RENEWABLE ENERGY TECHNOLOGIES

PHOTOVOLTAİC SYSTEM DESİGN AND OPERATİON MAİNTENANCE CONTROL MODULE

2022-2-TR01-KA210-VET-000098216

IN RENEWABLE ENERGY TECHNOLOGIES ACCORDING TO 4.0 STANDARDS NEW APPLICATIONS

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DESCRIPTIONS

AREA	Renewable Energy Technologies
JOB	Solar Energy Systems
NAME OF THE MODULE	Photovoltaic System Design and Operation Maintenance Control
DESCRIPTION OF THE MODULE	It is a learning material that provides knowledge and skills regarding photovoltaic system design and operation maintenance control. .
COMPETENCE	Photovoltaic system design and operation maintenance control
PURPOSE OF THE MODULE	**General purpose** You will be able to carry out photovoltaic system design and operation maintenance control in practice. Purposes 1. You will be able to design On Grid and Off Grid Photovoltaic systems. 2. You will be able to control On-Grid and Off-Grid Photovoltaic system operation and maintenance.

1. PHOTOVOLTAIC SYSTEM DESIGN

1.1. Solar energy potentials of Türkiye, Spain and Austria

Due to the increase in electrical energy consumption in the world and the difficulties in meeting this need, the economical use of electrical energy has become of great importance. Due to the oil and natural gas crises, increasing demand and prices, and environmental concerns, the importance of domestic and renewable energy resources (such as solar wind, geothermal) is increasing (Figure 1.1)

Solar energy systems have progressed technologically and decreased in cost, and solar energy has established itself as an environmentally clean energy source. The use of solar energy begins in residences in terms of daily life; It extends to communications, agriculture, industry, power plants, military services and space.

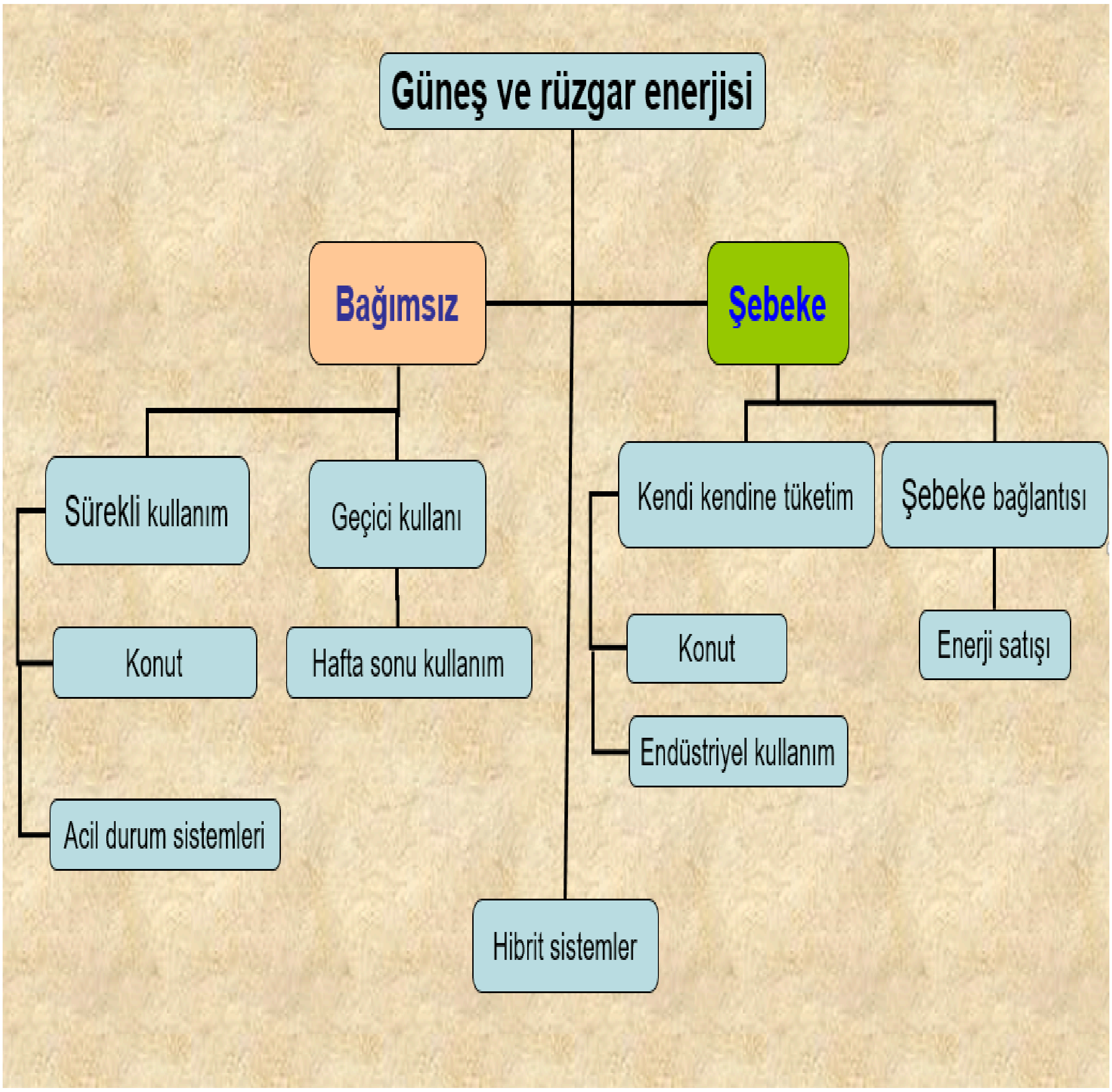
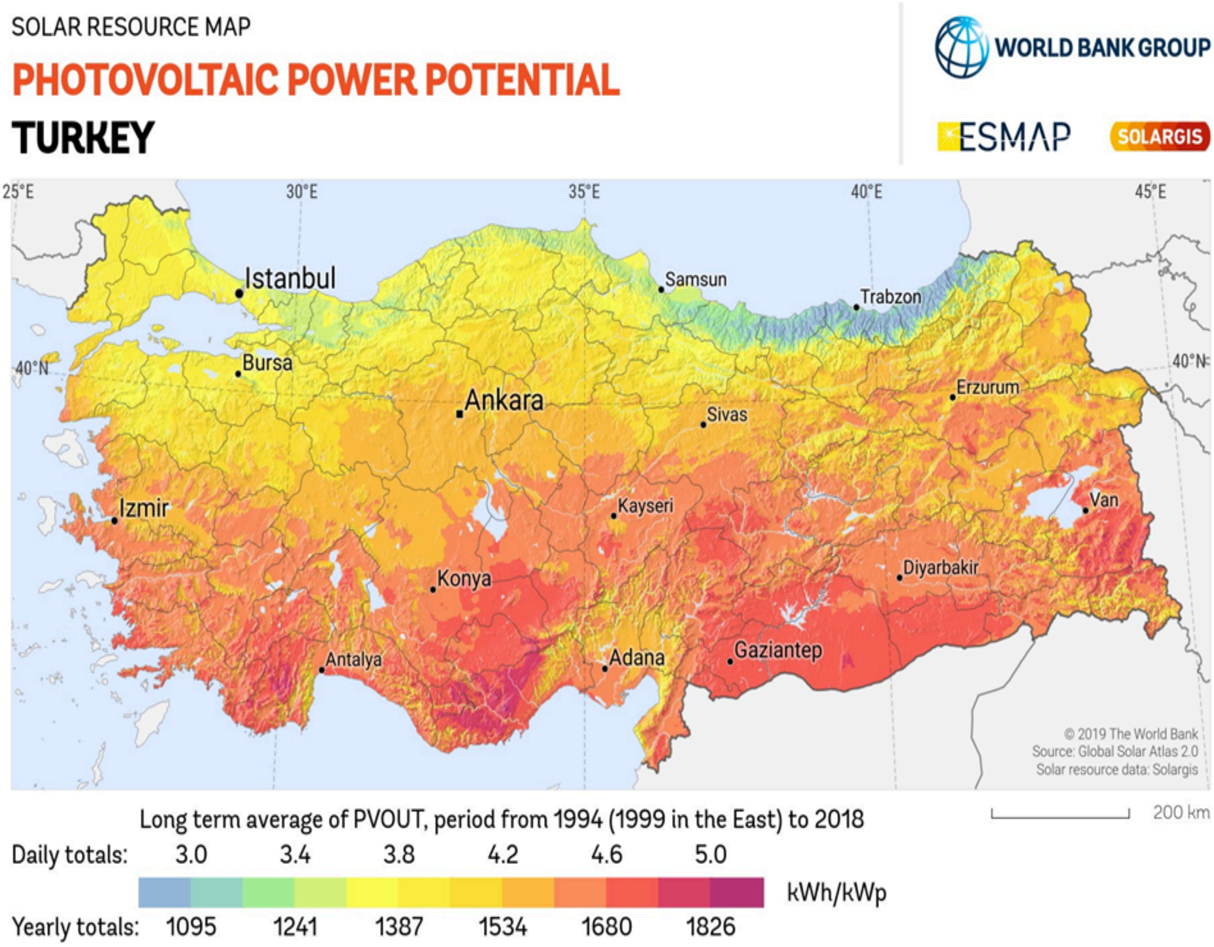


Figure 1.1: Solar and Wind Energy System

The sun is a clean and inexhaustible source of renewable energy. It can meet all the energy needed in the world with the power radiated by the Sun.

The sunshine duration and solar energy potential map in Turkey is also given (Figure 1.2).

It has been determined that Turkey's average annual total sunshine duration is 2640 hours (daily total 7.2 hours), and average radiation intensity is 1311 kWh/m2-year (daily total 3.6 kWh/m2).



Picture 1.2: Turkey's solar energy potential map

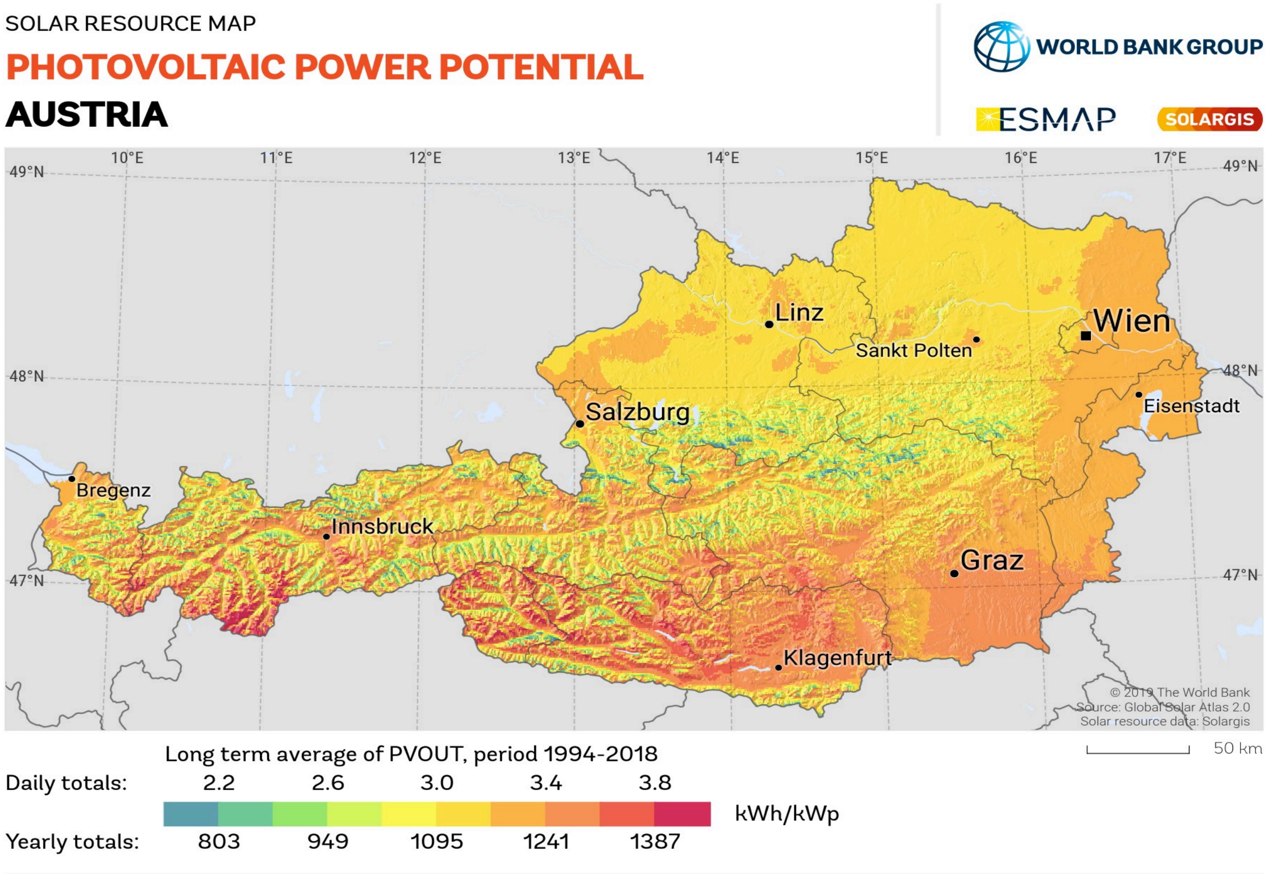
The sunshine duration and solar energy potential map in Spain is also given in (Picture 1.3).

Spain's average annual total sunshine duration is …………. hours (total daily ……….. hours), average radiation intensity ………. It has been determined that kWh/m2-year (daily total ……….. kWh/m2).

Picture 1.3: Solar energy potential map of Spain

The sunshine duration and solar energy potential map in Austria is also given (Picture 1.4).

It has been determined that the average annual total sunshine duration of Austria is …….. hours (total daily ……….. hours), the average radiation intensity is ……….. kWh/m2-year (total daily ……. kWh/m2).



Picture 1.4: Solar energy potential map of Austria

1.2 Photovoltaic (PV) solar system

Photovoltaic solar system is a system that converts photons from the sun into DC electrical energy by connecting panels in series/parallel and using inverters that convert the DC electricity obtained into 220v AC or 380 V AC voltage, bringing it to a voltage level that we can use in our daily lives (Picture 1.5). Photovoltaic systems are the most common among solar energy electricity generation systems..

Picture: 1.5: Photovoltaic solar system

1.3 Usage Areas of Photovoltaic (PV) Solar System

Photovoltaic solar systems are easy to install due to their modular structure and can be installed in all terrain conditions (Picture 1.6). It can be used in all areas where electricity is needed, but the main ones are as follows:;

- Vineyard/chalets
- Base stations
- Agricultural irrigation
- Park, garden, sign lighting
- Early warning, alarm and security systems
- Watchtowers and signaling systems
- Construction, construction site etc. field applications
- Mobile and marine applications
- Areas such as houses in the city, villages and towns
- Hotel etc. buildings
- Factory, workshop, industry etc. Businesses
- Indoor lighting
- Logistics and cold storages
- Shopping malls
- Markets and stores
- Hospitals, municipalities etc..

Picture 1.6: Photovoltaic solar system usage areas

2. PHOTOVOLTAIC SYSTEM ANALYSIS

There are many parameters that affect the system for FS to work efficiently. These parameters appear at different points, starting from the radiation intensity from the sun to the point where the AC voltage required to operate the receivers at the end of the system is supplied [3].

In order to establish FS, it is necessary to first determine the amount of energy to be consumed daily. Determining this value is directly related to the amount of power consumed by the electrical appliances we use at home and their usage time. After this value is determined according to user requests, the panel type that will meet the energy needs of the system should be selected. The number of panels in the system is determined by taking into account the energy conversion efficiency of each panel.

The efficiency values of solar panels are approximately 15% [7]. After the number of panels is determined, the battery capacity and number to be used in the system will be determined, taking into account that the system will be installed independently of the network. Battery capacity can be calculated by ratio of the daily amount of electricity consumed to the voltage value to be received from the battery. Since the voltage obtained and stored is direct current, a converter capacity must be available to make it suitable for use in homes. Converters convert the direct current coming into the input into alternating current with a rate of nearly 85% [3].

Parameters affecting the efficiency of FS; These are temperature, shading, matching losses, converter losses, storage losses and panel placement angle. Each of these mentioned variables are important variables to be considered in photovoltaic system design [3].

One of the values that play an important role in establishing FS is the regional solar heating values on the horizontal plane. Solar heating values are used to determine the number of panels to be used in establishing the system..

PS= (GEİ* SV)/(BMÜG* GOGS)
PS = Number of Panels
GEI = Daily Energy Need
SV = System Efficiency
BMÜG = Power Produced by a Module
GOGS = Average Daily Sunshine Time

Here, the number of panels is found from the equation above, but it is necessary to connect a certain number of modules in series to obtain the desired voltage value from the system. To provide the desired power output, it is necessary to connect a certain number of serial arrays in parallel. The factor to be taken into consideration when determining these values is the DC input voltage range of the inverter. This information is included in the technical catalog of the inverter [3].

2.1. Charge Control Unit

Charge control units are units that regulate the voltage between batteries and photovoltaic arrays. It is not desired to transmit the power from photovoltaic modules

directly to the batteries. The purpose of charge controllers is to protect batteries from overcharging. A good charge controller is expected to protect the batteries from excessive electricity produced after light falls on the solar panels and to prevent the batteries from discharging at points where electricity production is low [4].
The following equation is used when determining the capacity of charge control units. [5].

ŞC = GEİ / GGS

ŞC = Battery Charger
GEI = Daily Energy Need
GGS = Daily Sunshine Time

2.2 Determination of Converter Capacity

Devices used as receivers (load) in FS generally operate with 220 V and 50 Hz alternating current. A converter is needed to convert the direct current produced from the panels into alternating current. When determining the inverter capacity, it is desired that it be more than the power produced by the device to be used. The amount of power to be taken from the inverter output is calculated by multiplying the power coming to the inverter input and the inverter efficiency. [6].

ÇKAP= (GEI*ÇK)/GGS

MCAP = Converter Capacity
GEI = Daily Energy Need
MP = Inverter Loss
GGS = Daily Sunshine Time

2.3 Determining Battery Capacity and Number

The table below shows what the DC voltage of the system should be compared to the maximum output power values when determining the battery capacity [6].

Table 1: Battery Voltage According to Power Rating

Maximum AC Power	DC Voltage of the System
<1200 W	12 V
1200–2400 W	24 V
2400–4800 W	48 V

In creating the FS, just like the panels, the batteries are defined in the system according to the user's choice. The user will be able to see the system efficiency and the cost of the system due to the battery by selecting the batteries he wants to have in his system or indirectly for each of them. The number of batteries selected by the user in the system is given in the equation. [6].

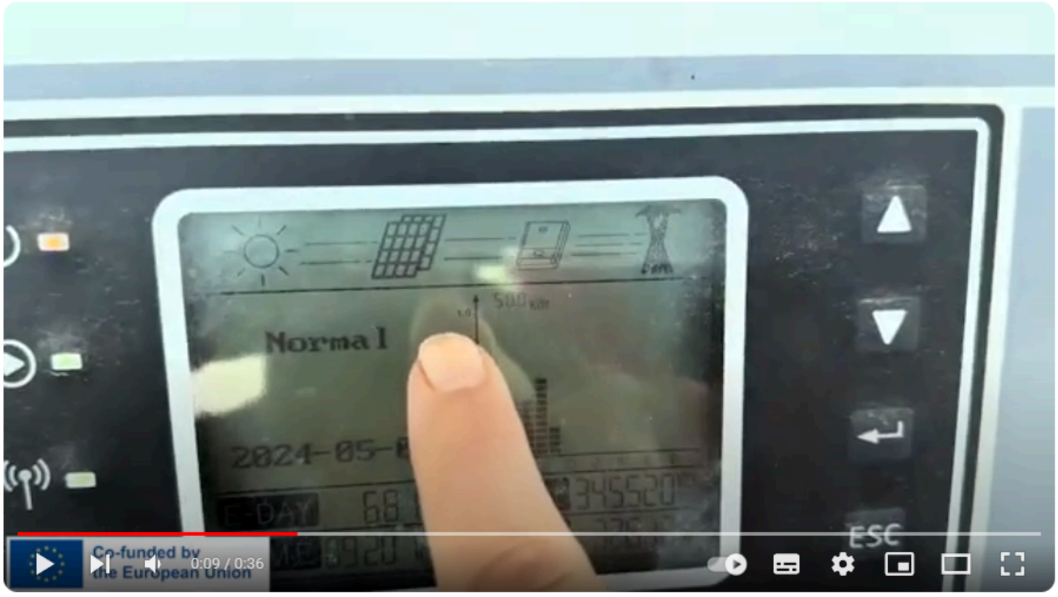
AS=(GEİ*AK)/(AV*AKAP)

AS = Number of Batteries
GEI = Daily Energy Need
AK = Battery Losses
AV = Battery Voltage
AKAP = Battery Capacity

To play the video, click on the image or click the link below and open it with your browser.
https://www.youtube.com/watch?v=7Eg9IlRMqSU

2.4 Inverters

While photovoltaic panels produce direct current, the electrical devices we use at home operate on alternating current. Today, power electronic devices used to convert direct current into alternating current are converters [1]. Photovoltaic panels are mostly designed to produce a direct current of 12 volts. Where a 220V alternating current is required, this can be provided by an electronic inverter. Using an inverter causes a significant power loss of up to 15%. However, alternating current allows the use of standard household appliances [5].



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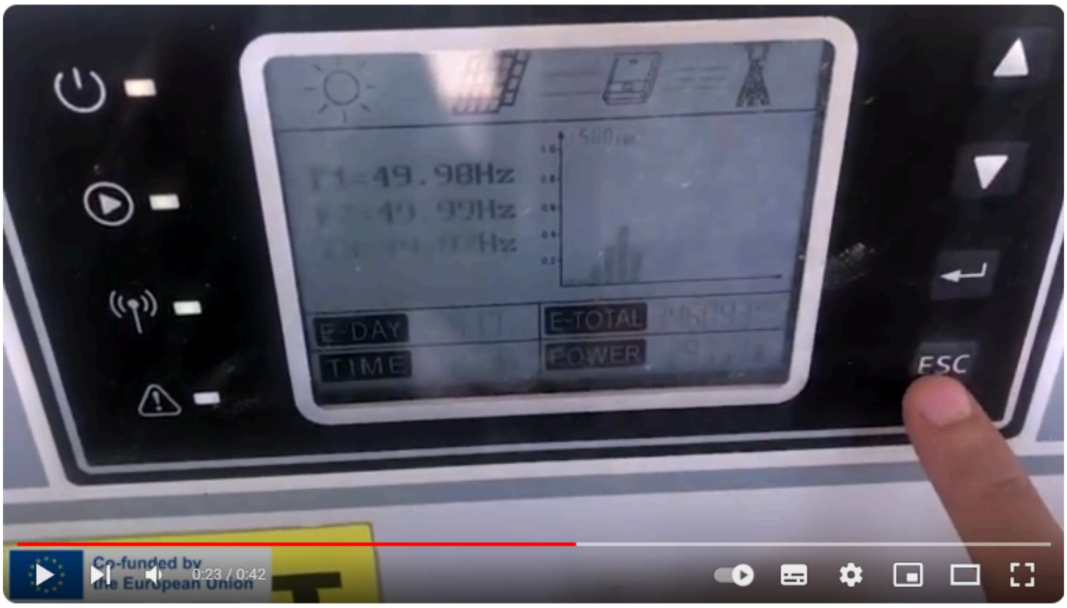
The converters used in FS differ from the converters used in other applications. This is because the system normally has to keep the voltage constant at the maximum operating point (MIN) required to operate. That's why grid-connected converters are mostly used to monitor the MIN point. For example, DC/DC converters are used to adjust the voltage by controlling the changes that may occur in the mains voltage. That's why the charge controller should be used in many systems.



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https://www.youtube.com/watch?v=qYElKC5hMx4

2.5 Solar Cells and Solar Cell Systems

Solar cells; They are electronic devices that directly convert solar energy into electrical energy when sunlight falls on it. There are no moving parts in this energy cycle. While only 1% of solar energy could be converted in 1914, in 1954 Chapin and Fuller succeeded in making photovoltaic diodes on silicon crystal that converted solar energy into electrical energy with 6% efficiency. In the years following this date, which can be considered a turning point for FS, research and first designs were made for power systems to be used in space vehicles. [9].

Solar cells are durable, reliable and long-lasting. They do not cause any electrical problems during their operation. The biggest threats that solar cell modules can face are lightning strikes and long-term (approximately 20 years) corrosion due to weather conditions. The biggest disadvantages of solar cell systems are the high initial investment cost and the low efficiency of solar cells. One of the best aspects of these systems is that they do not have negative effects on the environment, like all other renewable energy sources (wind, biogas, biomass, hydraulic, geothermal) [9]. Solar battery systems are divided into two: grid-connected systems and grid-independent systems.

2.6 On Grid Photovoltaic Systems (Grid Connected)

In grid-connected systems, the user's energy consumption is covered by the energy produced by the PV system. In cases where consumption exceeds production, the user takes the excess energy from the grid; On the other hand, in cases where the user's consumption is less than the production, the grid can be fed with excess energy (Image: 2.1)

Picture: 2.1: Photovoltaic solar system (on grid)

Main areas of use;
- Areas such as houses in the city, villages and towns

- Factory, workshop, industry etc. businesses
- Logistics and cold storages
- Markets and stores
- Hotel etc. buildings
- Indoor lighting
- Shopping malls
- Hospitals, municipalities, etc.

The power of grid-connected solar cell systems can vary from a few kW to several MW (Figure 2.1). Such systems are divided into two main groups. The first type of system basically meets the electricity needs of a residential unit. In these systems, the excess energy produced is sold to the electricity grid, and in cases where sufficient energy is not produced, energy is taken from the grid. There is no need to store energy in such a system. All it takes is to convert the direct current produced into alternating current and make it network compatible. The second type of grid-connected solar cell systems are large power generation centers that produce electricity on their own and sell it to the grid. [9].

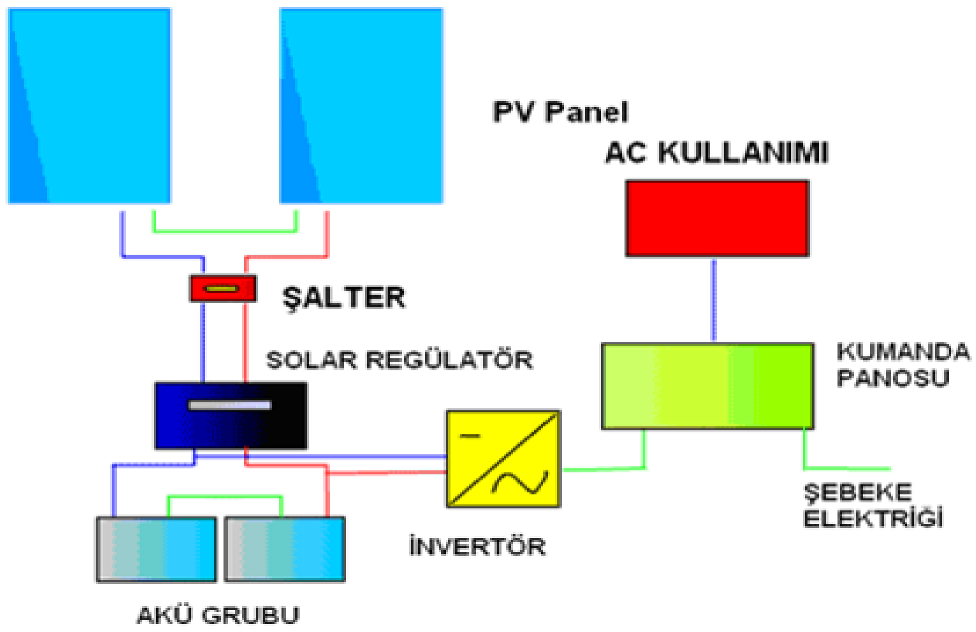


Figure 2.1.: Grid Connected System with AC Users

2.7 Off Grid Photovoltaic Systems (Without Grid Connection)

In these systems, the electrical energy produced by photovoltaic panels is stored in batteries and the user meets his energy needs (day and night) from these batteries. The capacity of the system can be sized to meet the user's needs during the period when electricity cannot be produced from the sun (Image: 2.2).

Picture: 2.2: Photovoltaic solar system (on grid)

Main areas of use;

- Vineyard / mountain houses
- Base stations
- Agricultural irrigation
- Park, garden, sign lighting
- Early warning, alarm and security systems
- Watchtowers and signaling systems in construction, construction sites, etc. field applications
- Mobile and marine applications

To play the video, click on the image or click the link below and open it with your browser.
https://www.youtube.com/watch?v=TVrHC3vEAek

The most typical and common use of FS is as independent systems that meet the energy needs in areas far from settlements. [one]. These systems can meet the energy demands of a wide variety of types of loads with powers ranging from a few W to several hundred KW (Figure 2.2 and Figure 2.3)

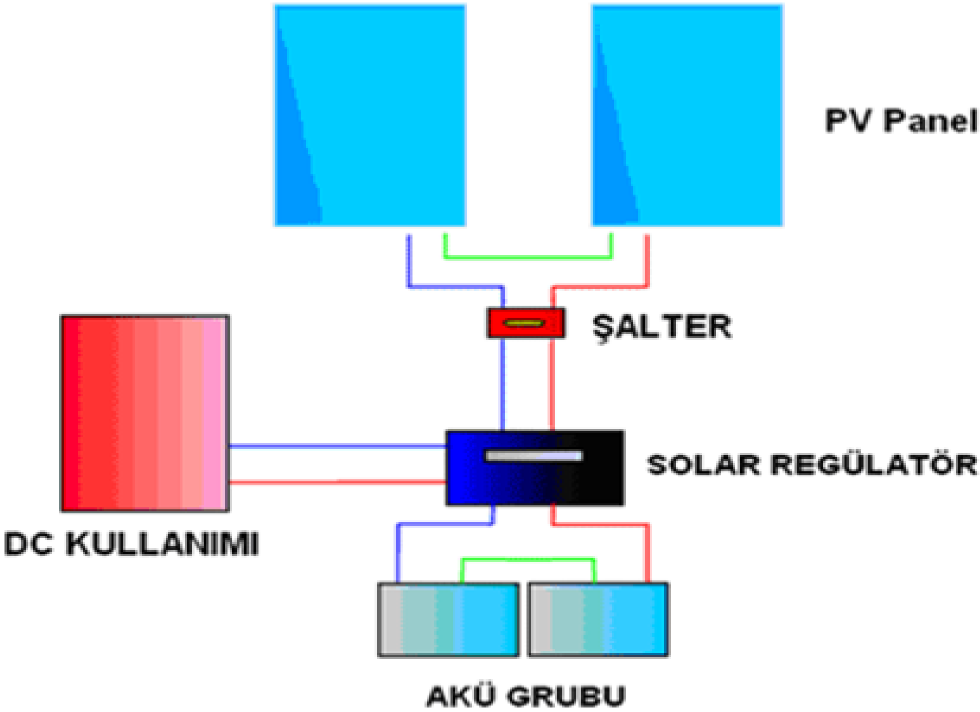


Figure 2.2.: Grid Independent System with DC Users

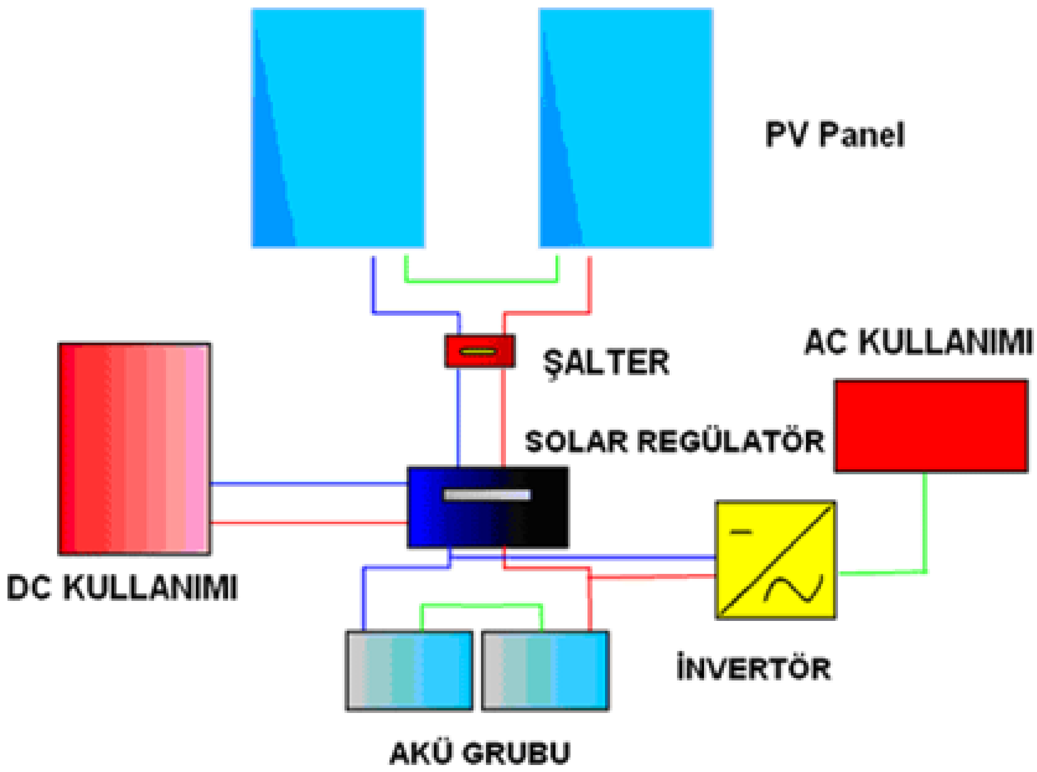


Figure 2.3.: Grid Independent System with DC and AC Users

3. PHOTOVOLTAIC PLANT DESIGN

1. Calculation of daily needs

2. Determination of the annual (especially for winter months) solar energy potential of the region to be established (irradiance value and number of sunny days)

3. PV panel, battery, charge controller, inverter and cable selection (You must choose a real brand and model for each product and use catalog data.)

4. Installation cost calculation

The numerical values below are sample values that vary for each situation.

You must use the formulas according to your own needs.

3.1. A System with 2 KVA Power

A- System is Independent from the Grid

S=2 KVA

Cosφ = 0.95

Average daily sunshine duration = 5.2 hours

Solen PM 110 model PV panel will be used in the system.

Panel power 110W

Vm = 16.5V

System installed capacity:

Ppv=S* Cos φ = 2000 *0.95=1900W

As a general rule in the literature, it is recommended that the inverter power be selected as 80% of the PV installed power.

Pinv= 0.80* Ppv

Pinv= 0.80*1900= 1520W

Pinv=1520/0.95=1600VA

Steca XPC 2200–48 model 1600 VA inverter will be used in the system.

İKAP=(GEİ*İK)/GGS

IKAP = Inverter Capacity

GEI = Daily Energy Need

HR= Inverter Loss

GGS= Daily Sunshine Time

1520=(GEI*1.05)/5.2=7.5kWh

(Inverter loss is 5%)

Sonnenschein 24V 240Ah battery will be used in the system.

AS=(GEİ*AK)/(AV*AKAP)

AS = Number of Batteries

AKAP = Battery Capacity

AV = Battery Voltage

GEI = Daily Energy Need

AK = Battery Losses

(7527.6*1.10)/(24*240)=1.437, that is, 2 batteries.

(Battery losses are 10%)

Number of modules connected in series:

n= Vnom / Vm=290 / 16.5=2.90

That is, 3 modules will be connected in series.

Number of parallel arms:

np = Ppv / Pseq=1900 / (3*110)=5.76

6 6*3 = 18, so 18 modules are required

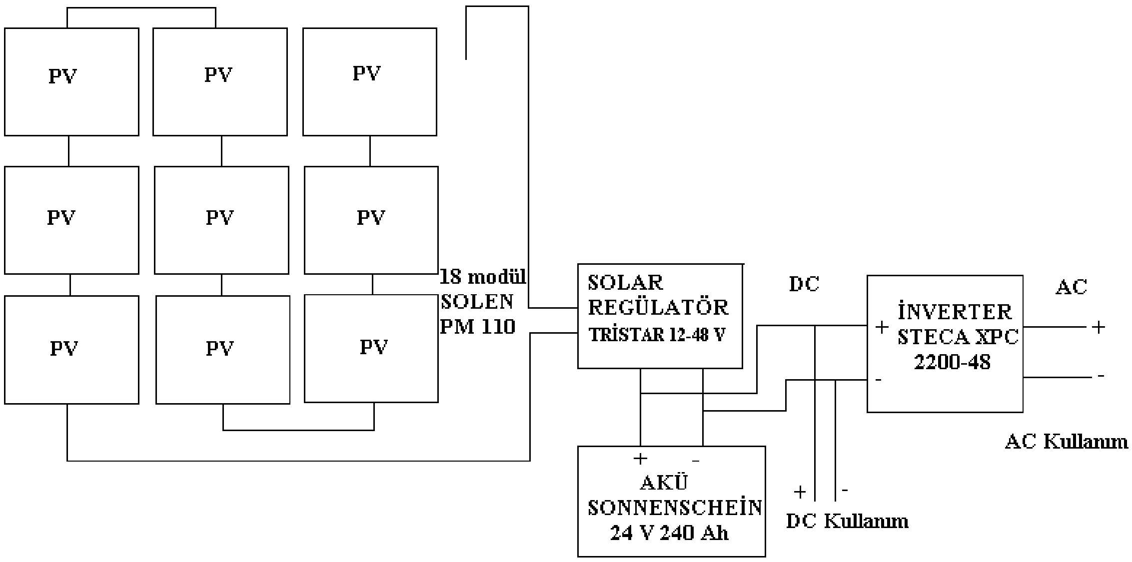
ŞRK=GEİ / GGS=7527.6 / 5.2=1500W

ŞRK = Charge Controller Capacity

GEI = Daily Energy Need

GGS= Daily Sunshine Time

2 KVA System Block Diagram (System is independent from the grid)**)**



2 KVA Discovery Summary of Off-Grid System

Product name	amount	Area (m2)	Price
Solen PM 110 Fotovoltaik modül 110 W 16.5 V	18 Piece	16	17193 TL
Steca XPC 2200-48 İnvertör 1600 VA	1 Piece		2605 TL
Tristar 12-48 v Şarj regülatörü	1 Piece		403 TL
Sonnenschein 24 Volt 240Ah Solar Battery - 12 x A602/240 Akü	1 Piece		209 TL
Total			20410 TL

B-System is Connected to the Grid

S=2 KVA

Cosφ = 0.95

Average daily sunshine duration = 5.2 hours

Panel power 110W

Vm = 16.5v

System installed capacity:

Ppv= S* Cos φ = 2000 *0.95=1900W

As a general rule in the literature, it is recommended that the inverter power be selected as 80% of the PV installed power..

Pinv= 0,80 * Ppv
Pinv=0,80*1900=1520W
Pinv=1520/0,95 = 1600VA

Steca XPC 2200–48 model 1600 VA inverter will be used in the system.

From the expression İKAP=(GEİ*İK)/GGS,

IKAP = Inverter Capacity

GEI = Daily Energy Need

HR= Inverter Loss

GGS= Daily Sunshine Time

1520=(GEI*1.05)/5.2=7527.6 wh=7.5kWh

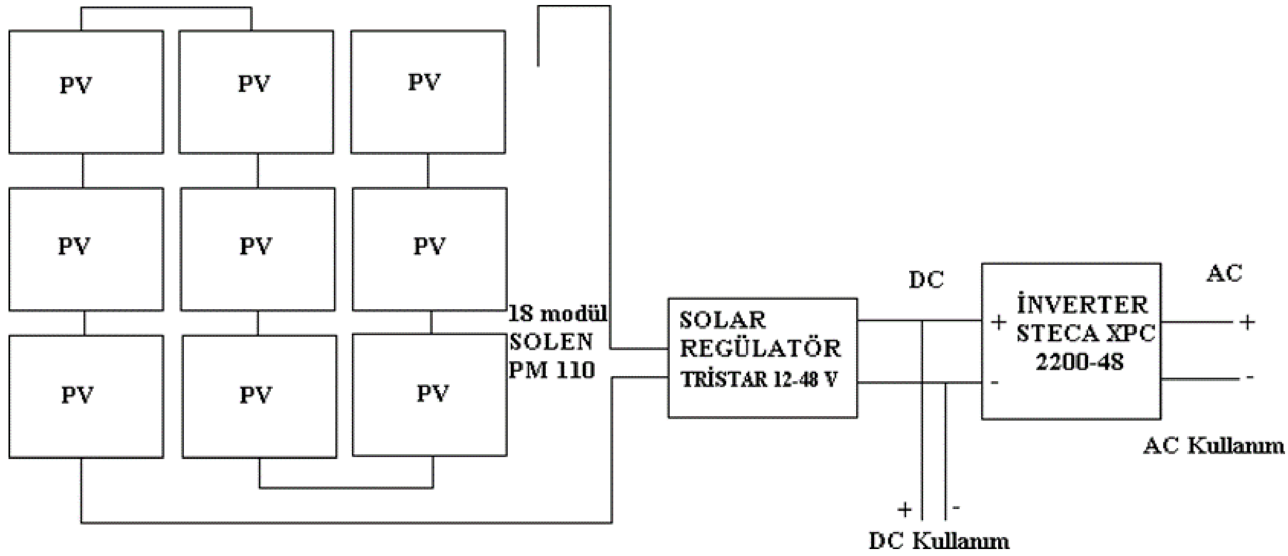
(Inverter loss is 5%)

<u>Number of modules connected in series:</u>

$$n = \frac{Vnom}{Vm} = \frac{48}{16,5} = 2,90$$

That is, 3 modules will be connected in series.
Number of parallel arms:
$n_p = P_{pv}/ P_{dizi}$=1900/(3*110)=5,76
6 tane 6*3 = 18 modules are required

2 KVA System Block Diagram (System connected to mains)



2 Discovery Summary of KVA Grid Connected System

Product name	Amount	Area (m2)	Price
Solen PM 110 Fotovoltaik modül 110 W 16.5 V	18 Piece	16	17193 TL
Steca XPC 2200-48 İnvertör 1600 VA	1 Piece		2605 TL
Total			19798 TL

3.2 10 KVA A Powerful System

Daily Energy Consumption of a House by Devices

Devices	Momentary Or 24 Hour Power Rating	Daily Working Time	Daily Total Energy Consumption
LED TV+Uydu Alıcısı	150W	12h/day	1800Wh/ day
A+ Standard Refrigerator	1200W	24h/ day	1200Wh/ day
A+ Washing machine	1200W	2h/ day	2400Wh/ day
A+ Dishwasher	1200W	1h/ day	1200Wh/ day
2hp Submersible Engine	1500W	2h/ day	3000Wh/ day
Boiler	1000W	3h/ day	3000Wh/ day
Lighting (10pcs 12W LED Lamp)	120W	12h/ day	1440Wh/ day

Total: 14040 Wh/ day

A- System Independent from Grid

S=10 KVA

Cosφ = 0.95

Average daily sunshine duration = 5.2 hours

Solen Coenergy SC180MA model PV panel will be used in the system.

Panel power 180W

Vm = 36V

System installed capacity:

$P_{pv}=S* \cos\varphi = 10000 *0.95=9500W$

As a general rule in the literature, it is recommended that the inverter power be selected as 80% of the PV installed power.

$P_{inv}= 0.80* P_{pv}$

$P_{inv}= 0.80*9500= 7600W$

Pinv=7600/0.95=8000VA

Conergy ISA 30K 30 KVA hybrid inverter will be used in the system.

İKAP=(GEİ*İK)/GGS

IKAP = Inverter Capacity

GEI = Daily Energy Need

HR= Inverter Loss

GGS= Daily Sunshine Time

7600=(GEI*1.10) / 5.2=35927wh = 40kWh

(Inverter loss is 10%)

Trojan 48Volt 250Ah Model: 8 x T–105 batteries will be used in the system.

AS=(GEİ*AK)/(AV*AKAP)

GEI = Daily Energy Need

AS = Number of Batteries

AKAP = Battery Capacity

AV = Battery Voltage

AK = Battery Losses

AS=(40000*1.10)/(48*250)=3.6, that is, 4 batteries**.**

(Battery losses are 10%)

According to the inverter catalogue, the battery pack output voltage should be 240 V. 240/48= 5, that is, 5 batteries will be connected in series, 4 parallel arms are required, a total of 20 batteries.

Number of modules connected in series:

n= Vnom / Vm=290 / 36=8.05

That is, 8 modules will be connected in series.

Inverter nominal voltage = 290 V

Number of parallel arms:

np = Ppv / Psequence=9500 / (4*180)=13.19

That is, 13 modules. 13*8 = 104 modules required

ŞRK=GEİ / GGS=40000 / 5.2=7692.3W

ŞRK = Charge Controller Capacity

GEI = Daily Energy Need

GGS= Daily Sunshine Time

Cable selection

The formula to be used to calculate cable cross-section:

$A[mm^2]=0.0175*2*L*P/(fk*U^2)$ (1)

A = Conductor Cross Section

fk[%] = Conductor Loss

0.0175 = Specific resistance for copper [Ohm × mm^2 / m]

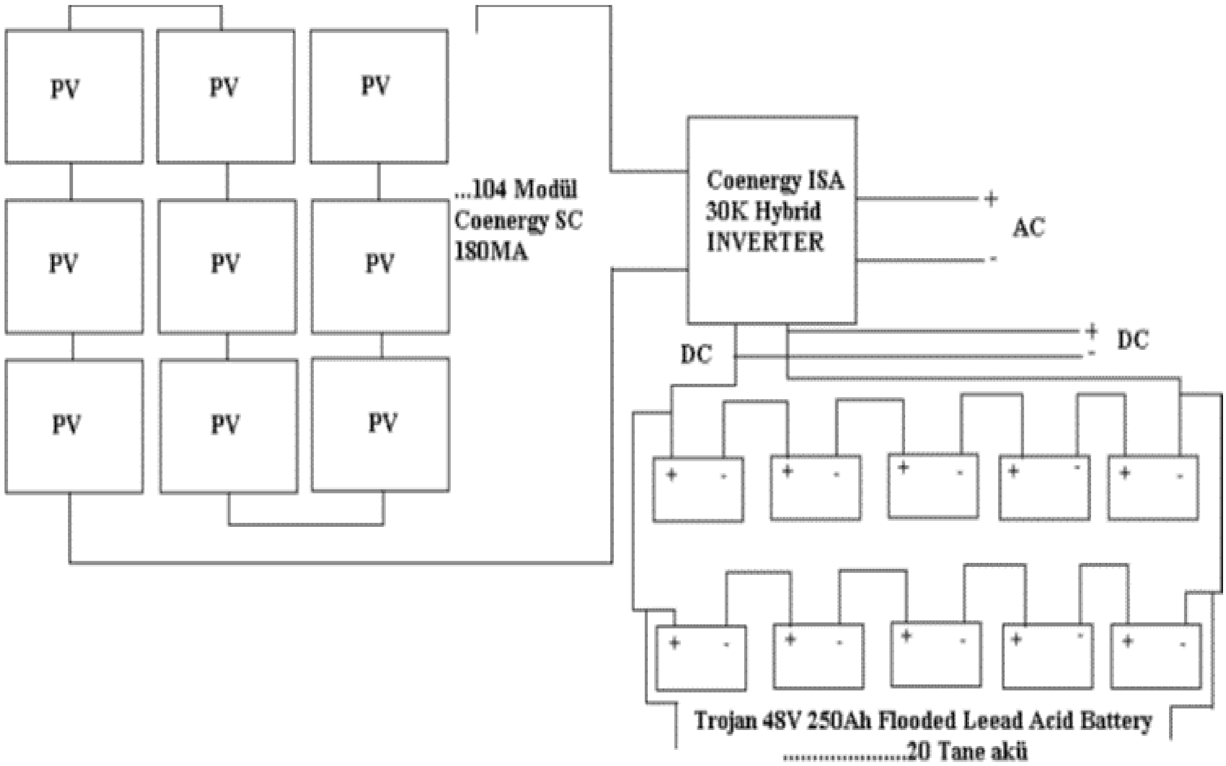
L[m] = Cable length

P[W] = Power to be received by the cable

U[V] = System Voltage Solar cable selection table for panel systems

Kablo Uzunluğu [m]	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-9
Amper [A]	Kablo Kesiti [mm^2]							
0-20	2,5	6	6	6	10	10	10	10
21-36	6	6	10	10	20	20	20	35
37-50	6	6	10	10	20	20	20	35
51-65	10	10	20	35	35	35	35	35
66-85	20	20	35	35	35	35	35	35
86-105	20	20	35	35	35	35	35	35
106-125	35	35	35	35	35	35	35	35
125-150	35	35	35	35	35	35	35	35
151-200	35	35	50	50	50	50	50	50

10 KVA System Block Diagram (System is off-grid)



10 Discovery Summary of KVA Off-Grid System

Product name	amount	Area (m2)	Amount
Coenergy SC 180MA Fotovoltaik modül 180 W 36 V	104 Piece	138	178211TL
Coenergy ISA 30K hybrid İnvertör 30KVA	1 Piece		69237 TL
Trojan 48Volt 250Ah Flooded Lead Acid Battery Bank, 8 x 6V T-105 Akü	20 Piece		7875 TL
Total			255323 TL

B-System Connected to the Grid

S=10 KVA

Cosφ = 0.95

Average daily sunshine duration = 5.2 hours

Solen Coenergy SC180MA model PV panel will be used in the system.

Panel power 180W

Vm = 36v

System installed capacity:

Ppv= S* Cos φ = 1000 *0.95=9500W

As a general rule in the literature, it is recommended that the inverter power be selected as 80% of the PV installed power.

Pinv= 0.80 * Ppv

Pinv=0.80*9500=7600W

Pinv=7600/0.95 = 8000VA

Conergy ISA 30K 30 KVA hybrid inverter will be used in the system.

From the expression İKAP=(GEİ*İK) / GGS,

IKAP = Inverter Capacity

GEI = Daily Energy Need

HR= Inverter Loss

GGS= Daily Sunshine Time

7600=(GEI*1.10)/5.2=35927.2 wh=40kWh

(Inverter loss is 10%)

Number of modules connected in series:

n= Vnom/Vm=290/36=8.05

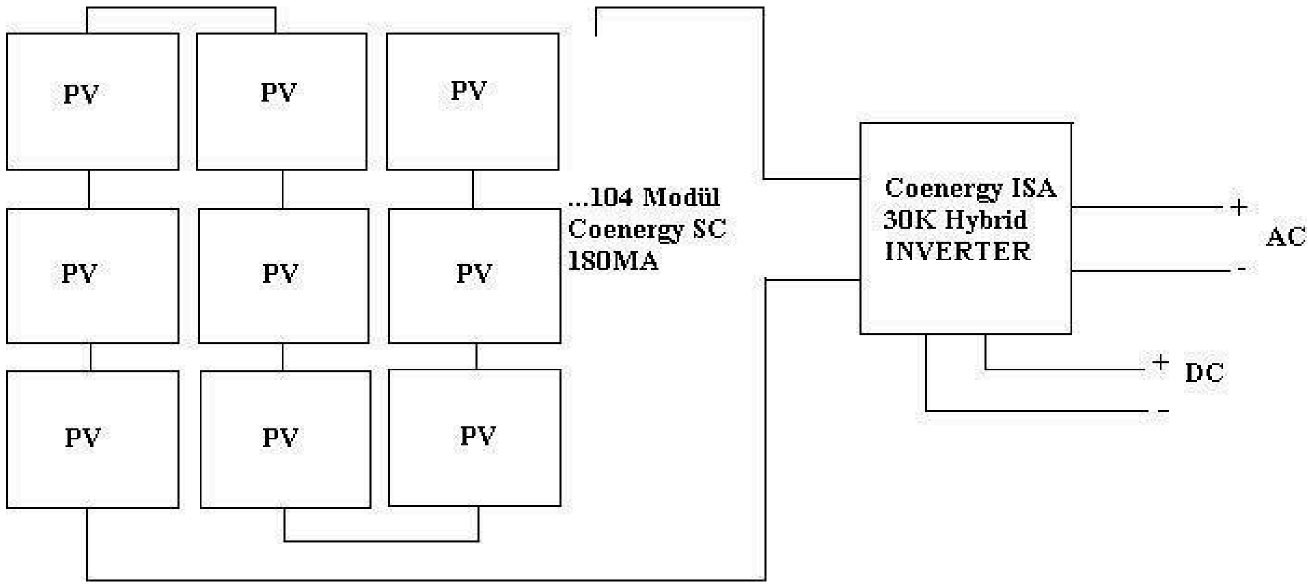
That is, 8 modules will be connected in series.

Inverter nominal voltage = 290 V.

Number of parallel arms:

np = Ppv/ Psequence=9500/(4*180)=13.19

13 13*8 = 104 modules are required.10 KVA Sistem Blok Diyagramı (The system is connected to the grid)



10 KVA Discovery Summary of Grid Connected System

Product name	amount	Area (m2)	Total
Coenergy SC 180MA Fotovoltaik modül 180 W 36 V	104 Piece	138	178211TL
Coenergy ISA 30K hybrid İnvertör 30KVA	1 Piece		69237 TL
Total			247448 TL

3.3. A System with 20 KVA Power

A- System is Independent from the Grid

S=20 KVA

Cosφ = 0.95

Average daily sunshine duration = 5.2 hours

Solen Coenergy SC180MA model PV panel will be used in the system.

Panel power 180W

Vm = 36V

System installed capacity:

Ppv=S* Cos φ = 210000 *0.95=19000W

As a general rule in the literature, it is recommended that the inverter power be selected as 80% of the PV installed power.

Pinv= 0.80* Ppv

Pinv= 0.80*19000= 15200W

Since cos φ =0.95

Pinv=15200/0.95=16000 VA should be.

Conergy ISA 30K 30 KVA hybrid inverter will be used in the system.

İKAP=(GEİ*İK)/GGS

IKAP = Inverter Capacity

GEI = Daily Energy Need

HR= Inverter Loss

GGS= Daily Sunshine Time
15200=(GEI*1.10) / 5.2=71854.54wh = 72kwh
(Inverter loss 10%)
Trojan 48Volt 250Ah Model: 8 x T–105 batteries will be used in the system.

AS=(GEİ*AK)/(AV*AKAP)

GEI = Daily Energy Need
AS = Number of Batteries
AKAP = Battery Capacity
AV = Battery Voltage
AK = Battery Losses

AS=(72000*1.10)/(48*250)=6.06, that is, 6 batteries.
(Battery losses are 10%)
According to the inverter catalogue, the battery pack output voltage should be 240 V. 240/48= 5, that is, 5 batteries will be connected in series, 6 parallel arms are required, a total of 30 batteries.

Number of modules connected in series:
n= Vnom / Vm=290 / 36=8.05
That is, 8 modules will be connected in series.
Inverter nominal voltage = 290 V
Number of parallel arms:
np = Ppv / Psequence=9500 / (4*180)=13.19

That is, 13 modules. 13*8 = 104 modules required

ŞRK=GEİ / GGS=72000 / 5.2=13846.15W

ŞRK = Charge Controller CapacityGEİ = Daily Energy Need

GGS= Daily Sunshine Time

The block diagram of the system is the same as the 10 KVA off-grid system.
However, the only difference is that 30 batteries are used in this system.

20 KVA Discovery Summary of Off-Grid System

Product name	amount	Area (m2)	amount
Coenergy SC 180MA Fotovoltaik modül 180 W 36 V	104 Piece	138	178211TL
Coenergy ISA 30K hybrid İnvertör 30KVA	1 Piece		69237 TL
Trojan 48Volt 250Ah Flooded Lead Acid Battery Bank, 8 x 6V T-105 Battery	30 Piece		11813 TL
Total			259261 TL

B- System is Connected to the Grid

S=20 KVA

Cosφ = 0.95

Average daily sunshine duration = 5.2 hours

Solen Coenergy SC180MA model PV panel will be used in the system.

Panel power 180W

Vm = 36V

System installed capacity:

Ppv= S* Cos φ = 20000 *0.95=19000W

As a general rule in the literature, it is recommended that the inverter power be selected as 80% of the PV installed power.

Pinv= 0.80 * Ppv

Pinv=0.80*19000=15200W

Since cos φ =0.95

Pinv=15200/0.95=16000 VA should be.

Conergy ISA 30K 30 KVA hybrid inverter will be used in the system.

From the expression İKAP=(GEİ*İK) / GGS,

IKAP = Inverter Capacity

GEI = Daily Energy Need

HR= Inverter Loss

GGS= Daily Sunshine Time

15200=(GEİ*1,10)/5,2=71857,54 wh=72kWh

(Inverter loss is 10%)

<u>Number of modules connected in series:</u>

$$n = \frac{Vnom}{Vm} = \frac{290}{36} = 8,05$$

That is, 8 modules will be connected in series.
Inverter nominal voltage = 290 V.

Number of parallel arms:

np = Ppv/ Psequence=9500/(4*180)=13.19
13 13*8 = 104 modules are required.
Therefore, the block diagram and cost analysis of the system 10 KVA is equal to that of the grid-connected system

3.4. Results

In this study, a 2, 10 and 20 KVA FS design was made and they were compared among themselves. In addition, in this study, what is important for such a facility and what type of material should be used are mentioned. In addition to these issues, since it is possible to access technical information such as materials and connection types in this study, it was preferred, even though it was expensive. If such information is available on other materials with the same features and more affordable prices, their use is an important point that will reduce the installation cost. As seen in the research, the initial board costs of FS are very high. However, no fee is paid during the use of the system, which means that the system will cover the initial installation cost after a certain period of time.

When the daily energy need in the system increased from 7.5 kWh to 72 kWh, that is, increased approximately 10 times, the space required to install the system, the materials to be used and the system cost also increased approximately 10 times. However, as seen in the research, there is not much of a cost increase between 10 KVA off-grid and 20 KVA off-grid systems. Additionally, 10 KVA and 20 KVA grid-connected system installation costs are the same. Considering these data on FS, it is clear that installing low-power FS is not of much benefit to the manufacturer.

The table below shows some numerical data in these systems.

Numerical data about the system

System Type	System Installed Power (W)	Daily Energy Need	Cost
2 KVA off grid	1900	7,5kWh	20410
2 KVA connected to the grid	1900	7,5kWh	19798
10 KVA off grid	9500	40kWh	255323
10 KVA connected to the grid	9500	40kWh	247448
20 KVA off grid	19000	72kWh	259261
20 KVA connected to the grid	19000	72kWh	247448

4.PHOTOVOLTAIC SYSTEM OPERATION AND MAINTENANCE CONTROL

4.1 Inverter Control

Materials	Suitability
Inverter mechanical installation must be carried out in accordance with the user manual..	
Inverter DC cable connections must be made in accordance with the user manual..	
Inverter AC cable connections must be made in accordance with the user manual.	
AC cable lugs must be suitable according to the cable type.	
Inverter communication cables must be made in accordance with the user manual.	
DC cable cross-sections must be suitable according to the approved project.	
Inverter protection and body grounding should be done according to the user manual. It is below the desired value. (2ohm)	
Inverter warning labels should be made appropriately.	
There is no damage to the inverter casing.	
Inverter power limitation should be made according to the project.	

4.2 ACTP Control

Materials	Uygunluk
The TMŞ specifications of the motor used must be in accordance with the approved project.	
The Inverter TMŞ features used must be in accordance with the approved project.	
Appropriate adjustment and activation of the KAK relay.	
AC between Inverter- ACTP and ACTP-TRANSFORMER	
Carrying out cable pulling and regulating works according to the approved project.	
Toroid connection is suitable.	
The cross-sections of AC cables must be in accordance with the approved project.	
AC cable lugs must be suitable.	
Emergency stop button is active.	
Protection relay activation/Reclosing.	
Fan is active.	
The energy analyzer must be active and current and voltage transformer ratios must be entered appropriately.	
UPS connections are appropriate.	
Warning labels are made completely and appropriately.	
The panel must be cleaned properly and there is no damage to the panel casing.	

4.3 AC, DC Carrier System Control

Materials	Uygunluk
T. system to be carried out in accordance with the approved project and to comply with the details in the approved project..	
Proper fixing of pans.	
Pans should be covered appropriately..	
Using insulating material on the return or sharp parts of the pan.	
Pan AC and DC warning labeling is appropriate to be.	
No rust on the pan.	
Galvanized repair after pan cutting process.	

4.4 Optimizer Control

Materials	Suitability
Optimizer mechanical installation must be in accordance with the user manual.	
Optimizer electrical connections must be in accordance with the user manual..	
Optimizer seri numaraları bakım onarım ekibine tesis ve projeye göre yeri doğru olarak teslim edilmesi.	
Optimizer sorunsuz devrede olması. (İzleme birimi ile görüşülerek teyit edilmesi).	

4.5 Panel and Construction Control

Materials	Suitability
The values of the panels used (Model, power, voltage and current) are in accordance with the approved project.	
Leaving a distance of 20mm between panels.	
Junction box and connectors of the panels must be suitable according to the given datasheet. It has IP68 feature.	
Proper connection of the panels.	
Panel and string head DC cables must be properly regulated and connectors must be protected against insulation.	
Panels are not damaged during transportation and installation.	
Matching of purlins as per order details provided.	
The fixing process of the purlins should be done properly.	
Mounting the panel fastening apparatus by leaving the appropriate number and distance according to the panel user manual.	
Tightening the panel fastening apparatus with the appropriate torque.	
No difference in elevation between panels.	
The alignment of the coffee tables must be appropriate.	
Properly closing the holes opened on the roof after the construction works are completed.	
String grounding should be done appropriately according to the approved project.	
String tagging should be done appropriately.	
After the project site installation is completed, the Is the material available?	

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