**Meeting Common Area Energy Needs in Multi-Dwelling Buildings with Photovoltaic (PV) Panels: Design and Calculations**

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| **Abstract**  In recent years, PV (photovoltaic) electricity generation has been installed especially on the roof areas of newly meeting the energy consumption of independent housing sections is not preferred very often due to insufficient roof space. However, the use of roof space for common areas of housing is frequently preferred. Increasing energy unit prices, together constructed buildings; in order to meet the energy consumption for common areas. In multi-storey residential buildings, with the necessity of electric vehicle charging station systems in parking areas, have increased the energy costs of common areas of housing. Although PV energy systems are suitable for increasing energy costs, the installation cost of PV systems is also high. For this reason, it is inevitable that calculations and designs for PV systems should be made with high precision accuracy. In this study, the design of photovoltaic (PV) electricity energy systems for multi-storey residential buildings is discussed. The installed power and demand power calculations, which are mandatory in the project preparation stages of the buildings, were made on the basis of the electric power table in the common areas and the necessary calculations were performed. In line with the demand power calculations, the energy power, number of panels, inverter capacity, cable sections of the PV system were calculated and a 2D design was created in the AutoCAD program. Then, the connection elements of the designed PV system to the main distribution panel inside the building were calculated and integrated into the design. As a result, the applicability of PV electrical energy systems in common areas of multi-storey residential buildings was demonstrated. The use of such systems has great potential in terms of environmentally friendly energy production and low energy costs. In addition, it will contribute to energy efficiency in future building projects by providing an important step towards sustainable energy solutions. In the future, equipping more buildings with such systems will be an important development in terms of energy independence and environmental sustainability. |
| Keywords: 2D Desing, AutoCAD, Demand Power, Photovoltaic(PV), Power Calculate, Sustainable Energy |

1. **Introduction**

In line with sustainable energy solutions, the necessity of environmentally friendly and low-energy-cost structures has become inevitable, considering current energy production and consumption costs. Consequently, the integration of renewable energy resources into buildings with structural features has been made mandatory during construction phases in many countries by governmental regulations. Türkiye is one of these countries [1]. According to the [1], at least 5% of the energy consumed in all buildings with an area of 5,000 square meters or more must be sourced from renewable energy resources. Suitable land for the installation of renewable energy systems is essential. High-rise buildings are predominantly located in urban areas and have limited available space. These areas are often insufficient for setting up renewable energy systems. Roof spaces, however, are the most suitable area for buildings. For this reason, solar energy systems, which are easy to integrate and install on roofs, are commonly preferred [2]. In buildings with multiple independent units, it is not possible to install a solar energy system capable of meeting the entire building's energy needs due to insufficient roof space. For mandatory renewable energy system installation, it is more likely that the energy consumption of the building's common areas will be met. According to the [3], electric vehicle charging stations have been made mandatory in building parking lots. With this requirement, the energy demand and consumption costs of the building's common areas have increased [4]. This has made the use of renewable energy systems, supported by current laws, inevitable. Although the installation of photovoltaic (PV) systems, referred to as solar energy systems, is easy, they are costly. At the same time, it is important that these PV energy systems meet the required power output [5, 6]. Therefore, the integration requirements of PV energy systems should be determined through calculations and models with high precision and accuracy. This study presents the calculations and 2D model drawings for the required PV energy system to meet the common area energy consumption in buildings with multiple independent units, using a sample structure as an example. The aim is to create a model project that can be applied to all buildings within the framework of relevant laws and regulations.

1. **Materials and Methods**

The characteristics of the example building model with multiple independent units are provided in Table 1.

**Table 1.** Characteristics of the example building model.

|  |  |
| --- | --- |
| Feature | Number |
| Houses | 20 |
| Workplace | 0 |
| Common Area | 1 |
| Lift | 1 |
| EVCS | 1 |

The electrical power characteristics of the example model building are provided in Table 2 and Table 3. The electrical characteristics of the independent units (houses) in the building have been equivalently planned. According to the [7], The power of the dedicated lines is fixed, and the characteristics of the socket, lighting, and other power lines are determined based on their specifications.

**Table 2.** The electrical power distributions of the houses in the example building model.

|  |  |
| --- | --- |
| Comsumption Type | Power(W) |
| Boiler | 150 |
| Oven | 2000 |
| Dishwasher | 2500 |
| Washing Machine | 2500 |
| Electrical Socket  Lamp  Total | 3600  250  **11000** |

**Table 3.** The electrical power distributions of the common area in the example building model.

|  |  |
| --- | --- |
| Comsumption Type | Power(W) |
| EVCS | 7500 |
| Lift | 8600 |
| Hiydrophore | 1000 |
| Water Pump | 1500 |
| Electrical Socket  Multiswitch  Intercom  Shelter room  Lamp  Fire systems  Total | 3600  250  300  2000  750  500  **26000** |

The powers provided in Table 2 and Table 3 are the installed power values. It is necessary to calculate the demand power. Subsequently, a building's simultaneous demand power calculation should be create [7, 8]. Bir dairenin talep güç hesabı;

*Demand Power = ((Installed Power-8000)× 0,4)+(8000×0,6*) (1)

*Demand Power = ((11000-8000)× 0,4)+(8000×0,6)=6000W* is found.

Lift Demand Power;

*Demand Power = Installed Power × 0,55)*  (2)

*Demand Power = 8600 × 0,55 = 4730W* is found.

The installed powers of all other common area electrical loads are assumed to be equal to the demand power. In this case, the demand power of the common area with an installed power of 26000 W is determined as 22130 W. Using the calculated installed power and demand power values, the building's simultaneous power table is created in Table 4.

**Table 4.** Power distribution table of the example building model.

|  |  |  |
| --- | --- | --- |
| Power Type | Power(W) | Explanation |
| Installed Power | 11000 | 1 House |
| Demand Power | 6000 | 1 House |
| Installed Power | 26000 | Common Area |
| Demand Power | 22130 | Common Area |
| Installed Power  Demand Power  Installed Power | 220000  120000  **246000** | 20 House(11000×20)  20 House(6000×20)  **All Building**(220000+26000) |

The installed power of 246000 W is determined according to the building's estimated simultaneous demand power. Using the simultaneous demand power calculation, the selection and implementation of the building's electrical materials are made [7, 8]. The building's simultaneous demand power, with the power values in Table 4, is determined by multiplying the demand power of the houses by the simultaneity factor constant, and then adding the common area demand power to this value [7]. In this case;

*Simultaneous Demand Power = (Demand Power(20 House) × 0,39) + Demand Power(Common* Area)  (3)

*Simultaneous Demand Power = (120000 × 0,39) + 22130 = 68930* is found.

The power value of the PV energy system, which needs to be determined for the building's simultaneous demand power, is calculated based on the desired minimum 5% threshold in the structures; The minimum required installed PV system power should be 3446.5 We. The calculated power values of PV systems are based on high-efficiency conditions. However, since it is not possible to consistently maintain the highest efficiency conditions, the systems need to have power exceeding the We value. In this study, the Wp value has been taken 15% higher than the We value. In this case, the power of the installed PV energy system is approximately 4000 We. Electrical calculations for solar panels and inverters in PV energy systems with 4 kWe power are necessary for the correct integration of the system. The series and parallel string connections of the solar panels are the most important factors determining the current and voltage values. Although the series or parallel connection of the panels does not affect the power value, it is crucial for system performance. Considering all these factors, the electrical characteristics of the proposed solar panels and inverter are shown in Table 5.

**Table 5.** Electrical characteristics of solar panels and inverters.

|  |  |
| --- | --- |
| PV Module and Inverter Information | |
| Panel Module Type | Polycrystalline |
| Panel Pmpp | 400 Wp |
| Panel Power Tolerence | 0-5 |
| Panel Voc | 49,56V |
| Panel Isc  Panel Vmpp  Panel Impp  Inverter Output Power  Inverter Max. DC Input Voltage  Inver Min. DC Voltage  Inverter Max. Output Current  Inverter Output Voltage | 11,23 A  42,75 V  10,53A  4 kWe  1000 V  100 V  10 A  230 V/400 V |

According to the electrical data in Table 5, 10 solar panels can meet the required 4 kWp/3.5 kWe power. However, it is not enough for only the power to be compatible. The other electrical characteristics must also be analyzed to determine whether they are suitable for the system’s efficient operation. The important parameters for the compatibility analysis are as follows: the current-voltage values at the panel output should not exceed the inverter input values according to the number of panels; the DC voltage from the panels should be above the inverter's minimum operating voltage; the inverter output voltage should not exceed the targeted kWe value; and the inverter output current should not exceed the maximum output current. If these parameters are met, the applicability of the model will be ensured.

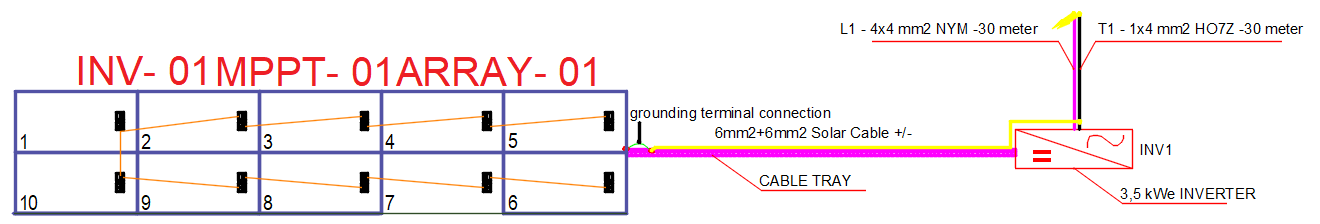
1. **Results and Discussion**

The series-parallel string numbers and configurations of 10 solar panels with 400 Wp power must fall between the inverter's minimum DC voltage level of 100 V and the maximum DC input voltage level of 1000 V. To minimize system energy losses, it is desired that the current value remains as low as possible. In this case, if it is suitable to connect all 10 panels in series, the use of parallel strings is not recommended.

*FV System Output Voltage = Number of Panels × Voc*  (4)

*FV System Output Voltage = 10 × 49,56 = 495,6 V < 1000 V, 495,6 V >100 V ,*495,6 V is suitable.

The 100 V – 1000 V range may vary for each inverter; however, this value applies to a single MPPT (Maximum Power Point Tracker) input of the inverter. Based on the example model, it is assumed that only one MPPT is used. If desired, multiple MPPT inputs can also be utilized. Regardless of the input power of an inverter, its output power will match its rated output. In other words, the AC power obtained from the PV system at the We level will be 3.5 kWe in this case. Additionally, since the panels are connected in series, the current value remains below the 40-50 A level, making it suitable to use 6 mm² solar cables for interconnections. Based on the data obtained in the study, the 2D roof model drawing of the PV energy system in the AutoCAD environment is shown as a top view in Figure 1.



**Figure 1.** The 2D drawing of the designed PV energy system.

**Conclusion**

An example of a multi-story building with many independent units was considered. Electrical power calculations for the building were made in light of current regulations, laws, and research. Based on the power calculations, the requirements for a PV energy system that can be installed on the roof to meet the energy needs of the common areas were specified, and calculations were made to meet these requirements. Finally, the design of the 2D single-line diagram for the PV energy system was prepared. As a result, we believe that this model, which includes the necessary calculations for the design of PV energy systems in the rapidly developing construction sector, the parameters that need to be considered in the design, and the basic 2D project representation, can be easily adapted to all similar projects.

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