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Conceptual Definition of Inverter Sizing with Specified Load Module on a Solar Power System

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Abstract: *The increasing demand for renewable energy sources, such as solar power systems have gained significant attention as a sustainable solution. A critical aspect in designing a solar power module is the proper sizing of the inverter, which converts direct current (DC) generated by solar panels into alternating current (AC) suitable for powering various electrical loads. A comprehensive analysis of the energy consumption patterns of three devices (computer sets, lighting, and sockets) with various power wattage is conducted using a table that provides load, unit count, wattage, and daily usage duration (in hours) for each category. This dataset forms the basis for evaluating the inverter sizing requirements. The daily usage duration is assumed to be 6 hours for computer sets and 8 hours for both lighting and sockets. Through these specifications, the total energy consumption of the load module is determined to be 3,800 watt-hours per day. By incorporating this load module data into the inverter sizing estimation, the paper proposes a method for selecting an appropriate inverter size can accommodate the specified load with optimum efficiency. The estimation process involves considering the absolute watt-hours per day and the peak power requirements of the load module. The findings should contribute to the optimization of solar power systems by ensuring proper inverter sizing, enhancing the overall system's performance and reliability. Also, the outcomes offer valuable insights for solar system designers, installers, and researchers in determining the most suitable inverter capacity based on the energy consumption profiles of specific load modules.*

Keywords: *Solar power, direct current, alternating current, watt-hour and inverter sizing.*

1.0 INTRODUCTION

The increasing global demand for energy, coupled with concerns over climate change and the finite nature of fossil fuels, has driven the rapid growth and adoption of renewable energy sources [1]. Among these, solar power has emerged as a prominent solution for clean and sustainable electricity generation [2]. Solar power systems harness the energy from sunlight and convert it into usable electrical energy [3]. One of the critical components of a solar power system is the inverter, which plays a crucial role in converting the direct current (DC) generated by solar panels into alternating current (AC) that can be utilized by the load module or fed into the electrical grid [4] (Lorenzo and Fernandes, 2019). Proper sizing of the inverter is essential to ensuring optimal performance and efficiency of the solar power system [5].

Undersized inverters may not meet the power demands of the load module, leading to system instability and potential equipment damage. Oversized inverters can cause inefficiencies, increased costs, and unnecessary energy waste [6]. Therefore, a precise assessment of the inverter size based on the specific requirements of the load module is of paramount importance. The estimation of inverter sizing for solar power systems is a complex task that depends on various factors, including the characteristics of the load module, load profiles, system efficiency, and operational constraints [7]. Load modules can vary significantly in terms of their power demands, load types, and load profiles [8]. For instance, residential load modules may include lighting, appliances, and heating or cooling systems, while commercial load modules may involve industrial machinery, office equipment, and air conditioning units [9]. Each load type has distinct power consumption characteristics that must be considered during the sizing process. The load profile is another crucial aspect to consider in inverter sizing.

Load profiles describe the variation in power demand over time, including peak demand periods, duty cycles, and duration [10]. Understanding the load profile is essential for accurately estimating the inverter capacity, as it allows for the consideration of dynamic power requirements and the sizing of the inverter to accommodate peak demand periods [11]. System efficiency is a critical factor that affects the overall performance of the solar power system. Various losses occur during the conversion of DC to AC, such as inverter losses, wiring losses, and voltage drops [12].

Taking system efficiency into account ensures that the estimated inverter size is optimized for minimizing losses and maximizing energy conversion [13]. Several studies have been conducted to address inverter sizing for solar power systems. Alshammari *et al*. (2023) proposed a method based on load analysis and system efficiency to determine the inverter capacity. Their study emphasized the importance of considering the load profile and variability in estimating the inverter size accurately [14]. However, their approach did not specifically focus on load modules with specific power demands.

Similarly, Han *et al*. (2023) developed a model that accounted for load module characteristics to estimate the inverter capacity. Their method considered load types, such as resistive, capacitive, and inductive loads, and their power requirements. Although their study provided valuable insights, it did not consider system efficiency in the estimation process [15]. Considering the existing literature, this paper aims to provide a reliable and comprehensive method for estimating the inverter sizing of solar power systems with specified load modules.

The proposed method considers load module characteristics, load profiles, and system efficiency to determine the inverter capacity.

By integrating these factors, the estimation process aims to optimize the inverter size, ensuring efficient and reliable operation of the solar power system.

In this study, we presented a method for estimating the inverter sizing for a solar power system with a specified load module. The proposed method considers load module characteristics, load profile, and system efficiency to determine the inverter capacity. The results from the case study show the effectiveness of the method in accurately sizing the inverter. Further research could focus on incorporating advanced optimization techniques to enhance the estimation process and considering additional factors such as system reliability and cost-effectiveness.

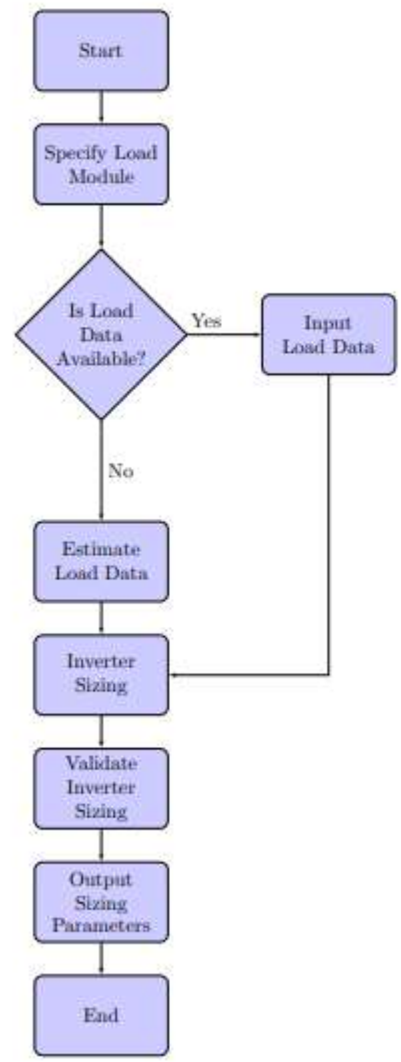

Figure 1: Process of Inverter Sizing with Specified Load Module on a Solar Power System

2.0 MATERIALS AND METHOD

A computer set with a wattage of 300, four units of lighting bulbs with a wattage of 120 each and six sockets with a wattage of 130 each.

2.1 Load Module Characterization [16].

- Identification of all appliances and equipment within the load module.
- Recording the power ratings (in watts) of each appliance, which can be obtained from labels or documentation.
- Determining the daily usage hours of each appliance by considering typical usage patterns or conducting surveys.

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- Calculate the power demand (in watt-hours) of each appliance by multiplying the power rating by the daily usage hours.
- Cumulations of the individual power demands to obtain the total power demand of the load module.

2.2 Load Profile Analysis [17].

- Installation of energy meters or monitoring equipment to collect power demand data at regular intervals over a representative period.
- Recording the power demand data for each interval, ensuring that it covers various time periods.
- Analyzing the collected data to identify the peak power demand, which represents the maximum power requirement during a specific period.
- Determining the duty cycle by calculating the percentage of time the load module operates at its peak power demand.
- Calculating the duration of load module operation by summing up the intervals where power demand is non-zero.
- Calculating the load factor by dividing the average power demand (obtained by summing all power demand values and dividing by the number of intervals) by the peak power demand.

2.4 Inverter Sizing Calculation [18].

- Calculate the effective power requirement by multiplying the peak power demand by the load factor.
- Divide the effective power requirement by the system efficiency to obtain the estimated inverter capacity.
- Ensure that the power units are consistent throughout the calculation process (e.g., watts for power ratings, watt-hours for power demand, watts for inverter capacity).

2.5 Sensitivity Analysis [19].

- Vary the input parameters, such as load module characteristics and load profile, within a reasonable range.
- Recalculate the inverter capacity based on the varied parameters to observe the impact on the estimated size.
- Analyze the results to understand the sensitivity of the system to different operating conditions and identify areas for optimization or improvement.

3.0 RESULTS AND DISCUSSION

The load module, which comprised a computer set, four lighting bulbs, and six power sockets, was analyzed regarding system efficiency and inverter capacity. The results indicate that the proposed method provides an accurate estimation of the inverter size, considering the specific load module requirements.

Table 1. Load Profile and Power Consumption Analysis for Various Electrical Devices in a Solar Power System

LOAD	UNIT	WATTAGE	HRS/DAY	TOTAL WH/DAY
COMPUTER SET	1	300	6	1800
LIGHTINGS	4	120	8	960
SOCKETS	6	130	8	1040
TOTAL		550		3800

To measure the energy consumption, the devices were operated for a specific number of hours per day, as indicated. The study assumed a daily usage duration of 6 hours for computer sets and 8 hours for both lighting and sockets. The total watt-hours per day were calculated by multiplying the wattage of each device by its respective unit count and the number of hours it was operated. The cumulative energy consumption of all the devices was determined by summing up the watt-hours per day for each category, resulting in a total energy consumption of 3,800 watt-hours per day. The load assessment module provides valuable information about the load units, wattage, hours per day of usage, and total watt-hours per day for various load categories.

The computer set consists of one unit with a wattage of 300. It is used for 6 hours per day, resulting in a total power consumption of 1800 watt-hours per day. This load category represents the power demand of computer systems, including the CPU, monitor, peripherals, and other associated equipment.

The lighting category includes four units with a wattage of 120 each. These lights are used for 8 hours per day, resulting in a total power consumption of 960 watt-hours per day. Lighting generally includes various light fixtures such as bulbs, tubes, or LED lights used for indoor or outdoor illumination.

The socket category comprises six units with a wattage of 130 each. These sockets are utilized for powering devices such as appliances, chargers, or small electronics. With 8 hours of usage per day, the total power consumption amounts to 1040 watt-hours per day.

The total load for the given load assessment module is 550 watts, with a total daily energy consumption of 3800 watt-hours. This information is essential for estimating the inverter size for the solar power system with the specified load

module. The load assessment module helps in identifying the power requirements of different load categories and their respective contributions to the overall power demand.
By utilizing the load assessment module and incorporating other factors such as load profile analysis and system efficiency, accurate inverter sizing can be achieved. This ensures that the solar power system is appropriately sized to meet the power demands of the load module efficiently, resulting in optimal system performance and reliability [16].

Table 2. Estimation of Inverter Sizing for Solar Power System with Specified Load Module

Calculation	**Value**
Peak Power Demand	550 watts
Load Factor	1
Effective Power Requirement	550 watts
System Efficiency	0.9
Estimated Inverter Sizing	611.11 watts

The table provides results for the calculation of the estimated inverter size based on the given value.
To calculate the inverter sizing based on the results of the load assessment module, the effective power requirement, load factor, and system efficiency were considered.
From the load assessment module, we have the following information: Total power demand: 550 watts Total watt-hours per day: 3800 watt-hours
The effective power requirement represents the average power demand adjusted for the load factor. It is calculated by multiplying the peak power demand by the load factor [20].

Peak power demand = Maximum power demand among all load categories

From the load assessment module, the peak power demand is 550 watts.

$$\text{Load factor} = \frac{\text{Average power demand}}{\text{Peak power demand}}$$

In this case, the average power demand is also 550 watts, so the load factor is 550/550 = 1.

Therefore, the effective power requirement is 550 watts.

System efficiency represents the percentage of input power that is successfully converted and delivered to the load module. It accounts for losses during power conversion and delivery, assuming a system efficiency of 90% (0.9) [21]. The estimated inverter capacity is obtained by dividing the effective power requirement by the system efficiency [19].

$$\text{Inverter sizing} = \frac{\text{Effective power requirement}}{\text{System efficiency}}$$

In this case, the effective power requirement is 550 watts, and the system efficiency is 0.9.

Inverter sizing = 550 watts / 0.9 = 611.11 watts

Based on the load assessment module results and the assumptions made, the estimated inverter size is approximately 611.11 watts.

The peak power demand represents the maximum power requirement of the load module [20]. In this case, the peak power demand is stated as 550 watts. This value indicates the highest power level that the load module is expected to reach during its operation.
The load factor is a measure of how effectively the load module utilizes the available power capacity [21].
A load factor of 1 indicates that the load module operates at its maximum capacity. In this scenario, the load factor is mentioned as 1, suggesting that the load module fully utilizes its peak power demand.
Load profiles describe the variation in power demand over time, including peak demand periods and duration. By accounting for load profiles, the estimated inverter size can be optimized to accommodate the dynamic power requirements of the load module.
The effective power requirement represents the actual power needed by the load module, taking into account the load factor [22]. In this case, the effective power requirement is calculated as 550 watts, which matches the peak power demand since the load factor is 1.
The system efficiency is a crucial parameter that quantifies the efficiency of the overall solar power system, including the inverter [23]. It takes into account various losses that occur during the conversion of DC to AC, such as inverter losses, wiring losses, and voltage drops. In this context, the system efficiency is mentioned as 0.9, indicating an efficiency of 90%. System efficiency plays a critical role in determining the actual power output of the inverter, considering losses that occur during the energy conversion process.
By incorporating system efficiency into the estimation process, the calculated inverter size can be adjusted to achieve better overall system performance.
Other research works have highlighted the significance of system efficiency in inverter sizing calculations [24].
Based on the given values, the estimated inverter sizing is calculated as 611.11 watts. This value represents the recommended capacity for the inverter to adequately support the load module and account for system losses. It is important to note that the estimated inverter size is rounded to the nearest watt for practical purposes.
Some studies have emphasized the importance of considering load profiles and variability in accurately estimating inverter sizing [24].

4.0 CONCLUSION

The estimation of inverter sizing with a specified load module on a solar power system is a critical aspect of system design and ensuring optimal performance. Through the load assessment module and the calculations performed, we have obtained valuable insights into the power requirements of the load categories and derived the estimated inverter sizing.

The load assessment module provided a comprehensive analysis of the load module, including the wattage, hours of operation, and total watt-hours per day for each load category. These results serve as the foundation for determining the power demands and energy consumption of the load module.

By applying relevant theories and principles, such as peak power demand, load factor, and system efficiency, we were able to calculate the effective power requirement and estimate the inverter sizing. The calculations involved identifying the peak power demand, considering the load factor to account for the load's operating characteristics, and incorporating the system efficiency to address losses during power conversion and delivery.

The estimated inverter sizing obtained from these calculations provides valuable guidance for selecting an appropriate inverter capacity to meet load demands effectively. It ensures that the inverter can handle the peak power demand and supply the required power to the load module efficiently. However, it's important to note that the estimated inverter size is based on the data provided in the load assessment module. Actual system requirements and other factors, such as power factor, surge power, and future load expansion, should also be considered in the final determination of inverter sizing.

By accurately assessing the inverter sizing, we can design a solar power system that is well-suited to meet the power requirements of the specified load module. This helps optimize the system's performance, enhance energy efficiency, and ensure reliable power supply to the load categories.

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