HAVEN HOOD

MicroGrid

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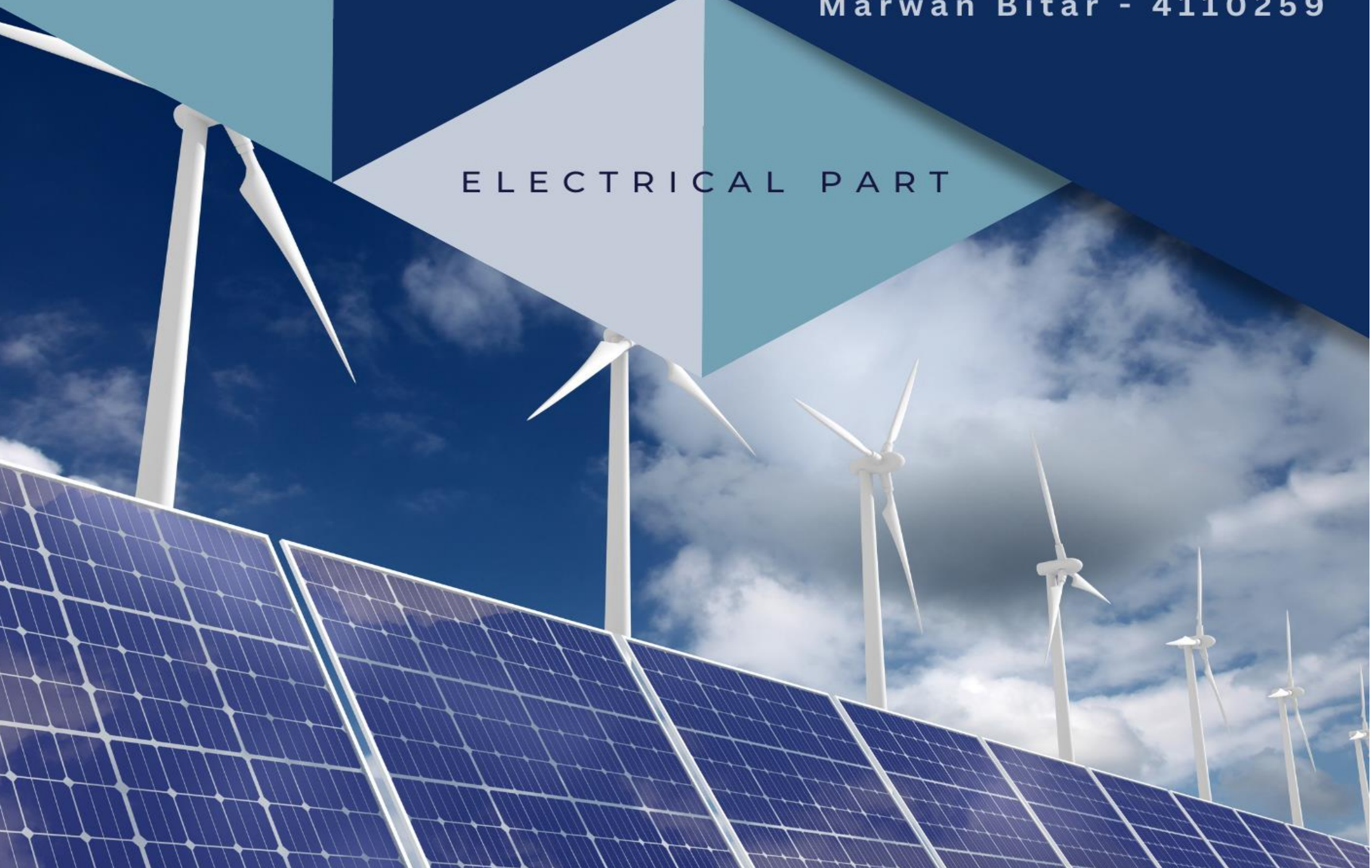
ELECTRICAL PART



Abstract

This report presents a project on establishing a microgrid power system for a special container-based refugee camp that operates mainly by renewable energy, specifically solar energy. Additionally, calculating all the loads that can be consumed in this city, such as homes, schools, hospitals, and others. The outcome is a design of an electrical plan by ETAP & PVsyst.

Keywords: microgrid – solar – source – load – electrical – Watt – power

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Introduction

The primary objective of this project is to determine the feasibility of using renewable energy sources to meet the energy demands of a small city. The project aims to choose the appropriate energy source for the city respecting its weather conditions, calculate the full costs of establishing renewable energy sources and calculate the extent to which the loads need energy. The findings of this project will provide valuable insights into the potential of renewable energy sources to power the city and contribute to a sustainable future.

The report will begin with a comprehensive analysis of the city's location, climate, and energy demands, including a discussion of the average solar radiation levels, wind speeds, and other meteorological parameters. This analysis will inform the selection of the appropriate renewable energy source for the city. In addition, this report also includes a comprehensive analysis of the market and economic aspects of establishing a renewable energy city. The market analysis will examine the current state of the renewable energy market and the trends that are shaping its future. The economic analysis will examine the economic feasibility of establishing a renewable energy city, including the costs and benefits of the project.

After that, it will discuss the load calculation to create a comprehensive design of the whole system, including the other Microgrid components such as inverter and other components. An ETAP design and PVsyst design will be built to demonstrate this Microgrid. However, the loads calculations will be clarified and detailed based on specific local and global regulations. Then, an exhaustive schedule will classify and illustrate all those loads' data and calculations.

Finally, the report will present an analysis of the energy consumption patterns of different electrical loads in the city, including the residential, commercial, and industrial sectors. This analysis will provide insights into the extent to which renewable energy sources are sufficient to meet the city's energy demands, even during periods of high demand.

Background

Microgrid

The terminology of "Microgrid" is becoming more and more popular in the electrical area. It is a communal topic that has a lot of applications in very various and wide areas. However, it has its own benefits and challenges. The report will start by defining this term, its types, and its components. Additionally, at the end of this report, the advantages and challenges will be discussed.

Definition

"A microgrid is a self-sufficient energy system that serves a discrete geographic footprint, such as a college campus, hospital complex, business center or neighborhood." (Wood, 2020)

It is a modern type of electrical grid that is becoming more and more desirable and applicable for various applications, like houses, manufactures, and other facilities.

Types

It can be grid-dependent or independent. We will use one of the independent types for the purpose of this project. However, we can classify the types as follows:

1- Campus / Institutional Microgrid: it is desired when we have multiple loads located in a tight geography combined with in-site generation. As a result, the governor can easily manage them. Resulting in a reduction of reliability on the main grid. It can be used on a university campus as an example.
2- Community Microgrid: it can serve up to thousands of customers. Also, it can share in the local generation of electricity in the area. It can use some renewable resources, energy storage elements, and power electronic components. Figure 1 demonstrates an example.


Figure 1: Community Microgrid in Freiburg, Germany

Figure 1 Source: https://commons.wikimedia.org/wiki/File:SoSie%2BSoSchiff_Ansicht.jpg

3- Industrial and Commercial Microgrids: sometimes a little interruption of electricity supply results in high losses for some institutions. So, installing an industrial microgrid is a key solution to such an issue. It is becoming more applied in many companies in North America and other areas.

4- Off-Grid Microgrid: it is the special type of microgrids that is used in this project. This type is never connected to the main grid. It is operated fully on its own. When having some geographical or economical dilemmas, it is a reasonable option to use this type. Mainly, it has a great advantage when there is no connection to the distribution system or there are no transmission lines. Also, renewable energy resources are used mostly in such projects. This type is designed to be a self-sufficient grid, so it will use more than one energy source since renewables have unexpected or deviation output. (Aljabban, 2020)

Components

A microgrid is basically a combination of energy generation system, energy storage system, and power consumption elements (the loads). In more order:

- Energy Generation: they can be traditional thermal generation sources, like fossil fuel or gas electric generators. Or, they can be renewable energy sources, like wind turbines or PV (photovoltaic) solar panels.
- Energy Storage: they have many essential tasks, like smoothing the output of renewable sources, frequency and voltage regulation, and sustaining power quality. For energy storage, we can use many types of technologies, like large chemical batteries, mechanical Flywheels, or heat storage technologies. (Aljabban, 2020)
- Electrical Loads: for such systems, we are producing power to the system, so there are many different loads that are consuming this power. These loads can be resistive, capacitive, or inductive loads, or even combined from any two types.

Comprehensive Analysis of The City

Cevdetiye, Osmaniye Merkez is a city located in the Osmaniye province of Turkey, situated in the eastern Mediterranean region. The city has a population of approximately 60,000 people and is known for its historical landmarks, cultural heritage, and agricultural production.

Location:

Cevdetiye, Osmaniye Merkez is located at an elevation of 141 meters above sea level and is situated at the coordinates of 37.07°N latitude and 36.25°E longitude. The city is surrounded by the Taurus Mountains to the north and east, which provide a barrier against the harsh continental climate of central Anatolia. The Mediterranean Sea is situated to the south of the city, which moderates the city's climate and provides access to the ports of Mersin and İskenderun.

Climate:

Cevdetiye, Osmaniye Merkez has a Mediterranean climate, characterized by hot, dry summers and mild, wet winters. The average temperature in the city is 19.3°C, with the hottest month being August, with an average temperature of 28.2°C, and the coldest month being January, with an average temperature of 8.3°C. The city receives an average of 784 mm of precipitation per year, with the wettest month being December and the driest month being July.

Source: The data from https://www.mgm.gov.tr/tahmin/il-ve-ilceler.aspx?il=Osmaniye

Energy demands:

Cavdetiye has a relatively low energy demand compared to larger cities in Turkey. The town's primary sources of energy are electricity, natural gas, and heating oil. In recent years, there has been a growing interest in renewable energy sources, especially solar and wind power.

Solar Radiation Levels:

Cevdetiye, Osmaniye Merkez receives an average of 2640 hours of sunlight per year, with an average daily solar radiation of 3.6 kWh/m2/day almost 1600-1650 kWh/m2/day shown in Figure 2. The city's location in the eastern Mediterranean region provides ample solar energy potential, which can be harnessed using solar photovoltaic panels, solar thermal systems, and other solar technologies. (Lam Ho, 2017)

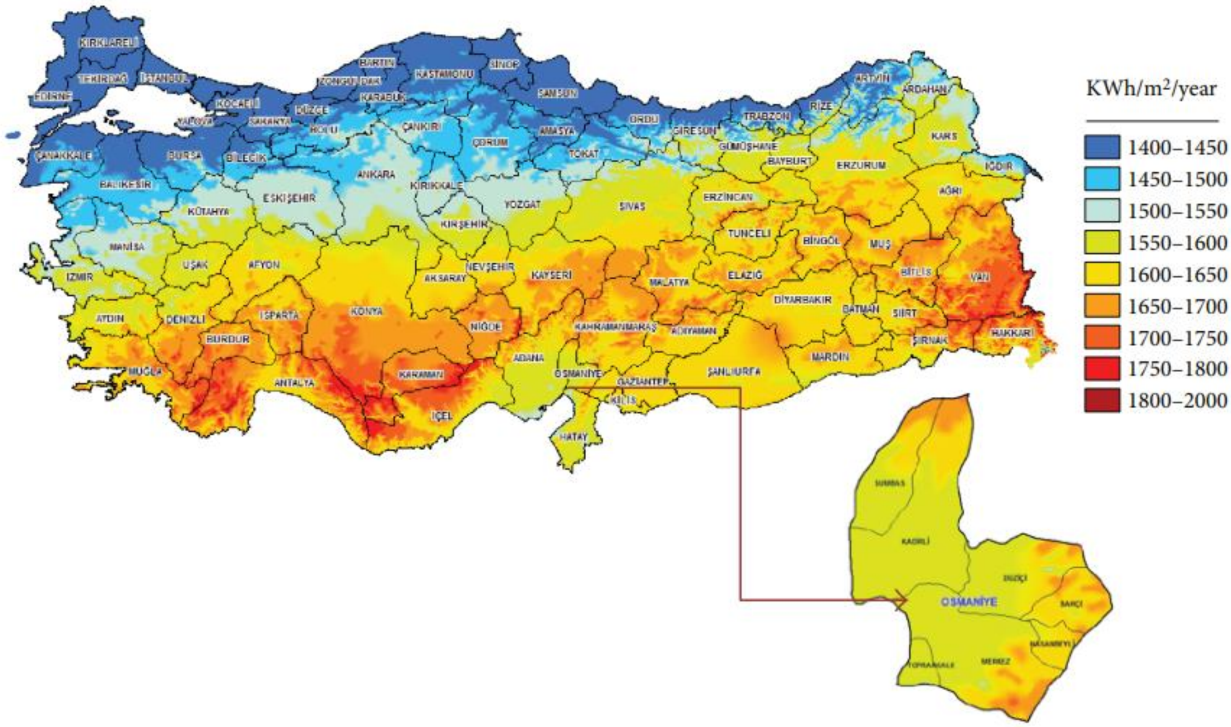

Figure 2: Annual Solar Radiation Levels and Location of Osmaniye in Turkey

Figure 2 Source: https://www.hindawi.com/journals/ijp/2017/3237543/

Wind Speeds:

The daily fastest wind in Cevdetiye, Osmaniye Merkez is 43.7 m/s, with the highest wind speeds occurring in the spring and autumn months. The city's location in a valley between the Taurus Mountains and the Mediterranean Sea can cause turbulent wind patterns, which can impact the efficiency of wind turbines and other wind energy technologies.

Source: The data from General Directorate of Meteorology (mgm.gov.tr)

Overall, Cevdetiye, Osmaniye Merkez has favorable conditions for solar energy production and a stable climate with relatively low risks of natural disasters. These factors can be leveraged to support the city's transition to renewable energy sources and to improve its energy security and sustainability.

Renewable Energy Sources

Renewable energy sources are sources of energy that can be replenished naturally in a relatively short period of time, either through natural processes or human intervention. These sources include solar energy, wind energy, hydro energy, geothermal energy, and biomass energy. Unlike fossil fuels, which are finite and will eventually run out, renewable energy sources can be continuously harnessed to provide clean and sustainable energy.

Types of Renewable Sources

First, solar energy has been exclusively utilized in this project due to its many advantages over other renewable energy sources. Wind, hydro, and geothermal energy were excluded because they have limitations in terms of availability, cost-effectiveness, environmental impact, and scalability.

Solar Energy:

Our reliance on solar energy resulted from a few reasons, the most important of which is its ability to provide all the energy needed for the region. Besides being cheaper than alternative sources, the cost of solar energy installation for a small city ranges from $500,000 with 1MWh to $2 million with 4MWh depending on the size and energy needs. However, long-term benefits such as reduced energy costs and decreased carbon footprint make solar energy a cost-effective option. (Simmes, 2023)

Wind Energy:

The cost of wind energy installation for a small city ranges from $1.3 to $11 million depending on capacity because it generally requires more infrastructure and upkeep than solar energy. It was eliminated since its price is twice as expensive as solar energy. In addition, it takes a very long period to conduct tests in the region to ensure the effectiveness of the turbines, and this period may range from more than 6 months. (Gielen, 2012)

Hydroelectricity:

Hydroelectric power can only be used in certain places because it needs a lot of running water. Although there is this amount of water available in the city, the main factor that prevented us from including hydroelectric power plants in our decision was their inability to supply the city with sufficient energy (due to some other political reasons in that area).

Geothermal Energy:

Geothermal energy requires specific geological features, which make it less widely available than solar energy. Furthermore, the cost of developing geothermal energy plants can be high, making them less cost-effective than solar energy. Additionally, it results in land use impacts and chemical emissions.

Solar Panels Applications

Solar panels are used for various applications, and the three primary applications are Grid-connected, Stand-alone, and Pumping. Here's a table explaining the differences between these applications:

Table 1

The differences between solar panels applications

Application	Description
Grid-connected	Solar panels are connected to the electrical grid and feed the excess energy back into the system.
Stand-alone	Solar panels generate and store energy in batteries, providing power when the grid is not available.
Pumping	Solar panels are used to power water pumps for irrigation or other water-related applications.

Grid-connected systems are the most common application for solar panels, and they can generate energy during the day and feed it back into the grid as shown in Figure 1. Stand-alone systems are typically used in remote areas where the grid is not available or unreliable. They require batteries to store the energy generated by the solar panels to provide power during the night or when the sun is not shining as shown in Figure 2. Pumping systems use solar panels to power water pumps for irrigation or other water-related applications as shown in Figure 3.

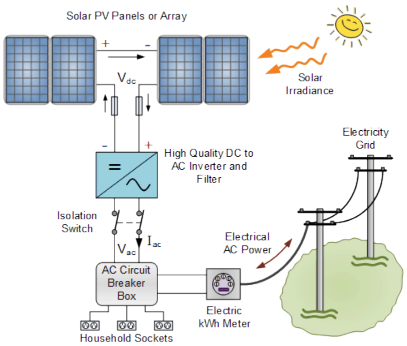

Figure 3: Grid-Connected Systems

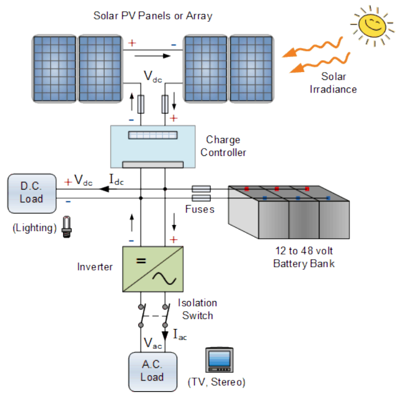

Figure 4: Stand-Alone Systems

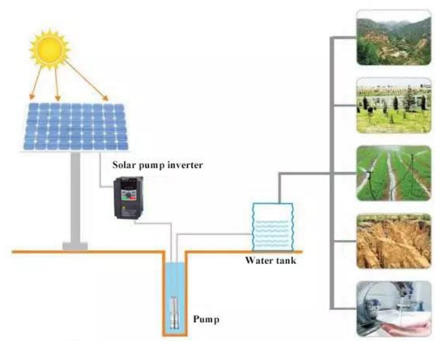

Figure 5: Pumping Systems

- Figure 3 Source: https://www.alternative-energy-tutorials.com/solar-power/grid-connected-pv-system.html
- Figure 4 Source: https://www.alternative-energy-tutorials.com/solar-power/stand-alone-pv-system.html
- Figure 5 Source: https://www.inverter.com/a-typical-design-of-solar-water-pump-system

Stand-Alone System Analysis

Standing on the idea of the project that we are working on; a stand-alone system is the best option. The architectural design will depend on direct sunlight in the morning to provide lighting or even for heating, and at night it will depend on solar energy that has been stored during the day. Based on the research we did; the stand-alone system is the right choice for this process. A stand-alone system can generate and store energy in large-batteries to keep things running at the night, and by choosing a stand-alone system, we can make sure that the city has a reliable source of energy during the night, without depending on the grid or direct sunlight. This type of system is ideal for remote areas where the grid is not available or unreliable, or in situations where the demand for energy is not constant. This will make it possible for the city to continue operating successfully and efficiently even when there isn't any direct sunshine. Another reason for stand-alone is that there are some other political regulations to exclude "dealing with the electrical grid" around that area.

Area Needed:

We are all aware that solar power plants require a lot of lands to function, so whether we choose to install our solar on rooftops or the ground, depends on these factors:
The efficiency of the solar panels, the type of solar panel technology used, the orientation and tilt of the solar panels, and the land use constraints and requirements. In general, estimate each 100 MW solar power will need 10% of the total land area. The actual land area needed can vary depending on the specific conditions and requirements of the project, and that will be clear at the end of the project. From: How much land you need for Solar? (linkedin.com)

There are primarily two types of solar panels:

1. (Crystallin) as shown in Figure 6.
2. (Thin film) as shown in Figure 7.

Crystalline solar panels: They are typically built of silicon and require an installation space of roughly 4-5 acres per MW. (Thussu, 2018)

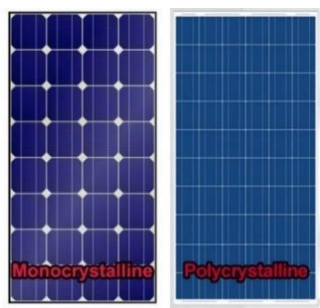

Figure 6: Crystalline solar panels

Thin film solar panels: For installation, they need roughly 6-7 acres per Megawatt of space and are either made of Cadmium Telluride (CdTe) or Copper-Indium-Gallium-Selenide (CIGS). (Thussu, 2018)

Figure 7: Thin Film Solar Panels

So as previously mentioned, the area needed for a stand-alone solar power system will depend on the energy demand of the city and the efficiency of the solar panels, and according to one estimate, a 1 MW solar power system would require between 5 and 10 acres of land, depending on the efficiency of the panels. For this project we will need (some specific value – not determined because the loads are not calculated because the architect analysis is not finalized yet) MW and therefore the estimated area is (some specific value – for the same reason) and this will be clear at the end of the project.

Types of Solar Panels:

Monocrystalline, polycrystalline, thin-film and other solar panel types as shown in Figures above are all available for standalone solar power systems. Thin-film panels can be more affordable for bigger installations while having a lower efficiency than monocrystalline panels, which are often the most expensive. Top solar panel manufacturers include SunPower, LG, and Panasonic.

Solar Panel Efficiency:

The current commercially-available solar panels with the highest efficiency are around 22%, which has significantly improved in the recent past. It is a known fact that solar panels with higher efficiency tend to come with a higher cost. Therefore, we decided to opt for Polycrystalline as it strikes a balance between efficiency and cost. The table below illustrates the efficiency levels of the most popular solar panels:

Table 2

The efficiency levels of the most popular solar panels

Panel type	Efficiency
PERC	Highest (5% more than monocrystalline)
Monocrystalline	20% and up
Polycrystalline	**15-17%**
Copper indium gallium selenide (CIGS)	13-15%
Cadmium telluride (CdTe)	9-11%
Amorphous silicon (a-Si)	6-8%

Table 2 Source: https://aurorasolar.com/blog/solar-panel-types-guide/

Energy Production:

Solar power from a single panel in a solar panel system typically produces about 2 kWh as shown in Figure 8, but at STC (Standard Test Conditions) depends on the specific panel's wattage rating and efficiency. For example, a 300-watt solar panel with an efficiency of 16% operating under STC can produce up to 300 watts x 0.16 = 48 watts of power. However, the actual output may vary depending on factors such as temperature, shading, and the angle of the panels and that will be clarified in the analysis section.

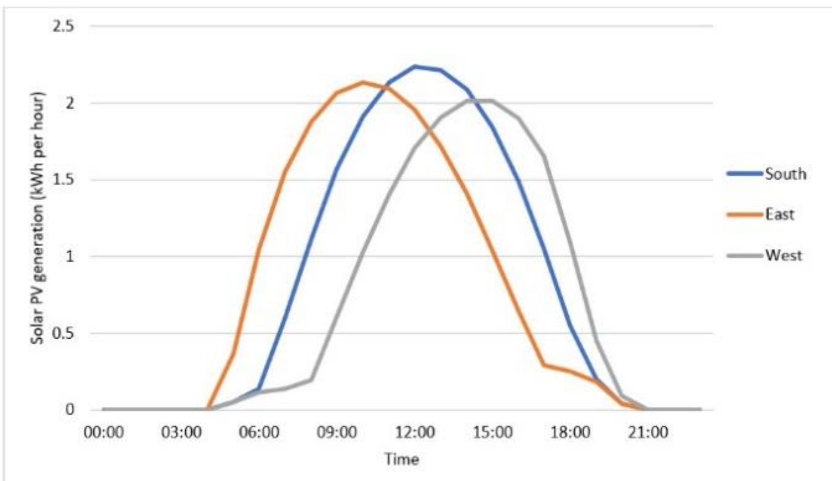

Figure 8: The Average PV Generation in Watts

Source: *How much electricity do solar panels produce?* National Energy Action (NEA). (2020, November 3). Retrieved from https://www.nea.org.uk/who-we-are/innovation-technical-evaluation/solarpv/how-much-electricity-solar-produce/

Cost of Installation:

The price to build a standalone solar power system will vary depending on the system's size, the components it uses, and the labor and material prices in the area. The National Renewable Energy Laboratory (NREL) estimates that in 2020, the cost to install a 1 MW solar power system in the United States would be roughly $1.25 per watt, or $1.25 million overall, and you can see the solar panel cost by types, as shown in the table below:

Table 3

Solar Panels cost of installation

Panel (Module) type	Average Cost per Watt
PERC	$0.32-$0.65
Monocrystalline	$1 – $1.50
Polycrystalline	$0.70 – $1
Copper indium gallium selenide (CIGS)	$0.60 – $0.70
Cadmium telluride (CdTe)	$0.50 – $0.60

Table 3 Source: https://aurorasolar.com/blog/solar-panel-types-guide/

Cost of Operation and Maintenance (O&M):

A stand-alone solar power system's ongoing running and maintenance costs will vary depending on a few variables, such as the system's size and complexity, the local climate and environmental conditions, and the types of components employed. According to (Enbar, Weng, & Klise, 2015) study, a 1MW solar power plant typically costs $17,000 annually for operations and maintenance, or $0.017 per kWh. The table below shows the PV O&M budget components and costs.

Table 4

PV O&M budget components and costs

Budget Item	Budget Range ($/kW-yr)	Notes
Overall Budget	$10.00-45.00/kW-yr*	Variable based on whether cost plus, extended warranty, and other items are included. Also, some O&M activities are non-linear which can affect overall outlays.
General Site Maintenance	$0.20-$3.00/kW-yr	Variable based on system size, location. (e.g., desert environments are less expensive than snowy locales that require snow removal from critical areas), and frequency of activity.
Wiring/Electrical Inspection	$1.40-$5.00/kW-yr†	Includes inspection of wires, junctions boxes, combiner boxes, AC/DC disconnects, service panel, etc.; string testing. Prices will differ, among other things, based on whether inspection covers 10% or 100% of the plant.
Panel Washing	$0.80-$1.30/kW-yr†	Variable based on technology (different form factors), cleaning regimen, prevailing wages, and other factors. As a result, some stakeholders provide cost metrics on a $/module basis.
Vegetation Management	$0.50-1.80/kW-yr†	Variable based on site characteristics and acreage. Often a "cost-plus" contingency item.
Inverter Maintenance	$3.00-7.50/kW-yr†	Activity typically encompasses cleaning of filters, torqueing, thermal imaging of internal components, minor equipment repair, etc.
Inverter Replacement	$6.00-10.00/kW**	Typically, plant owners only budget for one inverter replacement activity after the initial warranty period. Price ranges encompass different utility-scale inverter sizes and models.
Racking / Tracker Maintenance	Insufficient data	Racking maintenance is negligible, however tracker maintenance is more costly. Specific data points for the latter activity are insufficiently available.
Spares	$2.00-$20.00/kW-yr***	Most critical spares to have on hand include fuses, contacts, wiring, inverter parts (circuit boards, filters, fans, etc.), disconnect switches, and modules.

Table 4 Source: Source: Enbar, N., Weng, D., & Klise, G. T. (2015, December 1). Budgeting for solar PV Plant Operations & Maintenance: Practices and pricing. Budgeting for Solar PV Plant https://www.osti.gov/servlets/purl/1234935/

PVsyst Program

PVsyst is a piece of software used to simulate and design photovoltaic systems. It is a thorough tool that aids designers and engineers in maximizing the performance of solar panel installations. Listed below are some program specifics:

- Design: With PVsyst, you may create a solar panel system by choosing the number of panels, inverters, and batteries needed to meet the system's power requirements.
- Simulation: Once you have designed the system, you can simulate its performance under different conditions, including the location, climate, shading, and panel orientation. This helps you to optimize the system's performance by identifying the best configuration for your specific site.
- Reporting: PVsyst generates detailed reports that provide a comprehensive analysis of the system's performance. The reports include graphs, tables, and charts that make it easy to understand the system's performance under different conditions.

Analysis & Design:

Here we are still waiting for an architecture student to define the areas and the number of types of devices in each section. So, we need to calculate the loads. Once we have this information, we can start designing a solar energy system.

To elaborate on this, here's how the process typically works:

1. Define the areas and types of devices: To design a solar energy system, first we need to know the areas and types of devices that will be consuming power. This can include things like lights, appliances, refrigerators, and more. An architecture student would be responsible for defining these areas and the types of devices in each section.
2. Calculate the loads: Once we know the areas and types of devices, we can then calculate the loads. This involves determining the amount of power each device will consume and the

amount of time it will be used. This information is then used to determine the total power requirements for the system.

3. Design the solar energy system: With the load information, we can now design a solar energy system that can meet the power requirements of the devices. This involves selecting the appropriate solar panels, batteries, and other components to ensure that the system can generate and store enough power to meet the loads.

Electical Loads

Procedure

From the architectural side of this project, we can find that there are five types of containers, each type can be a different sub-space, so we will construct a full loads schedule for each sub-space for each type of containers.

However, the types of containers are:

1- Educational.

2- Shelter.

3- Shared.

4- Healthcare.

5- Outdoor.

All those sub-spaces have specific electrical devices. To find how much average power each device consumes, the best way was to look for the most popular online store used in the specified area in Turkey, then to look for most popular and most rated devices; to benefit from the experience of the previous consumers. But this way has many challenges for our case:

1- All most famous websites only have Turkish language when use. We could translate the websites but that would take more time and effort. However, we overcome this by using one of the most well-known websites: amazon.com (with choosing Turkey as location).

2- The electrical specifications (including rated volt, ampere, and power), mostly, are not mentioned. Therefore, we will need to search for each device separately on the manufacturer's website.

3- The conditions of the usage of the device vary. The room temperature will affect, the size of the device, the capacity, … etc.

To elaborate more, taking a refrigerator as example: "Many factors determine the power or watts your refrigerator uses, including its age, size, and type. For example, a larger fridge will likely use more watts than a small fridge. And a newer model will probably use less power than an older one. In addition, the kitchen's average temperature can affect the refrigerator's cooling system, which can also cause a variation in power usage." (Coast Appliances, 2022)

As a result, the best approach to do this was to search for previous studies about an average consumption for average size, capacity, conditions device.

For receptacles, we will take the following ratings according to (International Wiring Accessories and Cord Sets). Also, considering the rated values for the electrical outlets' capabilities in Turkey according to (Electrical Safety First):

- V rated = 220 V
- I rated = 20 Amps (as average value among the others – from the source)
- P rated = 3520 W

The power value depends on what is plugged in, TV, charger, fan, etc.so, we will assume an average use: assumption of 1800 W for each type and then addressing specific number for outlets per utility (in the Loads' Schedule, in the coming section)

For the lighting, we will have to do the following to calculate how much power it consumes:

1- The area needed (to be lighted) = in meter square (m^2).
2- The amount of luminous (luminous intensity) = in Lumens per meter squared (lm/m^2).
3- Multiply 1 by 2.
4- Lumens to Watts conversion: number of watts for specific amount of lumens, by the data in: (https://ledhut.co.uk/blogs/news/lumen-watt-chart), because this manufacturer's LEDs will be used. These LEDs form this manufacture are very common in such areas in Turkey, and their popularity is an indication of their reliability, with considering other factors can be found in their website.
5- Approximated number of light units (LEDs) for each sub-space.

Note: in the next section Table 6 will illustrate this.

Consequently, in Appendix (1) a detailed section about the previous procedure with the related sources. These values for the types or conditions of the devices will be used in the (Loads' Schedules section).

After getting all loads values for all devices, we will calculate how much power is used for each sub-space, therefore, how much power for each type of containers. Next, we will need to calculate the power dissipated in the transmission lines in the whole microgrid, including the consumed power by the wires in the small utilities (sub-spaces).

For the transmission lines on this system, they can be represented by R (resistance), L (inductance), and C (capacitance) values. In addition, they have their own analysis, like ABCD parameters. This analysis can be done after getting all the architect data regarding the number of facilities and sub-spaces, their loads, and their locations (to determine the lengths of the transmission lines).

Finally, we also need to consider the internal wiring in those utilities. The internal wires consume power as well. After concluding the analysis, we can determine if the power consumed by those wires can be neglected or not. This can be discussed after ETAP analysis and after calculating all loads data.

Schedules of Loads

As was mentioned, we will have different sub-spaces for each type of container. However, the combination of all the electrical loads of all sub-spaces will be the main electrical load for this project.

Based on (Saudi Building Code, SBC, 2018) and (Saudi Electricity Company, SE, 2015) Here is an example of what the schedule would look like (considering this for a sub-space being a kitchen as example):

Table 5

An example from Schedules of Loads

Electrical Loads	P rated (kW)	Demand Factor (DF)	Number of Devices	Total Consumption (kW) / Device	Total Power (kWh) / Utility
Lighting	1	0.9	6	5.4	6.8
Elec. Water Heater	1.5	0.2	1	0.3	
Heating Device	1.5	0.2	1	0.3	
Oven	2.8	0.05	1	0.14	

Fridge	0.3	1	1	0.3	
Receptacles	1.8	0.05	4	0.36	
-				0	
-				0	

Where:

P_{rated} = rated power for the device (in Watts).

DF = it is the demand factor, usually from a reliable institution. It refers to the device usage factor in a day. The institution is Saudi Electricity Company (SE). the data will be used is form Distribution Planning Standards (SE, 2015).

With:

Total Consumption = P_{rated} * DF * No. devices = $P_{device.total}$

Total Power = P_{total} = Summation of ($P_{device.total}$) for all devices.

Note 1: the whole schedule is not finalized => the architect student analysis is not finished yet.

Note 2: the numbers are just assumptions for clarification purposes.

For the lighting, we take the following example:

Table 6

Example for Lighting Calculation

Area (m^2)	Min. lux (lm/m^2)	Total Lumens (lm)	No. of Lights	Approx. (No. of Lights)	Total Power for Lighting
125	250	125*250 = 31250	31250/1300 = 24.03	24	240 Watts

Where:

1- **Area * Minimum Lux = Total lumens (lm).**

2- **Total lumens / (LED lumens) = No. of Lights**. LED lumens here is 1300 lm for this example, it is determined by the manufacturer.
3- **Approximate No. Lights** = approximation for the number of lights.
4- **Total Power = No. Lights * P_{rated},** with rated power taken 10 W for each LED in this example.

Note 1: the whole schedule is not finalized => the architect student analysis is not finished yet.

Note 2: that this table method is based on the information from (Grondzik & Kwok, 2014) and they wrote it from the International Building Code (IBC).

In Appendix 2 there are schedules for Min. Lux and DF for areas and devices.

OTHER GRID COMPONENTS

Charge Controller

A charge controller, also known as a charge regulator, is an electronic device used to regulate the amount of electric current flowing into and out of a battery bank during the charging process. The main function of a charge controller is to prevent overcharging and undercharging of the battery bank, which can reduce the lifespan of the batteries and cause permanent damage. It regulates the charging process by monitoring the battery voltage and current, and adjusting the charging voltage and current accordingly to ensure that the batteries are charged efficiently and safely.

Figure 9: Charge Controller

Energy Storage

The process of storing energy in particular devices or systems so that it can be used as required later is known as energy storage. This enables businesses and industries to conserve energy for use during periods of rising demand or system failure. Thus, energy storage keeps the supply-demand equilibrium for consumers always stable and avoids problems like erratic power and unexpected price increases. For this project we will use a special type of batteries provided by PVsyst to store the generated energy.

Inverter

Inverter is a device that converts the direct current (DC) electricity generated by solar panels into alternating current (AC) electricity that can be used to power appliances and devices in a home or business. Solar panels generate DC electricity, which is not directly usable by most household appliances and the power grid. Therefore, an inverter is needed to convert the DC electricity into AC electricity, which is the standard form of electricity used in homes and businesses.

Backup Generator

A backup generator is a device that provides an alternate source of power when the primary power source is unavailable or fails. Backup generators are commonly used to provide electricity during power outages, emergencies, or in remote locations where there is no access to grid power. Backup generators typically work by converting mechanical energy into electrical energy. The generator has an engine that drives an alternator, which produces electricity. The electricity generated is then distributed to the electrical circuits in the building or facility through a transfer switch.

ETAP Design

ETAP is a powerful software program used in electrical power system analysis and design. This program allows engineers to model and analyze complex electrical power systems, including transmission, distribution, and industrial systems. ETAP offers a wide range of modules, including load flow, short-circuit analysis, protective device coordination, arc flash analysis, and dynamic stability analysis. According to Moniruzzaman and Uddin (2019), ETAP is a reliable tool for engineers to design and optimize electrical systems, ensuring the safety and reliability of the power supply. Furthermore, the program provides comprehensive reports and visualizations, which aid in decision-making processes and increase the efficiency of power system design.

For creating a special ETAP design with a detailed and wide analysis and studies, we had the same issue of not having all the data from the architecture student, and this was discussed in (**PVsyst Program**; *Analysis & Design*).

Evaluation

Advantages & Disadvantages of Microgrid

Microgrids are emerging as a viable solution for sustainable and resilient power systems. They are self-contained power systems that can operate independently of the main grid or can be connected to it, allowing them to provide backup power or to support the main grid during peak demand. One of the key advantages of microgrids is their ability to improve the reliability and resiliency of the power supply, especially in remote or rural areas. They also offer the potential for increased energy efficiency and reduced carbon emissions. However, microgrids also face several challenges, including high initial costs, limited scalability, and the need for careful planning and management to ensure optimal performance. As a result, the decision to deploy a microgrid requires careful consideration of the specific needs and constraints of the system in question (Shiva Prasad et al., 2020; Su et al., 2019).

Challenges

The installation and operation of microgrids pose several challenges. One of the main challenges is the lack of a standardized design framework, which makes it difficult to ensure interoperability and compatibility among different microgrid components and systems (Su, Wang, Han, Shi, & Hu, 2019). Additionally, the intermittent nature of renewable energy sources, such as solar and wind, can lead to fluctuations in power output, which can affect the stability and reliability of microgrids (Shiva Prasad, Ramakrishnan, & Iyengar, 2020). Another challenge is the need for sophisticated control algorithms that can effectively manage and coordinate the operation of multiple energy sources and loads (Su et al., 2019). Furthermore, the cost of deploying and maintaining microgrids can be high, which can be a significant barrier for smaller communities and organizations (Shiva Prasad et al., 2020). These challenges highlight the importance of continued research and development to address the technical, economic, and social aspects of microgrid deployment and operation.

Recommendations

After working with this project so far, here are some recommendations:

1- Working with such project needs a collaborative team, high soft skills, project planning, etc… Every increase in such skills improves the progress and outcomes of the project.
2- Conduct a feasibility study: Before implementing a microgrid, it is important to assess the technical, economic, and environmental feasibility of the project. This includes evaluating the available energy sources, the load requirements, the cost of equipment and installation, and the potential environmental impact (Fang, Misra, Xue, & Yang, 2012).
3- Ensure interoperability and compatibility: To ensure the effective and efficient operation of a microgrid, it is important to ensure interoperability and compatibility among different components and systems. This includes using standard communication protocols and control algorithms (Su et al., 2019).
4- Develop a control strategy: A well-designed control strategy is crucial for the effective operation of a microgrid. This includes developing control algorithms that can manage and coordinate the operation of different energy sources and loads to optimize energy generation and consumption (Shiva Prasad et al., 2020).
5- Consider energy storage: Energy storage technologies, such as batteries and flywheels, can help to address the intermittent nature of renewable energy sources and improve the reliability of microgrids (Fang et al., 2012).
6- Monitor and maintain the system: Regular monitoring and maintenance of the microgrid is essential to ensure its safe and reliable operation. This includes monitoring the performance of different components and systems, identifying, and addressing issues in a timely manner, and conducting routine maintenance and repairs (Su et al., 2019).

Conclusion

In conclusion, based on our analysis of the data, this project has a great potential to grow and to be implemented effectivily. Microgrid technology offers a promising solution for addressing the challenges of modern energy systems. However, there are also some areas that require improvement, such as transmision line analysis and designing a comperhensive contorl system. It is important that we address these issues in order to continue to develop our approaches in our projects and to improve our skills. Overall, the data suggests that we are on the right track, and with some targeted improvements, we can improve this project more and more, also, microgrids represent a promising avenue for achieving a more reliable, secure, and sustainable energy future.

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Appendix (1)

Power Consumption for The Devices (used devices so far)

- Water heater: (average power for 10 Gallons water heater)
  1- https://learnmetrics.com/water-heater-wattage-how-many-watts-water-heater-uses/
- Heating device: (avg power for an average size space heater)
  1- Power consumption: https://news.energysage.com/how-many-watts-does-a-space-heater-use/
  2- Size: https://www.pickhvac.com/space-heater/room-size/
- Receptacles: (avg power for average usage)
  1- Power consumption: https://learnmetrics.com/how-many-watts-can-an-outlet-handle/
  2- Turkey ratings: https://internationalconfig.com/turkey-receptacles-outlets-sockets.asp
  3- Turkey ratings 2: https://www.electricalsafetyfirst.org.uk/guidance/advice-for-you/when-travelling/travel-adaptor-for-turkey/
- Oven: (avg power for normal size oven)
  1- https://www.perchenergy.com/energy-calculators/electric-oven-energy-use-cost
- Fridge: (avg power with avg size and conditions)
  1- https://www.coastappliances.ca/blogs/learn/how-many-watts-does-a-refrigerator-use
- Printer: (avg power for average use of desk-size printer)
  1- https://www.electricrate.com/printer-power-consumption/
  2- If it is a large business printer, it will consume an average of 2 kW based on the same previous source.
  3- Some sub-spaces have been assigned a large printer depending on their use.
- Computer: (avg power for average size and components)
  1- https://news.energysage.com/how-many-watts-does-a-computer-use/
- Negatoscope: (P rated for the following model)
  1- https://www.medicaldepot.com.ph/product/negatoscope-single-panel/
- Examination Light: (P rated for most types)
  1- https://www.medicalexpo.com/medical-manufacturer/examination-lamp-28863-_3.html
- Paper Dispenser: (P rated for most types)
  1- https://www.philstar.com/opinion/2016/03/07/1560717/meralcos-orange-tags
- LED: (avg power for normal type) 10W = 900lm
  1- Power consumption: https://news.energysage.com/how-many-watts-does-a-light-bulb-use/

2- Lumines to Watts (from the manufacturer: LED HUT): (it is one of the most popular, well known, and efficient LED manufacturers in Europe. However, their products are well spreaded in Turkey as well) https://ledhut.co.uk/blogs/news/lumen-watt-chart

Appendix (2)

DF for some areas (from SE Distribution Planning Standards)

Code	Customer Category	DF
C1	Normal Residential Dwelling	0.60
C2	Normal Commercial Shops	0.70
C3	Furnished Flats	0.70
C4	Hotels	0.75
C5	Malls	0.70
C6	Restaurants	0.70
C7	Offices	0.70
C8	Schools	0.80
C9	Mosques	0.90
C10	Mezzanine in Hotel	0.75
C11	Common Area/Services in Buildings	0.80
C12	Public Services Facilities	0.75
C13	Indoor Parking	0.80
C14	Outdoor Parking	0.90
C15	Streets Lighting	0.90
C16	Parks & Garden	0.80
C17	Open Spaces	0.90
C18	Hospitals\Medical Facilities	0.80
C19	Medical Clinics	0.70
C20	Universities/High Educational Facilities	0.80
C21	Light Industries	0.90
C22	Workshops	0.90
C23	Cooling Stores	0.90
C24	Warehouses	0.70
C25	Community Halls	0.80
C26	Recreational Facilities	0.80
C27	Farms/ Agricultural Facilities	0.90
C28	Fuel Stations	0.70
C29	Bulk Factories	0.90

S/N	Type of Load	Demand Factors Used by SEC			
		Residential	Commercial	Industrial	Agr. Farms
1	Central A/Cs	0.9	0.9	0.9	0.9
2	Window Type A/Cs	0.6	0.6	0.7	0.7
3	Lighting (Interior / Exterior)	1.0	1.0	1.0	1.0
4	Refrigeration / Cooling	0.6	0.6	0.6	0.6
5	Fans / Blowers	0.2	0.2	0.2	0.2
6	Equipment Used in Kitchens	0.2	0.2	0.2	-
7	Water Heaters	0.2	0.2	0.2	-
8	Laundry Equipment	0.2	0.2	0.2	-
9	Appliances Used for Recreation	0.2	0.2	-	-
10	Appliances Used for Services	0.2	0.2	0.2	-
11	Equipment Used in Office / Labs	-	0.2	0.2	-
12	Welding Equipment	-	0.15	0.20	-
13	Electric Motors Used for Crafts, Workships & Service Centers	-	0.25	0.25	-
14	Electric Motors Used for Batch Work, Fluctuating of Multiple Production	-	-	0.4	0.4
15	Electric Motors Used for Continuous Process and Mass Production	-	-	0.6	-
16	Process Heating Using Ovens	-	-	0.35	-
17	Process Heating Using Furances	-	-	0.7	-
18	Miscellaneous (not covered above)	0.1	0.1	0.1	0.1

NOTE: Demand factors are based on the following:
- IEEE STD 241-1974
- Electric Utility Engineering Reference Book by Westinghouse.

Lighting Schedule

Location	Illumination Level in Lux
Entrances, hallways	100
Living room	300
Dining room	150
Bed room General	300
Dressing tables, bed heads	200
Tables games	300
Games or recreation room	100
Kitchen	200
Kitchen sink	300
Laundry	200
Bathroom	100
Bathroom mirror	300
Sewing	700
Workshop	200
Stairs	100
Garage	70
Study	300

Source: Grondzik W. T. & Kwok A. G. (2014). Mechanical and electrical equipment for buildings (12E ed.). Wiley. Retrieved April 7 2023 from http://site.ebrary.com/id/10935017.