduction

The photovoltaic (PV) systems have become an option to reduce utilities costs for many social sectors [1]. One of the essential components of PV systems is the PV modules. The PV modules convert the solar energy into electric energy [2]. This electric energy will have a direct current (DC) electricity flow. Most of the power electric systems of the society, including common electric grid, work with an alternative current (AC) electricity flow.

An inverter is integrated as an indispensable component to the PV systems in order to convert the DC electricity of the PV module output into AC electricity for the electric grid. The inverter is an electronic device that uses principles theory of power electronics to transform the DC voltage into AC voltage compatible in frequency, and others characteristics, with the grid [3]. Fig. 1 shows a

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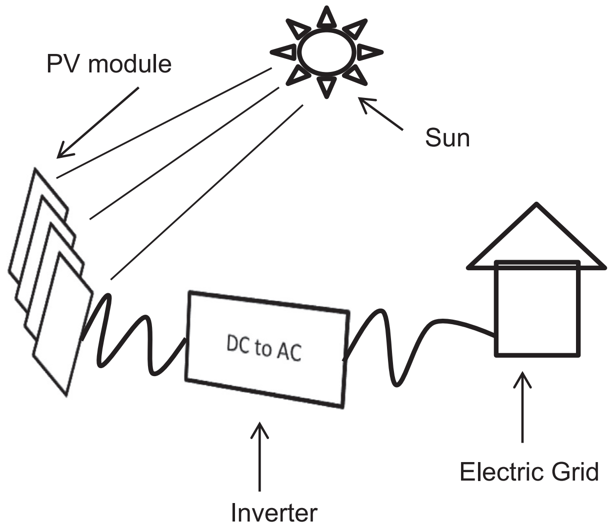

Fig. 1. Conceptual diagram of a PV system.

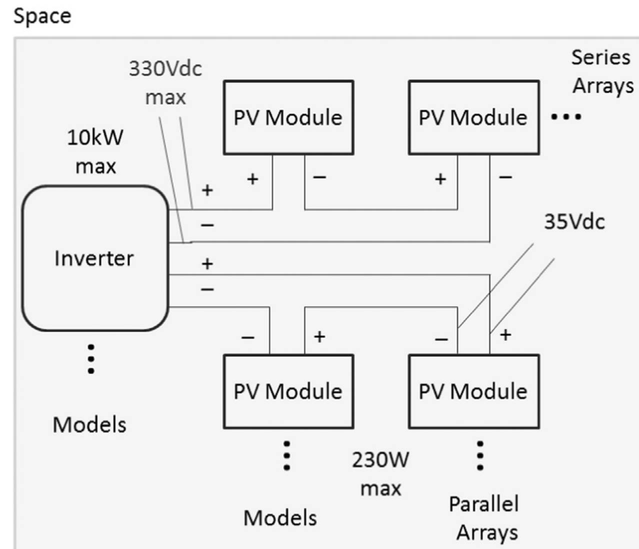

Fig. 2. Hypothetical example of a PV system.

conceptual diagram for a PV system. The sunlight reflected over the PV module is converted to DC electricity. Then the inverter converts the DC voltage of the PV modules into AC voltage compatible to the electric grid, for instance to use it in home appliances.

While a PV system has other components likes cables, breakers, fuses, and lightning rods, among others, the inverters and PV modules are likely to make up the major part of the PV system's costs [4,5]. For instance, fifty percent of total life cycle PV plant maintenance costs for SunPower's managed PV fleet are related to the inverters replacement reserve [6].

The battery system is not contemplated as a component of the PV system due to the net metering service that could be offered by the utility services provider. A net metering service of a utility would supply power for their clients when they need it, for example, to supply power during the night. Restricted by the electric design, a period of time when this power exchange will be zero is established [7]. That being said, a correct selection of the inverters and PV module in a PV system design could also reduce the initial investment of PV systems using batteries.

1.1. Problem description

When an engineer wants to design a PV system, he or she is presented with the difficult dilemma of selecting the adequate inverters and PV modules models. This models' selection needs to considerate many factors, for instance, electric specifications, space limitations, and different parameter's constraints depending on the inverters and modules combinations [8,5]. Design specifications include maximum DC voltage of inverters' input, power capabilities of PV modules, PV array configuration, and electric restrictions according with the National Electric Code, equipment brands, among others.

With this kind of challenging restrictions the models costs could be last priority. The optimal selection of these components with the goal of minimize costs is established as a linear programming problem. The objective of this model is to minimize the purchasing costs of inverters and PV modules for a required capacity by selecting the appropriate combination of them for a given list of models with their specifications. Also, this model suggests an array configuration for the proposed solution in order to meet all the design requirements.

Fig. 2 illustrates a hypothetical example of a PV system with a 10 kW inverter that have a maximum input voltage of 330 V and PV modules of 35 V. The system capacity could be estimated with the number of modules connected in the systems. The input voltage of this type of inverter restricts the maximum numbers of module that could be connected in a series configuration. For example, three modules connected in series configuration will have a $(35)^*(3)^*(1.25)=131.25$ V according with the National Electric Code [9]. The 131.25 V is an acceptable series configuration for the inverter maximum input voltage because it is smaller than 330 V. With this in mind, electric parameters, models specifications, models combinations, arrays configurations, available space, and maximum acceptable weight are some of the factors in consideration when an engineer wants to design a PV system.

The PV systems initial investment is one of the reasons why people with interest in this kind of technology often get discouraged to make the decision of installing it [10]. There exist other options as the green loans and power purchasing agreements with an external investor. However, an optimal selection of the inverters and PV module could offer the best deal available in the market.

Another reason that inspired this research was the constant variation of inverters and PV modules models in the market [11]. About every six to eight months these models begin to be obsolete or superseded by competing with new models that have higher specifications. More than that, this type of market is fairly new with many brands and models that come in and out of the marketplace continuously. This aims to have a programming tool in order to calculate the optimum array depending on the models available in the market when a decision has to be made.

Also, it aims to formulate this problem as a lineal programming problem to minimize costs, given a required PV system capacity, instead of maximizing the power generation of the PV system. Simultaneously, it is expected to provide the PV designer a tool that considers the economic aspect of the available models that are taken into consideration. This ensures a connection between economics and design factors of this kind of system designs.

1.2. Literature review

This review was divided in two optimization approaches; cost minimization and power maximization. Both approaches search to improve the PV design considering different contains and factors. Few studies were found with the objective to minimize costs by comparing equipment prices. Multiple inverter systems could