RENEWABLE ENERGY TECHNOLOGIES

PUTTİNG SOLAR PANELS İNTO OPERATİON MODULE

2022-2-TR01-KA210-VET-000098216

IN RENEWABLE ENERGY TECHNOLOGIES NEW APPLICATIONS ACCORDING TO 4.0 STANDARDS

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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

FIELD	**Renewable Energy Technologies**
OCCUPATİON	**Solar Energy Systems**
NAME OF THE MODULE	**Commissioning Solar Panels**
DESCRIPTION OF THE MODULE	It is a learning material that provides knowledge and skills regarding commissioning the solar panels used in the installation of the solar power plant.
COMPETENCE	Putting solar panels into operation
PURPOSE OF THE MODULE	**General purpose** When the solar energy systems workshop environment is provided, you will be able to practically carry out the commissioning of solar panels. **Purposes** 1. You will be able to lay power cables. 2. You will be able to lay data cables. 3. You will be able to measure the grounding resistance. 4. You will be able to connect the panel group to the converter

1. RUNNING POWER CABLES

Only lines and power cables with appropriate features for this area are used for the electrical installation of solar energy systems. Direct current main power cables and alternating current lines connected between solar modules are different from each other. The conductors that provide the connection between solar modules and the lines that provide the connection between the solar modules and the distribution panel are called DC power lines. Power cables used in DC power line are generally used in outdoor environments. In order to install a safe installation against grounding and short circuit faults, positive and negative power cables should not be routed together through the same channel. In applications, it is generally common to use double-layer insulated and single cables. In addition, solar cables to be used outdoors must be resistant to ambient temperatures. Solar cables are used outdoors, especially in a wide temperature range and resistant to the sun's harmful ultraviolet rays and adverse weather conditions.

Metal protective armor can be used to increase the protection of solar power cables to be laid underground against rodents, the corrosive effects of the soil and overvoltages. Although the power cables used are generally copper (Cu) conductors, recently aluminum (Al) cables have started to be used instead of expensive copper cables to reduce costs. However, aluminum cables have a much lower current carrying capacity than copper cables. For example, you can only carry the current you carry with a copper cable with a cross-section of 150 square millimeters with an aluminum cable with a cross-section of 240 millimeters. An increased cross-section will negatively affect the processing and connections of the cable.

1.1 Pulling Cables Between Units and Distribution Panels

Lines from 1.5 mm2 to 6 mm2 can be connected in solar panel junction boxes. Red, blue and black cables are used in solar junction boxes to ensure regular connections. Parameters that give the voltage, temperature and cross-section values of the cables used may vary depending on the manufacturing companies. The main power line coming from the solar modules is collected in the distribution panel and connected to the inverter from there. Since distribution panels are outdoors, the cables coming to the panels must be protected. In some places, PVC insulated lines are used to reduce costs, but since these lines are not resistant to ultraviolet rays emitted by the sun, they are laid in protective pipes.

Laying of cables can also be done in channels dug in the ground. (Picture 1.1.) In this case, the laying of the cables should be done in a way that they are not exposed to mechanical loads. All ends of the direct current power cable are equipped with switches so that they can be easily disconnected from the facility. For this purpose, direct current switches and disconnectors are used. To provide grounding and short circuit protection, positive and negative direct current power lines are made with independently insulated solar power cables. Despite lightning strikes, it is inevitable to use insulated lines in solar power plant facilities.

In the power cable laying in the ground channel, the distance between the single power cables is selected appropriately and the cables are covered with soil. Installation materials used for outdoor cable laying work must also be resistant to weather conditions. The connection elements used in this type of cabling are;

- Protective pipe
- Lamellar tube
- Cable channels
- Cable clips or cable ties
- Cable connection clamps
- Cable clamps

Can be listed as. Here, cable ties may be preferred for ease of installation.

Picture 1.1: Power cables lined up side by side in the channel in the solar power plant

1.2. Installing Power Cables Connecting Lugs

It is of great importance that the connections of solar panel and module lines and direct current power cables, which are among the components of the solar energy facility, are made carefully. Making connections with appropriate materials and quality is very important for the operational reliability and life of the facility. Fire and efficiency losses caused by electric arcs can be prevented with quality connection workmanship. Depending on the type and shape of the connection to be made, appropriate socket and connection shapes are technically determined and appropriate materials are produced.

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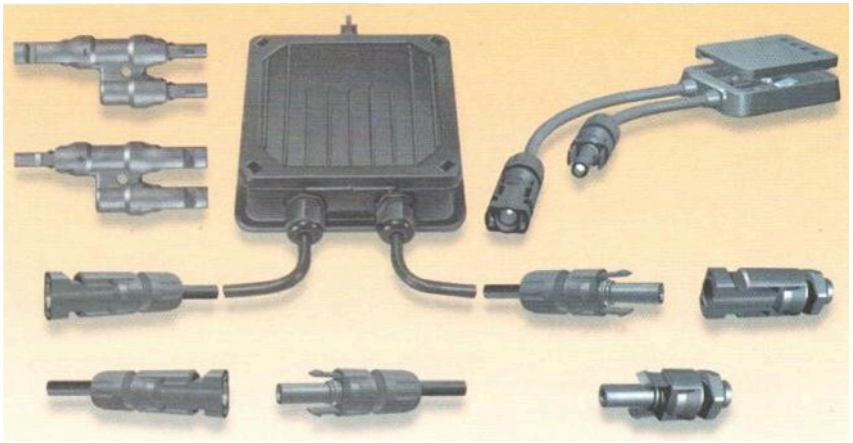
https://www.youtube.com/watch?v=jGfDbPTE7NQ

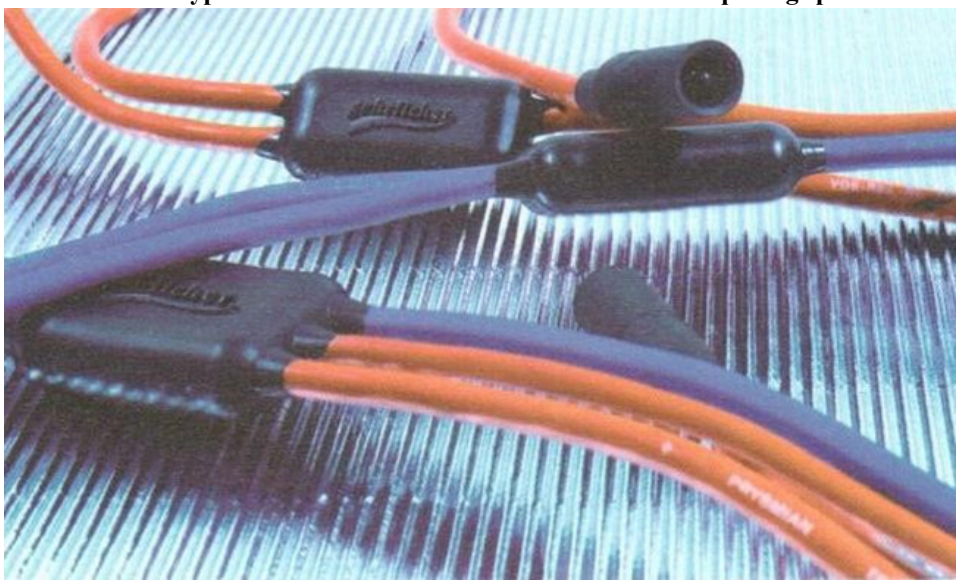


Picture 1.2: Solar panel connection box and solar cable connection sockets

Socket connections to be used in solar energy facilities must comply with the specified safety standards. However, every manufacturer in the market sells and uses products of their own design. This means that there is currently no standardization in such products. Some sockets require a special hand tool for connection, while others may have screws or clamps. Picture 1.4 shows a type of socket that can be connected without requiring any special tools.

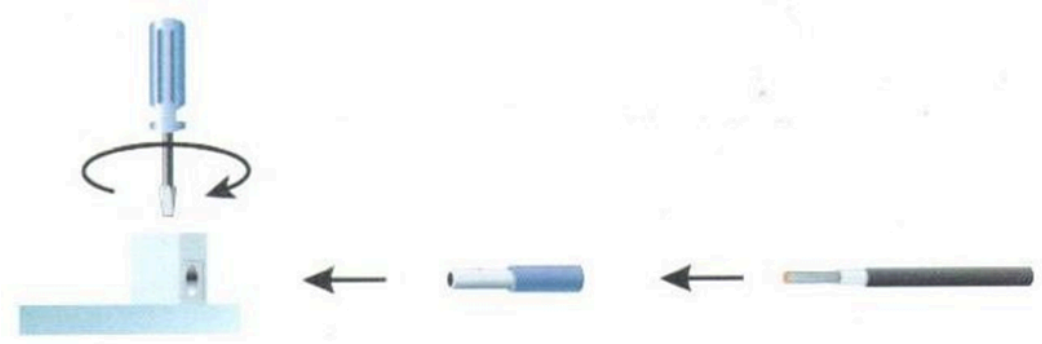
Picture 1.3: Male and female solar cable connection socket (connector)

Picture 1.4: A type of socket that can be connected without requiring special tools



Picture 1.5: Special adapter connection sockets

Generally, there are several types of connections. It is a type of connection made by attaching a thin-tipped connection shoe to the end of thin-wire cables and after inserting the end of the shoe into the slot, it is tightened with the help of a screwdriver (Figure 1.1).



Şekil 1.1: Vidalı sıkıştırma

Another connection type is the screw connection type. This is the type of connection made by inserting the cable lug attached to the cable end between the screw and the nut and compressing it (Figure 1.2).

Figure 1.2: Screw connection

A third connection type is the connection made with a spring clamp. Here, the conductive part of the stripped cable is inserted into the slot and compressed without attaching any cable lugs (Figure 1.3).

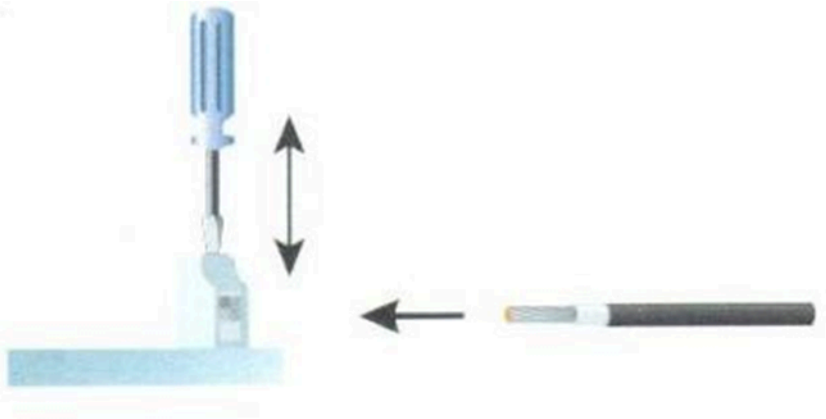


Figure 1.3: Clamping with spring clamp

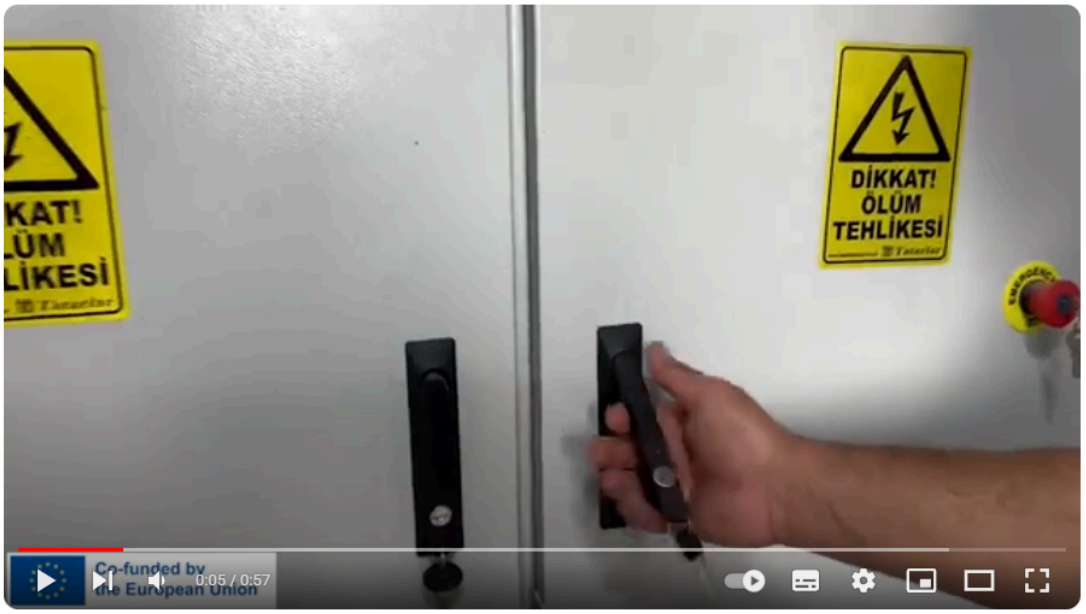
Finally, another connection method is the connection via connection sockets. Solar module connection can be made easily and protected against touch via socket connections. This connection also greatly facilitates the installation work (Figure 1.4).

Figure 1.4: Connection sockets

1.3. Making Input Connections of Power Cables

The connections of solar panels and the modules formed by the panels, cable lines and direct current power cables are extremely important issues. Therefore, connections must be made carefully. Connections made with poor quality workmanship may cause electrical arcs to occur during operation and, as a result, the risk of fire.

Before making power cable entry connections, the appropriate cable lug is installed and the connections are made regularly and tightly by attaching them to the appropriate terminals. While tightening the screws, the cable is straightened several times and the connection gap in the terminal is removed, and then tightened again. In this way, the cable is connected without any air gap or looseness.



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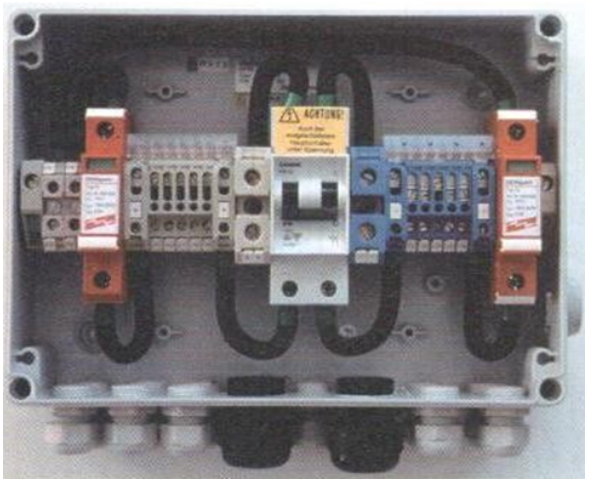
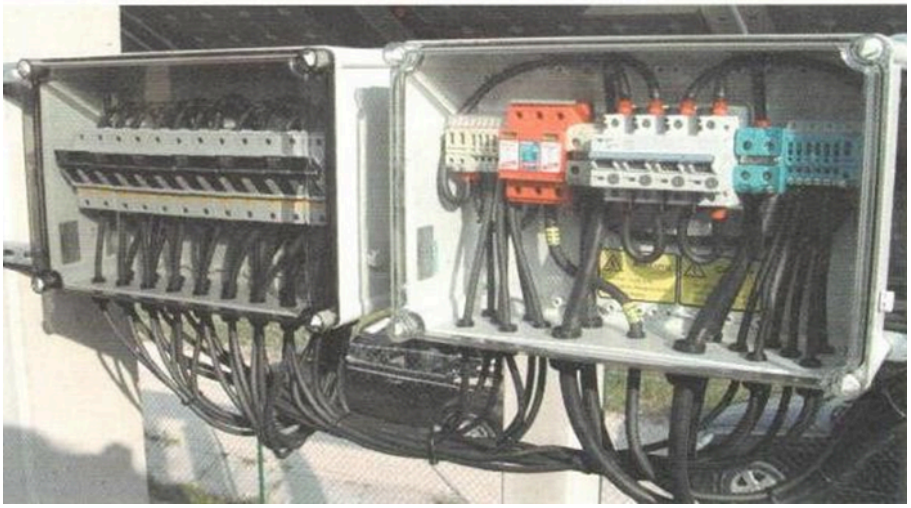


Picture 1.6: Junction box

The cables coming from the solar modules to the panel and collected in the distribution panel are numbered and coded according to the project. Coding the cables before installation makes installation easier. In case of a malfunction in the panel or junction box, coding the cables makes it easier to find the fault. Sometimes the devices on the panel can be removed and replaced with new ones. In this case, the newly installed device can be easily connected without any errors, thanks to the codes on the cables. During the coding process;

- Coding should be done before cable assembly.
- Codes must be suitable for the project.
- Cable codes must be visible and legible when looking at the panel.
- Encoders must be installed properly and all numbers and texts must be in the same direction.
- An encoder suitable for the cable diameter and structure should be used and the encoder should not fall off later.
- Matters such as should be taken into consideration



Picture 1.7: Junction box and distribution panel connections

2. RUNNING DATA CABLES

It is of great importance to monitor each unit and system that makes up the photovoltaic (PV) system during operation of the established power plant in order to increase the efficiency while producing electrical energy. Solar radiation, which is the most important factor affecting the operation of the system, varies greatly on a daily, seasonal and annual basis. For this reason, every unit in the system is monitored to see the energy produced by the system at normal solar radiation values during operation. In order to ensure continuity and energy security in energy production, it is necessary to measure the meteorological and electrical parameters of the system and to transmit the measured values safely in the monitoring and control of the photovoltaic (PV) system. Different methods are used in practice for data transmission. During field monitoring, data cables are pulled and monitoring is done in control rooms. Wireless data transfer can also be done in cases where it is difficult to pull the data cable or the processing is done from remote locations.

The main parameters to be monitored in photovoltaic energy systems include radiation intensity, ambient temperature and humidity, panel temperature, current and voltage values of photovoltaic panels, and Alternating Current and voltage values at the inverter output depending on the structure of the system. Each measured quantity is sent as data to the monitoring unit, computer or storage unit and processed there.

2.1. Installing Data Cables with Specified Features in the Project between the Units and Distribution Panels

Data cables are a conductor that carries signals. Data cables are generally covered with protective layers, ensuring transmission occurs with as little data loss as possible. It is used to transport the values of system parameters accurately and without loss during production in solar power plants. It carries data, energy and signals. Wired communication is indispensable in long distance and high frequency communications. There are many types of cable standards that can be used with different features depending on the data and network structure.

Data cables to be laid between PV units and distribution panels in solar power plants must be laid in a protected manner against exposure to the external environment. Such cables carrying data must be protected from exposure to atmospheric conditions outdoors. Therefore, cables to be laid underground must be laid in pipes.

2.2. Drawing Data Cables with Specified Features in the Project Between the Distribution Panel and the LV Panel

The installation of data cables between the panels is made according to the environment where the panels are located (Picture 2.1). If the panels are in the open field, cable laying procedures in the open field are followed. In transitions from open to closed environments, elements of various sizes made of galvanized sheet metal, commonly referred to as cable ducts or cable trays, are used in closed areas. Since data cables carry signals, they should be kept as far away from energy-carrying cables as possible in such channels. Otherwise, it may cause interference or distortion in the signals. In such cases, cutting off contact between cables would be a healthier solution. If possible, it should be preferred to carry these cables in separate channels.

Entry apparatus suitable for cables should be used at panel entries, and connections should be made with a cable head (or cable lug) suitable for the characteristics of the cable.

Panel entry holes must be protected against moisture, liquid and physical impacts that may come from the external environment. In internal panel connections, the cable length should be adjusted according to actual requirements and the connection should not be too long or too short. Cables should be kept as short as possible, avoiding the formation of circuits that produce parasitic currents caused by magnetic fields. Cables should be stripped as close to the connection point as possible. All ground circuits should be avoided. Because they are very sensitive to strong magnetic fields.

Picture 2.1: Cable installation between panels

2.3. Fixing Data Cables to Ducts

Properly fixing the data cables laid inside the channel is important both in terms of appearance and technical workmanship. In addition, it provides great convenience in preventing or eliminating cable faults that may occur during operation in the future (Figure 2.2).

When passing the cables through the channels, care should be taken not to bend or damage the cables. If cables need to be bent, the minimum bend radius should be: 10 x cable diameter. Sharp angles should be avoided in the paths or passages of the cable. The connection of the cable shield, which is the conductive part that prevents the cable from being affected by external electrical signals, should be as short as possible. Multiple displays can be connected together. Place a physical mark on the end of each cable. The name of each device to which the cables are connected should be impressed at the end of the cable. The wiring must comply with the following colours:

Picture 2.2: Cables properly fixed in the duct

3. MEASURING EARTH TRANSITION RESISTANCE

3.1.Measuring with a Grounding Measuring Device

In order to ground the solar power plant, soil resistance must be determined. Grounding resistance is the sum of the radiating resistance of the grounder and the resistance of the grounding conductor. The grounding must be maintained as long as the facility is in operation. Therefore, grounding should be kept under control by measuring grounding resistance at regular intervals.

To measure grounding resistance, a grounding resistance measuring device must be installed. We can use Figure 3.1 for the measurement mechanism. The rods of the measuring device are driven into the ground at a distance of 5 to 10 meters from the ground electrode. Digital megger is used in this type of measurement (Figure 3.1).

Picture 3.1: Digital grounding resistance measurement device

To measure soil resistance, make the connection shown in Figure 3.1.

- Turn the 2/3 electrode method button to the 3-electrode measurement position.
- Check the auxiliary grounding resistance values for C and P within the auxiliary grounding resistance range.
- Perform the measurement using the appropriate resistance range.
- Business grounding: 2 Ohm (Maximum)
- Protection ground: 4 Ohm
- Lightning rod: 10 Ohm
- MV protection: Must be 5 Ohm.

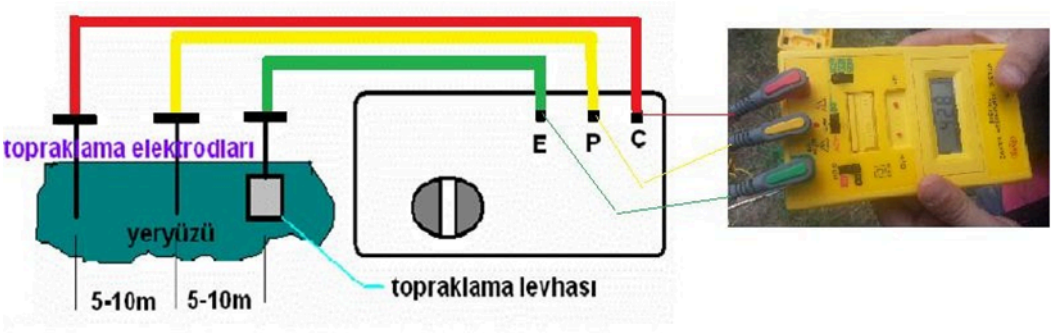


Figure 3.1: Three-electrode grounding measurement setup

The distance between the grounding device and the meter tips should be 5 to 10 meters apart. It is necessary to pay attention to this while performing the measurement. The places where we will drive the sticks should be wetted before measuring. Cables must be securely attached to the connection tongs. The electrodes should not be touched while measuring.

4. CONNECTING THE PANEL GROUP TO THE INVERTER

4.1. Grouping Cables Coming from Panel Groups

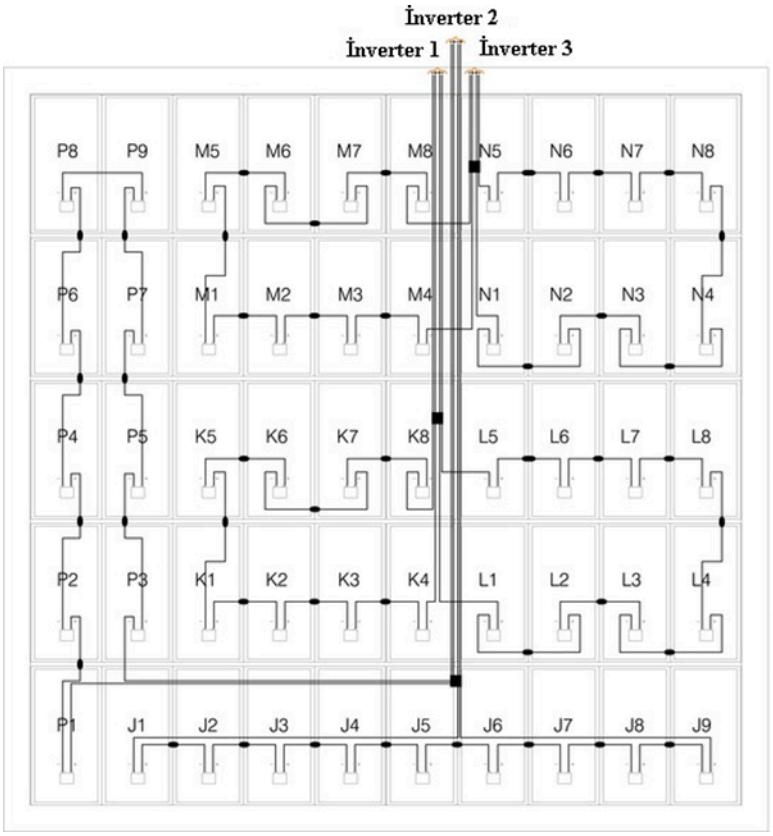
As you know, solar panels are connected to each other in groups in series and parallel in order to obtain different levels of voltage and current. The shape of the connection is made during project planning to achieve the targeted power of the system. Solar panels listed according to the project are connected to each other according to this plan. Figure 4.1 shows the connection diagram between the solar panels that will be connected to 3 Inverters.

In solar power plants, inverters determine the connection type of the facility. Depending on the connection type of the inverters, a centralized or decentralized connection is obtained. The structure of the serial and parallel circuit, which is established by creating arrays of solar modules, should be ideally arranged according to the inverter. Any incompatibility (current and voltage incompatibilities) that may occur during connection will be reflected as loss in the system. The main goal is to create a grouping that will keep these losses to a minimum.

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=6VDuOuL902s

The voltage range of the system can give an idea about the type of grouping to be done. In the small voltage range (120 volt direct voltage and below), fewer modules will be connected in series. In such a grouping format, central inverter connection may be preferred. Figure 4.2 shows the connection of the modules connected to the central inverter to obtain low voltage. The thing to consider about such a system is that it produces high currents. This naturally causes the cable cross-section to increase and affects the efficiency of the inverter.



Şekil 4.1: Gruplandırılmış güneş panellerinin eviricilere (inverter) bağlantısı

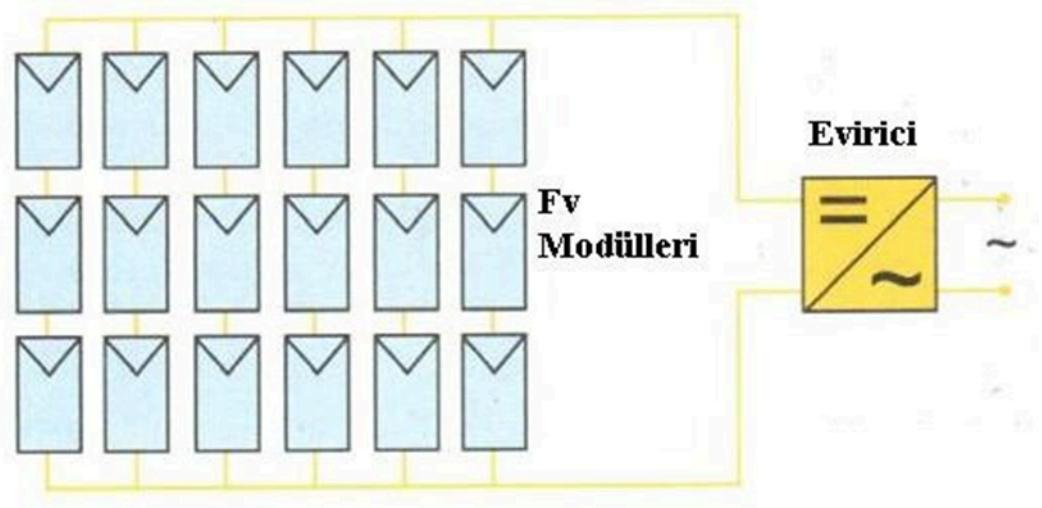


Figure 4.2: Central inverter connection with low voltage level

Another type of grouping is parallel connection. In this connection type, the modules are connected to the alternating current busbar by creating more than one parallel circuit and connecting an independent inverter to each circuit. Such a parallel circuit system is seen in Figure 4.3.

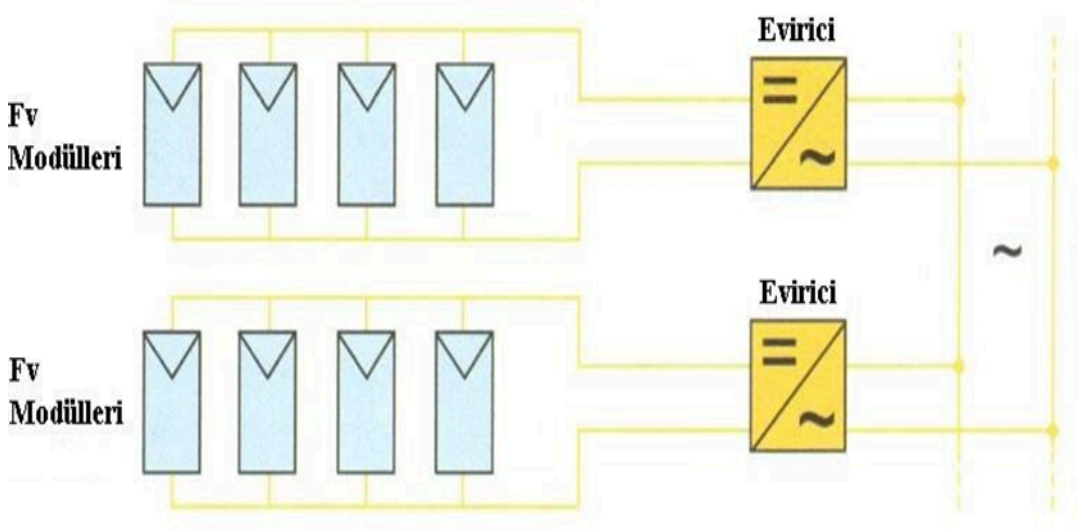


Figure 4.3: Parallel circuit connection type

In order to obtain high voltage (between 120 volts and 1000 volts) in medium and large facilities, long array connections are made by serial connection of solar modules. In this type of connection, although the voltage value is high, the current value is low due to the serial connection and therefore the cable cross-section used is lower (Figure 4.4). However, if some modules in long directories are overshadowed in such a system, the efficiency of the system will be greatly reduced.

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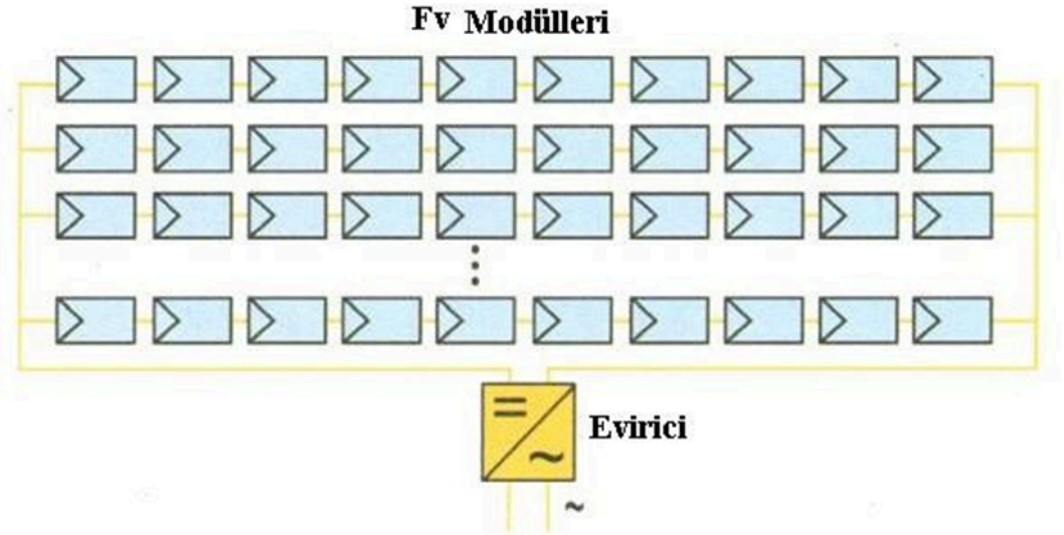


Figure 4.4: High voltage connected system with central inverter

Another grouping of panels is the master and slave inverter connection type. In this type of system, multiple slave inverters are connected together with the main inverter. At low irradiance values, the main inverter operates. When the radiation increases and therefore the power produced by the solar panels increases and the main inverter power is exceeded, slave inverters come into play and share the load in a balanced manner. For balanced distribution of the load, the main and slave inverters are turned on and off using a specific control loop. This increases the efficiency of the system (Figure 4.5).

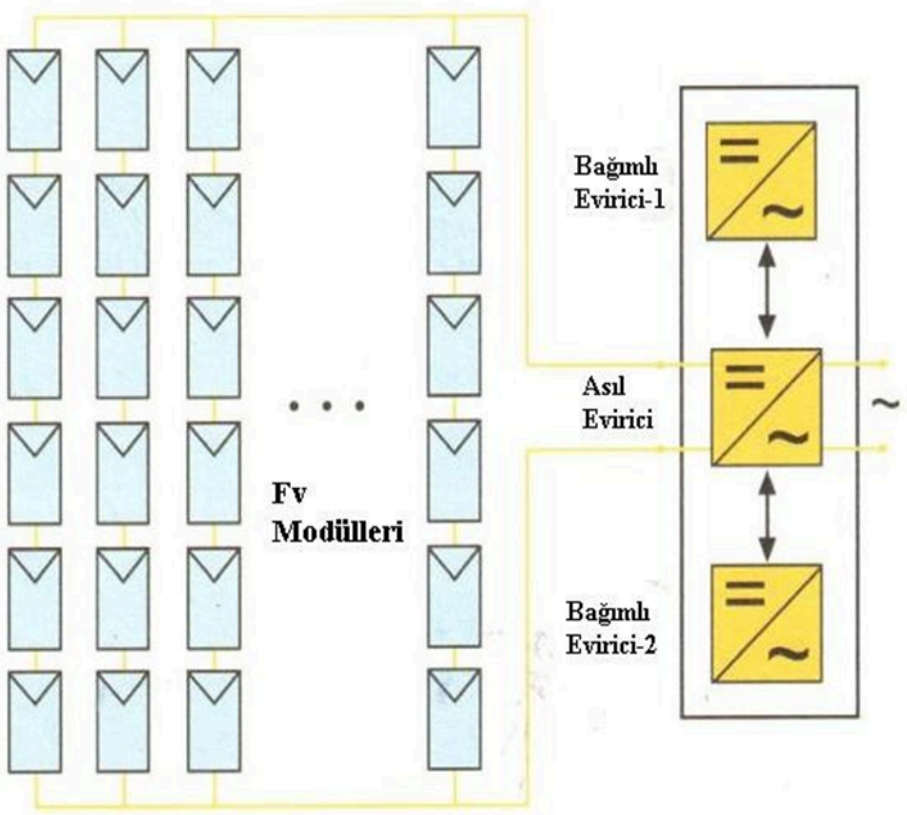


Figure 4.5: Master and slave inverter connection with central inverter system

Another connection method of the modules is the connection using string inverters. As you know, long solar module array connections cause high power losses during shading. Another option for such long arrays is to connect an inverter per long array in very large facilities. Installation of a solar power plant is facilitated by connecting an inverter per array. Such a connection type can be seen in Figure 4.6.

Connection types can be increased even more. In recent years, the module inversion method has emerged. This is a connection made by mounting a small inverter on each solar panel. Sometimes these are also called microinverter solar panels. The output of the solar panel can be used directly as alternative energy.

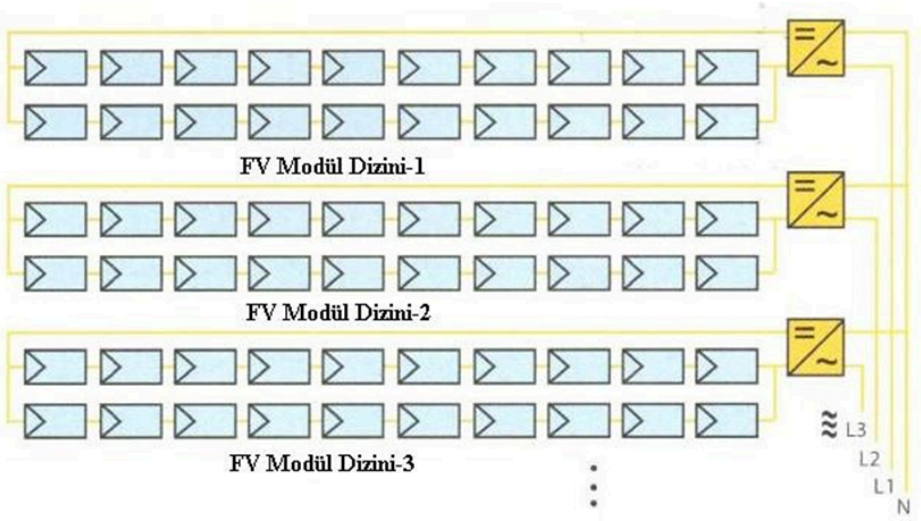
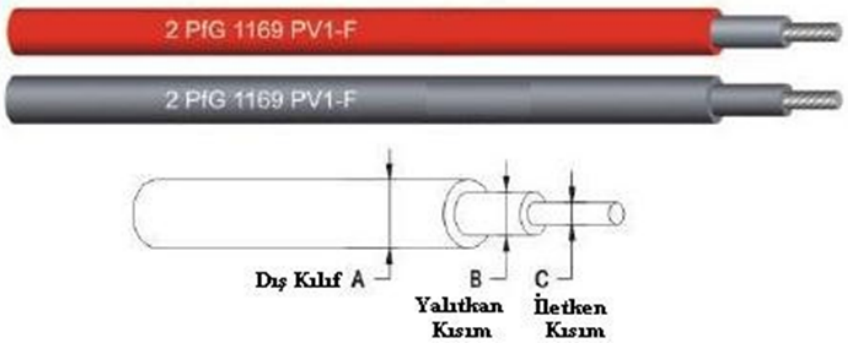


Figure 4.6: String inverter connection type

4.2. Connecting the Grouped Cables to the Inverter with the Appropriate Socket

An inverter is a device that converts the DC voltage produced by solar panels into the alternating voltage we use at home. In other words, it converts 12, 24 or 48V DC battery voltage into 1 phase 230V – 3 phase 400V AC 50 Hz voltage. Solar type inverter cables specially produced for inverters in photovoltaic applications are produced with superior quality raw materials. The cables used for the inverters contain tinned copper conductor wire conforming to VDE 0295 / IEC60228 class 5. The inner part of the cable consists of a special copolymer layer that is combined electronically with rays (Picture 4.1)



Picture 4.1: Solar cable

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 4.2).

Picture 4.2: A type of connection socket (connector) used in inverter connection

When making the first connection of the inverter cable or before starting maintenance work, the mains voltage is turned off and a waiting period of at least 10 minutes is passed. This period is used to allow the capacitors to discharge to a non-hazardous voltage value after the mains voltage is turned off. The voltage between the inverter P/+ and N/- terminals is measured with a measuring device. Care should be taken to carry out connection work in a voltage-free condition. Otherwise, you may face the risk of electric shock.

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=GHctRdaCZYQ

When connecting inverter cables, keep the signal cables 10 cm away from the power cables to avoid noise (interference in the signal cable) problem. After the cable connections are completed, there should be no cut cable pieces left inside the inverter.
In some cases, cut cable pieces 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

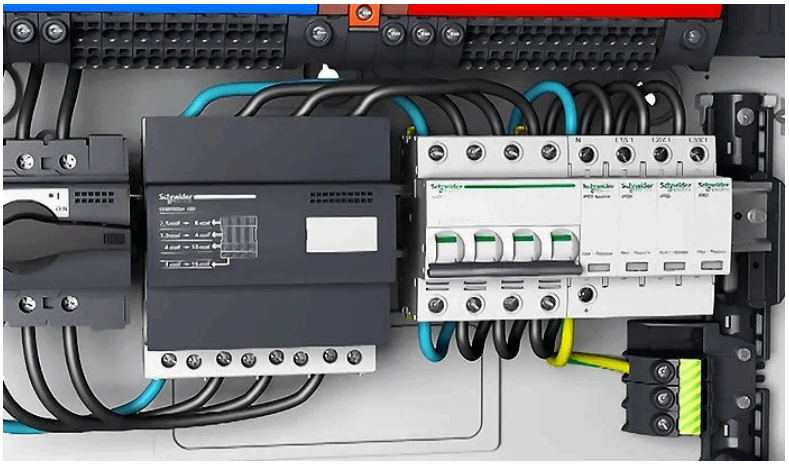
malfunctions. Tighten the connection screws to the specified torques. If a screw is tightened looser than specified, it may cause a short circuit or malfunction. If a screw is tightened harder than specified, it may cause malfunction, crack or breakage. Insulated solar cable lug or connection socket is used for energy input connections.

5. IN PHOTOVOLTAIC SYSTEMS SURGE ARRESTOR

In order to protect Solar Systems against sudden overvoltage and lightning strikes, an LV Surge Arrester system should be used in front of DC, AC and Data lines (Picture 4.3). It is recommended to use Class B+C products in DC combinerboxes. The selected products must have protection values against both 10/350 ms lightning curve and 8/20 ms mains surges. The use of DC B+C class surge arresters in the combinerboxes used in the DC parts of inverters ensures sustainable energy production of the facility for many years and is of great importance in preventing possible damages. The quality of the product used is as important as the product selection.

The production and testing standard of PV surge arresters is EN 50539-11. Products that do not have this certificate should not be used in our investments and projects. Non-standard products can cause more harm than good to our system. Sudden overvoltage pulses occur within 25 nanoseconds, and with non-standard products, this pulse may cause arcing. Therefore, compliance with UTE C61-740-51 and EN 50539-11 standards should be sought in the product to be used and its documents should be examined. In addition to standard and product type, product technology is also important in product selection.

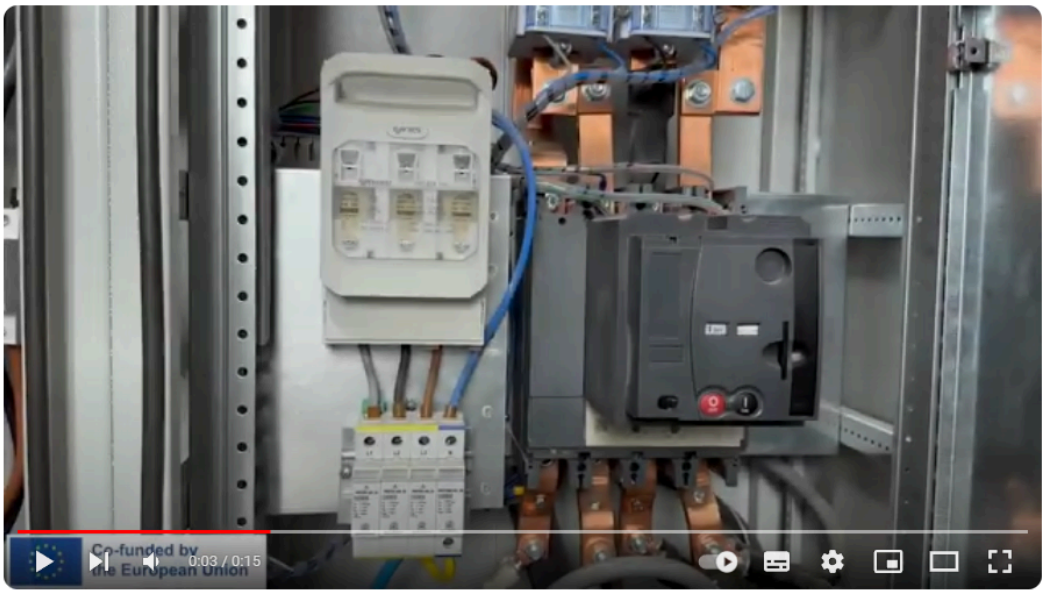
It carries. Products with VG technology can perform both rapid and unlimited damping. For this reason, we recommend that you use EN 50539-11 B+C CLASS (type1 +2) VG Technology PV surge arrester in your projects.



Picture 4.3: Panel-mounted surge arrester

5.1. Protection of PV Power Plants

Photovoltaic power plants connected to the grid are exposed to many sudden overvoltages, especially from the grid. In order to be protected from the electrical effects of lightning, a DC and AC LV SPD arrester system must be installed (Picture 4.4). Many EPC companies that use lightning arresters do not use surge arresters, drawing the shock to the facility and not protecting other systems, especially the inverter. When choosing a surge arrester, it is necessary to use a B+C class product to provide protection against lightning and mains strikes. Unless questioned, the surge arrester systems in inverters are used as class C, in other words TYPE II, instead of B+C.



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https://www.youtube.com/watch?v=LTGpwJeCZQ8

Picture 4.4: surge arrester

5.2. AC and DC Surge Arresters

If PV systems are connected to inverters, IEC62109-2 (Safety of power converters used in PV power systems requirements for inverters) sets out requirements regarding the grounding device (and the inverter topology). These are minimum inverter insulation requirements, generator ground insulation resistance measurement requirements, and generator residual current determination and ground fault alarm requirements.

The manufacturer's instructions for the PV modules and other equipment that make up the PV generator should be considered to ensure optimal grounding. Connection of a current-carrying DC conductor to ground is not recommended. However, if the AC and DC sides are properly separated, grounding of one of the energized conductors is allowed.

If functional grounding is required and possible, it is preferred to provide it via high impedance (rather than direct connection).

The designer must verify that the inverter is suitable for DC grounding. Transformerless inverters are not suitable and the grounded DC conductor may interfere with the DC isolation monitoring system integrated into the inverter. Therefore, if the DC conductor needs to be grounded, this must be done in the inverter with the approval and knowledge of the inverter manufacturer.

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=nwwIc_SA5qQ

5.3 Protection of DC Lines

Products integrated into 10/350 and 8/20 curves on DC lines will be gradually used for protection purposes. (The use of B+C class products is recommended.) Operating temperature range should be -40 +80 C, IP Protection should be 20. There must be + – or + – earth connections. It is recommended that all lines be protected according to the characteristics of data and cat communication lines. In the class D category, it is recommended to use products tested according to the 8/20 curve.

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