RENEWABLE ENERGY TECHNOLOGIES

INSTALLING THE CONVERTER SYSTEM

MODULE

2022-2-TR01-KA210-VET-000098216

IN RENEWABLE ENERGY TECHNOLOGIES ACCORDING TO 4.0 STANDARDS NEW APPLICATIONS

TÜRKİYE ULUSAL AJANSI
TURKISH NATIONAL AGENCY

Co-funded by the European Union

This learning material was prepared within the scope of the New Applications in Renewable Energy Technologies According to 4.0 Standards project numbered 2022-2-TR01-KA210-VET-000098216. It is intended to guide vocational education trainers. It is free for users, cannot be sold or reproduced. It will be published as an e-book on the Project Website (http://www.renewableenergy40.com).

DESCRIPTIONS

FİELD	**Renewable Energy Technologies**
OCCUPATION	**Solar Energy Systems**
NAME OF THE MODULE	**Converter System Installation**
DESCRIPTION OF THE MODULE	It is a learning material that provides knowledge and skills regarding the preparation of the construction used in the installation of solar energy systems.
COMPETENCE	Installing the converter system of solar panels
PURPOSE OF THE MODULE	**General purpose** You will be able to mount the inverter and control panel and make cable connections at the designated location on the solar stand. **Purposes** **1.** With the appropriate equipment, you will be able to mount the converter at the designated location on the solar stand. **2.** You will be able to assemble the control panel with the appropriate tools.

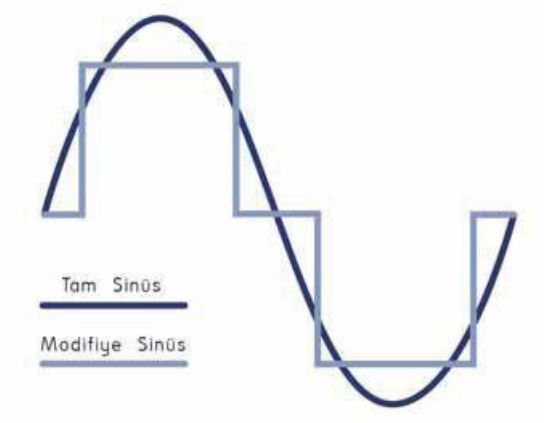
1. DETECTION OF THE INVERTER LOCATION

1.1. Determining the Installation Location

The inverter converts the DC energy produced by solar panels into AC energy (220V-50 Hz) used in homes. In general, inverters are divided into two types, modified sine wave inverters and full sine wave inverters, in terms of their output waveforms (Figure 1.1). It is difficult to distinguish the subtle difference between the two waveforms, but their performance should be considered in terms of the devices they operate.

Modified sine wave inverters: Modified sine wave is an imitation of full sine wave. A sine-like wave is obtained with square wavelets. Its advantage is that it is cheap; TV, computer, small appliances, lamps etc. It operates smoothly. Some televisions and computers, especially professional and industrial devices, can understand this very subtle difference. This will not damage the device, but it may be annoying. For example, on some televisions, a thin line may appear on the screen.

Full sine wave inverters: Full sine wave is the output we receive from the grid, just like at home. It is very clean, neat and the best. Therefore, it can be used in all applications without any problems and your devices will heat up less. The full sine wave feature is necessary to meet and not disrupt inductive loads such as washing machines, dishwashers and refrigerators. If you are going to run a motor, air conditioner, refrigerator as a load, or for industrial devices and applications, a full sine wave inverter is definitely recommended.



Shape 1.1: Inverter output waveforms

The power of the inverter should be selected according to the instantaneous total power of the devices that are expected to operate at the same time. For example, if you want to operate a 2 kW washing machine, a 300 W television and a 200 W lamp at the same time, you will need to choose a 2500W (2000W+300W+200W) inverter.

Inverters used in solar energy PV systems can be divided into three groups. These;

- Central inverters to which the whole system is connected,
- String inverters to which panel arrays are connected,
- These are panel inverters to which a single panel is connected.

Of these three groups, central inverters are most used

. Converters (inverters) convert solar energy sources that produce direct current into alternating current.

They are products that convert (mains current) into the heart of the system. These are divided into two: on-grid (on-grid) and off-grid (off-grid).

On-grid: These are inverters that can sell or supply to the grid by converting the direct current coming from solar panels into alternating current.

Off-grid: These are inverters that charge the batteries with the direct current coming from the solar panels and convert the direct current received from the batteries into alternating current.

System data can be obtained by establishing a connection between the RS 232 port on some inverter types and the computer. Especially in inverters used in grid-connected PV systems, the power and the generated electrical energy value can be viewed on the screen on the device.

The inverter, one of the basic elements of the solar panel system, must be inside the solar panel system power panel (Picture 1.1). The power panel of the solar panel system includes a charge controller along with the inverter. In some cases, there may be battery groups inside the solar panel system panel, and sometimes there may be external battery boxes outside the panel.

Picture 1.1: Solar panel system power panel

Solar panel system power panel, inside buildings; In open areas, it should be in a place that can be controlled in accordance with the project.

The following warnings should be taken into consideration when mounting the inverter into the solar panel system power panel:

- The inverter is mounted securely with bolts only in a vertical position and on a solid ground.
- It is checked whether the distance and cooling between the two inverters are sufficient.
- The location where the inverter will be installed should be protected from direct sunlight, high temperature and high humidity.
- The inverter should never be installed in the immediate vicinity of easily flammable materials.

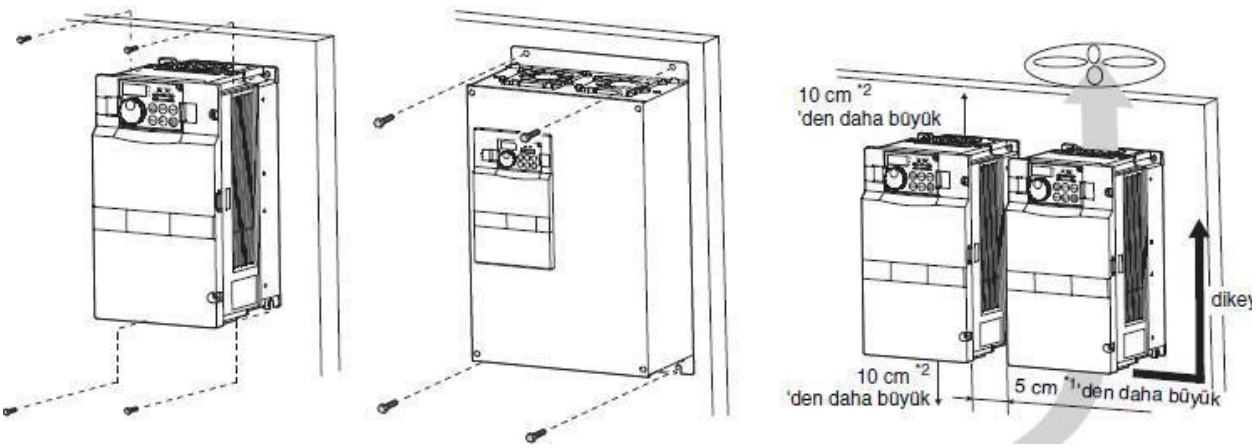


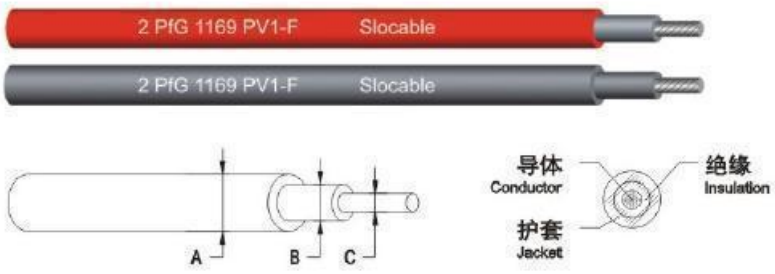
Figure 1.2: Installation of the inverter in the panel

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=kzXSyZZ-lB0

1.2. Converter Cable Connections

An inverter is a device that converts the DC voltage in the battery into the alternating voltage we use at home. In other words, it converts 12, 24 or 48 V DC battery voltage into 1 phase 230V – 3 phase 400 V AC 50 Hz voltage. Solar type inverter cables, specially produced for inverters in photovoltaic applications, are specially produced with superior quality raw materials.

The cables used for inverters contain tinned copper conductor wire conforming to VDE 0295 / IEC60228 class 5. The inner part of the cable consists of a special copolymer combined electronically with rays and a second polyolefin copolymer layer surrounding it (Picture 1.2).

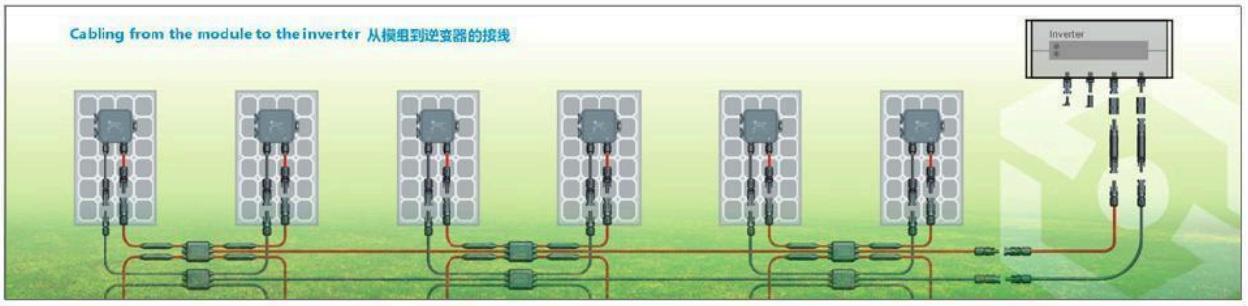


Picture 1.2: Solar cables

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=WfeNtk8WFcY

The nominal cable cross-section of solar cables must be approved by TÜV. It should have a dense cable diameter and not take up much space. It must definitely be long-lasting and durable. Solar cables and connectors should be used when connecting the inverters (Picture 1.3)(Picture 1.4).

Picture 1.3: Connectors (sockets) used for connection of solar energy modules to the inverter



Picture 1.4: Inverter cable connection

Before starting the inverter wiring or maintenance work, turn off the mains voltage and observe a waiting period of at least 10 minutes. This period is used to allow the capacitors to discharge to a non-hazardous voltage value after the mains voltage is turned off. Measure the voltage between P/+ and N/− terminals with a meter. There is a risk of electric shock if the connection work is not carried out in a voltage-free state.

To avoid noise problems when connecting the inverter cables, keep the signal cables 10 cm away from the power cables. After the cable connections are completed, there should be no cut cable pieces left inside the inverter. For example, cut pieces of cable may cause an alarm or malfunction. Do not allow sawdust or foreign objects to enter the inverter while drilling the mounting holes. Be careful to set the current/voltage input selection switch correctly. An incomplete adjustment may cause malfunctions. Tighten the connection screws to the specified torques. If a screw is tightened looser than specified, it may cause a short circuit or malfunction. If a screw is tightened more firmly than specified, it may cause a short circuit, malfunction, crack, or breakage. Use insulated cable ferrules/lugs for power input and motor connections. If long-distance cables (especially shielded motor cables) are used, the inverter may be affected by the charging current caused by the capacitance in the cables.

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=ds152b7C0gs

2. INVERTER CONTROL PANEL

2.1. Control Panel Elements and Layout

Control panel elements; The package consists of switches, control buttons, signal lamps, contactors, fuses, charge controller and inverter. In addition to these, fasteners, cable trays, carrier rails and terminal blocks are the elements used in the panel.

Package switches: Multi-position switches consisting of many contact slots arranged and packaged consecutively on a shaft that can rotate around an axis are called package switches (Figure 2.1).

Picture 2.1: Package switch

Control buttons: These are the elements used to start or stop the operation of a circuit (Figure 2.2). It is divided into three: start, stop and jog (dual-way) buttons.

Picture 2.2: Control buttons

Signal lamps: The element that indicates with light whether a control element or circuit is working or not is called a signal lamp (Picture 2.3).

Picture 2.3: Signal lamps

Contactors: Large powerful electromagnetic switches that are used to open and close electrical circuits and can be controlled remotely with a drive system are called contactors

Picture 2.4 Contactor

Fuses: These are circuit elements used to protect the receivers working in the circuit with the electrical supply lines against overloads, high currents caused by short circuits, and the people using them against possible accidents (Picture 2.5).

Picture 2.5: Automatic fuse

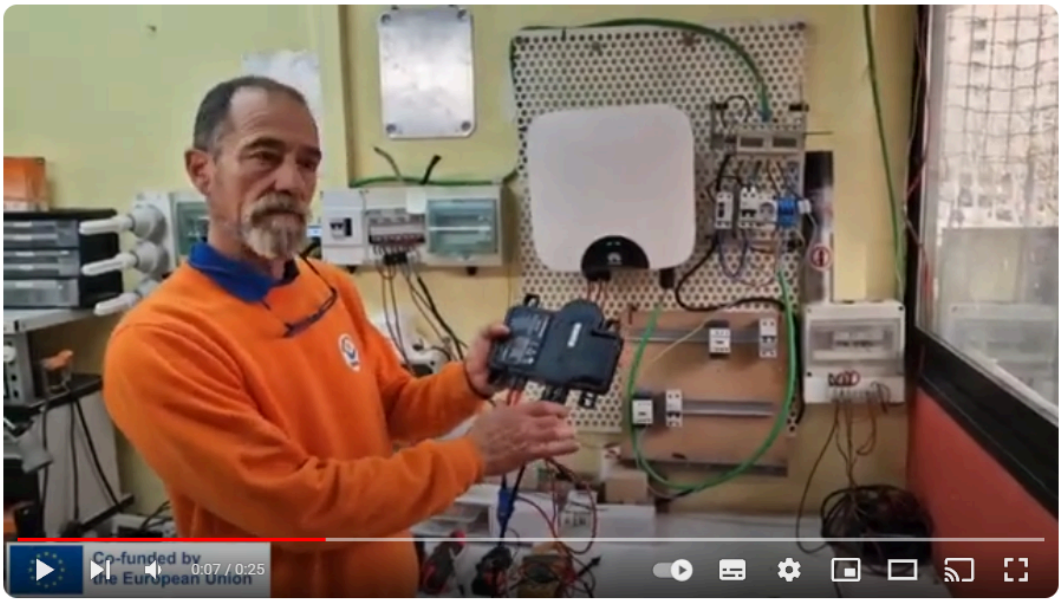
Charge controller: The direct current received from the solar panels will prevent the batteries from overcharging, thus preventing the batteries from being damaged and, as a result, reducing the performance and lifespan of the batteries. The charge controller controls the charge level in the batteries and prevents damage to the batteries by regulating the charge in case of any excess (Picture 2.6).

Picture 2.6: Charge controller

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&t=1s

Inverter (çevirici): It converts the 12 volt DC voltage obtained from solar panels into 220 volt AC voltage (Picture 2.7).

Picture 2.7: Inverter



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=P3Wv9Fimo14

It is necessary to comply with the following rules in the placement of control panel elements:

- Before placing the panel elements, it should be determined how many sections the panel will consist of according to its features.
- The entry and exit points of energy to the panel must be determined.

 For easier reading, measuring instruments should be placed near the top of the panel and on the front cover.

 Signal lamps should be above the ammeters.

 A residual current relay should be placed at the output of the main switch.

 Fuses and switches should be placed according to the direction of energy arrival.

 If the energy supply is from above and the output is from below, fuses should be placed at the top.

 Signal lamps should be located above the switches.

 Signal lights and switches should be on the front cover.

 Fuses should be located inside.

 Contactors should be placed in the middle part.

2.2. Control Panel Installation

Before the panel is assembled into place, the equipment belonging to the panel must be installed in its place. The equipment belonging to the panels is first mounted on the platforms of the panel, and after the other operations of the panel are completed, these platforms are placed inside the panel.

To mount wall type panels to the wall, the installation process is carried out with the help of the wall mounting holes on the back of the panel. For the installation process, the wall must first be drilled with the help of a drill. The panel assembly process is completed with the help of dowels and screws of appropriate length to securely fix the panel to the wall.

When installing the control panel, it is necessary to pay attention to the following instructions:

 The control panel must be installed on a flat surface and vertically.

 Since the panel will get hot while it is on, all four edges should be open and should not be blocked in any way.

 The panel should not be mounted inside another control panel or inside a narrow enclosure.

 The hanging part of the panel must be securely fixed to the wall with the screws and dowels that come with it, and then it must be hung on the panel hanger.

2.3. Connecting the Control Panel Supply Cables

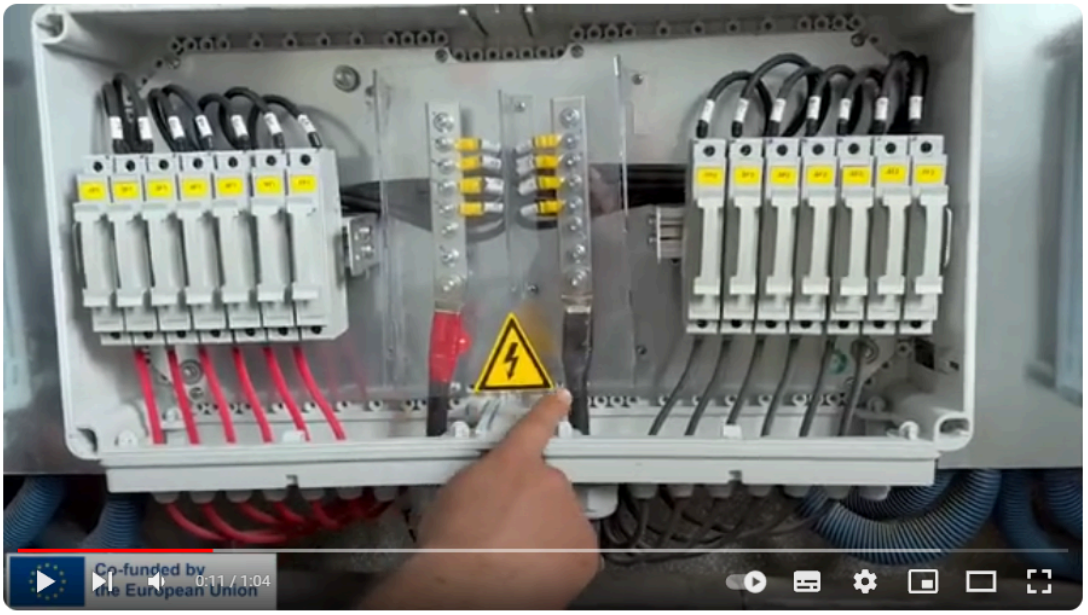
The channels used in the panel should be selected according to the amount of cable. If the duct is small, it will cause the cables to get squeezed and as a result they will overheat. If the

channel is too large, it will take up too much space in the panel and increase the cost. It is more preferred to have the power cables in the open rather than in the channel. Since power cables constantly carry large currents, keeping them exposed provides ease of cooling. Power cables with a diameter greater than 6 mm2 are fed directly from the busbar and go open in the panel.

If both power and control cables will pass through the same channel, it is recommended that the power cable be at the bottom and the control cable at the top, because control cables create more numerous and complex images than power cables. Control cables are more likely to malfunction. Sometimes there is a need to make changes to the control structure. For all these reasons, keeping the control cable on top provides ease of intervention.

Control cables are laid in the channel and tied after the installation work is completed. In this way, the cables gain a smoother appearance. At the same time, flexibility is provided. For the lacing process, after the cables are tied with clips, they are attached to the clip hooks mounted on the bottom of the channel with rivets or bolts. If the number of cables is small, compression tubing that self-shrinks as it heats up is used for lacing. After the cables are laid in the channel, the channels are closed with a channel cover (Picture 2.8).

Picture 2.8: Cables completed in duct placement



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=N1K7EChcDew

Control cables are soft and difficult to shape. Since they go through the channel, their shaping is not very important. Therefore, it is collected with clips or macaroons and fixed on the rail. While the control cables are connected to the devices, some excess cable is left in consideration of the possibility of shortening the cable in case of a later location change or malfunction in the device. This excess is eliminated by shaping the cable.

When assembling the cables, which are cut to size and fitted with lugs/ferrules, to the device and terminal:

It is necessary to pay attention to the following points:

- Elements such as lugs, ferrules and jacks must be attached or soldered to the end of the cable.
- Cables must be connected to the terminals specified in the project.
- The cables should be given a certain form and the cables lying side by side should have the same shape.
- The bare part of the cable inside the terminal should not be left outside.
- The insulated part of the cable or lug/ferrule should not enter the terminal block.
- In terminal blocks that are tightened with a single screw, such as contactors, the cable should be inserted to the left of the screw according to the tightening direction.
- The terminal screw should not be tightened loosely and the cable should not come off when pulled by hand.
- Only one cable should be entered into each terminal, and if double entry is mandatory, terminal duplication should be performed using an umbilical bridge.
- Terminal screws must be tightened with the appropriate screwdriver.
- When attaching power cables to the main busbars, they should be tightened to the ruler value using a torque wrench.

The internal connection of the panel on which the material has been placed is made using control cables in accordance with the panel connection diagram. When making conductor connections, the conductor ends should be peeled carefully, the conductor part should not extend beyond the connection and the connection points should be tightened tightly. In order to easily track the circuit later, cable inputs and outputs should be numbered with the same number, and different cables should be numbered separately. After the connection process is completed, the panel should be tested and made sure that the device is working. If the control elements are working properly, the cables should be clipped for a neat appearance and placed in the cable channel and the channel cover should be closed tightly.

The installation of power cables of electrical panels is done with the help of busbars and cable lugs in large (high current) panels, and by connecting appropriate lugs to the power cable in other panels.

REFERENCES

- Eshıa Enerji SL. (2024). *Training notes*. Eshıa Enerji SL. https://www.eshia.es/
- N2 Anıma GmbH. (2024). *Training notes*. N2 Anıma GmbH. https://n2anima.com/
- European Commission. (2024). *Photovoltaic Geographic Information System*. https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html
- Kıvanç Solar Panel Production Facility. (2024).
- Keçel, S. (2007). *Development of a model for meeting household electricity needs with solar panels in different regions of Turkey* (Master's thesis, Gazi University, Institute of Science).
- Ewing, R. A. (2003). *Power with Nature: Solar and Wind Energy Demystified* (1st ed.). Pixyjack Press.
- Foley, G. (2005). Photovoltaic energy: Applications in rural areas of the developing world. In A. Kandemir (Ed.), *Turkey Development Bank A.Ş.* (pp. 10-42). Ankara.
- Gilbert, M. M. (2004). *Renewable and Efficient Electric Power Systems*. John Wiley & Sons.
- Güven, S. Y. (2006). An example application of solar cell-assisted environmental lighting and irrigation systems. *Engineer and Machine*, 548, 46-48.
- Quaschning, V. (2005). *Understanding Renewable Energy Systems*.
- Köroğlu, T., Teke, A., Bayındır, K. Ç., & Tümay, M. (n.d.). *Design of solar panel systems*. Çukurova University, Department of Electrical and Electronics Engineering.
- Solargis sro. (2024). *Solargis sro*. https://solargis.com/
- Electrical Engineers Chamber Mersin Branch. (2019). *GES Brochure*.
- Ceylan, İ., & Gürel, A. E. (2022). *Solar Energy Systems and Design*.
- Entegro Energy Systems. (2024). *Entegro Energy Systems*. https://entegro.com.tr/
- Eşme, U. (2023). *Lecture notes*. Tarsus University, Faculty of Engineering.
- Ministry of National Education (MEB). (2022). *Renewable Energy Systems MEGEP modules*.
- Solarvizyon. (2023). *Solarvizyon*. https://solarvizyon.org/
- 123RF. (2024). *123RF*. https://www.123rf.com
- Durak, M., & Özer, S. (2012). *Solar Energy: Theory and Practice*.
- Phonosolar. (2024). *Phonosolar*. http://www.phonosolar.com/
- Smart Solar Technologies. (2024). *Smart Solar Technologies*. https://www.smartsolar.com.tr/
- Öztürk, A., & Dursun, M. (2011). *Design of 2, 10, and 20 KVA photovoltaic systems*. Düzce University.
- Göktekin Energy. (2023). *Operation and maintenance checklist*.