Solar Power System
An Introductory Guidebook

Small and Medium Enterprises Development Authority
Ministry of Industries & Production
Government of Pakistan

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Table of Contents

1 ACRONYMS

V	Voltage
I	Current
A	Ampere
W	Watt
kW	Kilo Watts
VA	Volt Ampere
kVA	Kilo Volt Ampere
PV	Photovoltaic
CSP	Concentrated Solar Power
AC	Alternating Current
DC	Direct Current
MPPT	Maximum Power Point Tracker
PWM	Pulse Width Modulation
AGM	Absorbent Glass Mat
VAC	Alternating Voltage
VDC	Direct Voltage
WAPDA	Water and Power Development Authority
BTS	Base Transceiver Station
UPS	Uninterruptible Power Supply
VOC	Open Circuit Voltage
SCC	Short Circuit Current
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
STE	Solar Thermal Energy

GWh	Giga Watt Hour
MW	Mega Watt
MSW	Municipal Solid Waster

2 DISCLAIMER

This information memorandum is to introduce the subject matter and provide a general idea and information on the said matter. Although, the material included in this document is based on data/information gathered from various reliable sources; however, it is based upon certain assumptions, which may differ from case to case. The information has been provided on AS IS WHERE IS basis without any warranties or assertions as to the correctness or soundness thereof. Although, due care and diligence has been taken to compile this document, the contained information may vary due to any change in any of the concerned factors, and the actual results may differ substantially from the presented information. SMEDA, its employees or agents do not assume any liability for any financial or other loss resulting from this memorandum in consequence of undertaking this activity. The contained information does not preclude any further professional advice. The prospective user of this memorandum is encouraged to carry out additional diligence and gather any information which is necessary for making an informed decision, including taking professional advice from a qualified consultant/technical expert before taking any decision to act upon the information.

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3 INTRODUCTION TO SMEDA

The Small and Medium Enterprises Development Authority (SMEDA) was established in October 1998 with an objective to provide fresh impetus to the economy through development of Small and Medium Enterprises (SMEs).

With a mission "to assist in Employment Generation and Value Addition to the national income, through development of the SME sector, by helping increase the number, scale and competitiveness of SMEs", SMEDA has carried out ‘sectoral research’ to identify policy, access to finance, business development services, strategic initiatives and institutional collaboration and networking initiatives.

Preparation and dissemination of prefeasibility studies in key areas of investment has been a successful hallmark of SME facilitation by SMEDA.

Concurrent to the prefeasibility studies, a broad spectrum of business development services is also offered to the SMEs by SMEDA. These services include identification of experts and consultants and delivery of need based capacity building programs of different types in addition to business guidance through help desk services.

3.1 Industry Support Program

In order to enhance competitiveness of SMEs and achieve operational excellence, SMEDA established an Industry Support Cell (ISC) for provision of foreign technical support and knowledge transfer in collaboration with International Development Organizations. SMEDA's Industry Support Program (ISP) initially launched with Japan International Cooperation Agency (JICA) actively engaged in reducing energy inefficiencies and improving production and quality of products with the support of foreign experts. Later on, similar activities with other international partner organizations like German Corporation for International Cooperation (GIZ), Training and Development Centers of the Bavarian Employers' Association (bfz), Germany were also successfully initiated.

4 BACKGROUND

Energy is the most discussed subject and has become a basic necessity for the societies. It is an essential factor on to which economies depend and prevail. Self-sufficiency in energy leads to prosperity and economic growth in the country. The oil and gas reserves are limited and constantly depleting at an increasing rate in order to meet the growing demand. The reserves will soon end if the consumption continues at the current pace of growth. For that reason, to maintain continuity of energy supply, alternative energy resources have gained more significance and therefore, they are being explored on a fast track.

The importance of energy generation cannot be underestimated due to its pivotal share in the industrialization process of the country. During the fiscal year 2015-2016 the total power generated in the country was 118,426[1] GWh of which the share of thermal power generation was 67%, wind power plants contributed 0.6%, hydel power plants contributed 29% and nuclear power plants added 3.5% to the bulk.

The increasing share of expensive thermal electricity generation has led to increased receivables of the utilities companies. Hence, there is a strong need of the time to increase the hydel generation or explore other cheaper renewable and alternative energy sources. This means that Pakistan need to rethink on its energy policy shifting towards more feasible options for generation of electricity.

5 SOURCES OF POWER GENERATION[2]

On a broader scale, generation sources are divided into three major categories namely thermal, nuclear and renewable resources. These sources are further classified into different sub categories, which are explained below:

[1] *Power system statistics NTDC 2015-2016 (41st Edition)*

[2] *Energy scenario in Pakistan, August 2013, Karachi Chamber of Commerce and Industry*

5.1 Thermal Energy Resources

A thermal power plant runs by converting heat energy to electricity. It is typically driven by steam where water is heated and turned into steam, which spins the steam turbine and electrical generator. After passing through the turbine, steam is condensed and recycled. To run the plant, different fossil fuel resources may be used for heating like Coal, gas (natural, LNG, LPG), Oil (Shale, furnace) etc.

5.2 Nuclear Energy

Nuclear energy originates from the splitting of uranium atoms in a process called fission. Fission releases energy that can be used to make steam, which is then used in a turbine to generate electricity. Though the share of nuclear energy is not significant but its importance cannot be denied. Nuclear energy is being rapidly recognized around the world.

5.3 Renewable Energy Sources

Different renewable energy sources are briefly described below:

5.3.1 Solar Energy

Solar energy is divided into two major categories like solar photovoltaic and Solar Thermal Energy (STE). Solar photovoltaic convert solar energy into electricity with the help of solar cells that is used to charge batteries to provide power during night. Solar energy has excellent potential in Pakistan that receives high level of solar radiation throughout the year.

Solar thermal energy is a technology that utilizes solar energy for thermal effect, which could be converted to electricity through a thermal power plant

5.3.2 Wind Energy

Wind energy is a very cheap source of power generation in windy areas. Wind power can be converted into electrical power using wind turbine. Wind farms consist of multiple wind turbines for the purpose of generating power.

5.3.3 Tidal Power

A tidal power plant makes use of the daily rise and fall of ocean water due to tides. Tidal power is viable in a relatively small number of locations around the world.

5.3.4 Geothermal Energy

Geothermal energy is referred to as the energy found and stored within the earth. It is mainly formed by the radioactive decay associated with very high temperatures at the core of the earth. The high temperature and pressure cause some adjacent rocks to melt, creating magma, which further penetrates and heats rock and water in the crust of the earth. This energy can be converted into electrical energy by applying special

technologies like dry steam power plants, flash steam power plants and binary cycle power plants.

5.3.5 Biomass

Biomass can be described as the organic matter used as a fuel for power generation. Biomass has been recognized as a clean, reliable, renewable source of energy. Unfortunately, true potential of this source of energy has not been explored for power generation in Pakistan. However, in recent years, waste to energy technologies have been developed to produce clean energy through the combustion of Municipal Solid Waste (MSW) through power plants equipped with the most modern pollution control equipment to clean emissions. Some popular examples of biomass are bagasse, rice husk, wood chips and some crop residue

Bagasse can be a good source and an available resource, which can be used to generate electricity in Pakistan.

5.3.6 Biogas

Biogas, one of the most significant types of biomass energy, makes optimal utilization of the natural resource of animal dung. It provides (soot-free) clean gas for meeting cooking and energy needs as well as enriched bio-fertilizer for increased productivity of agricultural land. Being clean and renewable, it contributes towards environment protection, sustainability of ecosystem and conservation of biodiversity.

5.3.7 Hydro-Electric Power Plants

Hydel or hydropower refers to the power derived from the energy of falling and running water, which is converted into electricity by connecting it to turbine generators. Water flowing in the rivers has kinetic energy. This kinetic energy is used to drive turbines and produce electricity, and the power thus generated is known as Hydel energy.

6 SOLAR POWER – AN INTRODUCTION

Solar power is a type of renewable energy and in other words it is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using Concentrated Solar Power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic convert light into an electric current using solar cells.

Photovoltaic (PV) systems use solar panels, either on rooftops or in ground-mounted solar farms, converting sunlight directly into electric power.

A solar cell, or photovoltaic cell (PV), is a device that converts light into electric current using the photovoltaic effect. The array of a photovoltaic power system, or PV system, produces direct current (DC) power, which fluctuates with the sunlight's intensity. For practical use this usually requires conversion to certain desired voltages or alternating

current (AC), through the use of inverters. Multiple solar cells are connected inside modules. Modules are wired together to form arrays then tied to an inverter, which produces power at the desired voltage, and for AC, the desired frequency/phase.

6.1 Why Solar Power?

In modern world, fossil fuels are the major source of energy that has a high cost and have adverse environmental effects. Use of solar energy has become popular in recent years because of:

- Global energy demand is increasing and fossil fuel reserves are depleting quite rapidly
- Continued usage of fossil fuels is damaging our environment
- Solar energy is one of the most promising alternative to fossil fuels

7 MERITS & DEMERITS OF SOLAR POWER

7.1 Merits

Solar power is not only sustainable source of energy but also indefinitely renewable. Solar power can be used to generate electricity; it is also used in relatively simple technology to heat water (solar water heaters). The use of skylights in home construction can also greatly reduce energy expenditure required to light rooms indoors during the day.

Solar panels require little maintenance. After installation and optimization they are very reliable due to the fact that they actively create electricity in a short span of time and do not require any type of mechanical parts that can fail.

7.2 Demerits

The primary disadvantage of solar power is that it obviously cannot be created during the night. The power generated is also reduced during times of cloudy weather (although energy is still produced on a cloudy day). Solar panel energy output is maximized when the panel is directly facing the sun. This means that panels in a fixed location will produce reduced energy when the sun is not at an optimal angle. Many large scale solar "farms" combat this problem by having the panels on towers that can track the sun to keep the panel at optimal angles throughout the day.

Currently, most efficient solar cells only convert just over 20% of the sunlight into electricity. With increased advances in solar cell technology this number is likely to increase. Besides their low conversion efficiency, solar panels have a substantial initial investment. However, the cost of solar panels incurred is only the initial cost, after buying and installation they produce energy free of cost.

8 APPLICATIONS

Following are some of the solar energy applications:

a) Solar power generation
b) Solar geysers
c) Solar lights
d) Solar cars and other automobiles
e) Solar fans and other appliances

Most of the widely used application of solar power is to produce electricity.

9 COMPONENTS OF SOLAR SYSTEM

Following are the components of the solar systems

a) Solar PV Panels
b) Mounting Structure
c) Charge Controller
d) Inverter
e) Batteries
f) Solar Tracker
g) Protection

9.1 Solar PV Panels

Solar panels are made of photovoltaic cells combined together in series and parallel combination with the standard life of 10-25 years. They are enclosed in tempered glass and aluminum bracket to make the panel weather resistant. The cells convert sunlight to electrical energy generating DC power.

9.1.1 Types of Solar Panels

There are two types of solar panels, which are commonly used i.e. Mono-crystalline and Poly-crystalline.

a) Mono-crystalline is suitable for high temperature regions i.e. temp > $35C^{o}$
b) Poly-crystalline is referred to the region which has usually temp < $35C^{o}$

	
Poly-Crystalline Panel	Mono-Crystalline Panel

9.1.2 Power Rating of Solar Panels

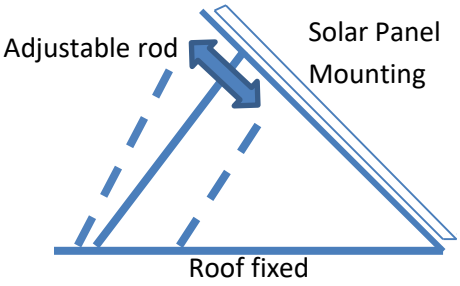
Solar panels are available in different power ranges from 150W-300W both in mono-crystalline, and poly-crystalline. They also have voltage ranges of 12/24/48VDC, which is considered in their connections that is in parallel and series form.

9.1.3 Efficiency

Efficiency of solar modules ranges from 10-20%. However, higher the number of panels higher will be the efficiency of system. Mono-crystalline is considered to be A-grade panels but the efficiency depends on the climatic conditions of the region.

9.2 Mounting Structure

Mounting structure for solar panel is usually made of angle iron or aluminum, it has six rods in the shape of triangle, the middle rods are adjustable to the summer, winter and autumn weather, the lower rods are to be fixed on roof and the solar panel are fixed on the upper rods.



9.3 Charge Controller

Charge controller in solar system is its core component, which takes power from panels and provides it to batteries.

9.3.1 Types & Specification

There are two types of solar charge controller

a) MPPT (Maximum Power Point Tracking)

b) PWM (Pulse Width Modulation)

a) MPPT (Maximum Power Point Tracking)

MPPT charge controller function depends on the running load and charging condition of batteries i.e. if the batteries are full then it provides the power to the capacity of running load only. As load increases it automatically increases the power supply and vice versa.

It has 150VDC input PV voltage, 12/24/48VDC output voltages to the batteries and current rating of 10-60Amps.

b) PWM (Pulse Width Modulation)

PWM charge controller operation just like a switch in between solar panels and batteries i.e. if a solar panel has output voltage 17V and it is connected to a battery then it decreases the PV voltage and operates in between 10-15V. In PWM charge control the connection of PV panels is dependent on the battery system so that the energy lose is minimum. Its PV voltages is < 50V, output 12/24/48VDC and current rating of 10-40 Amps.

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9.4 Inverters

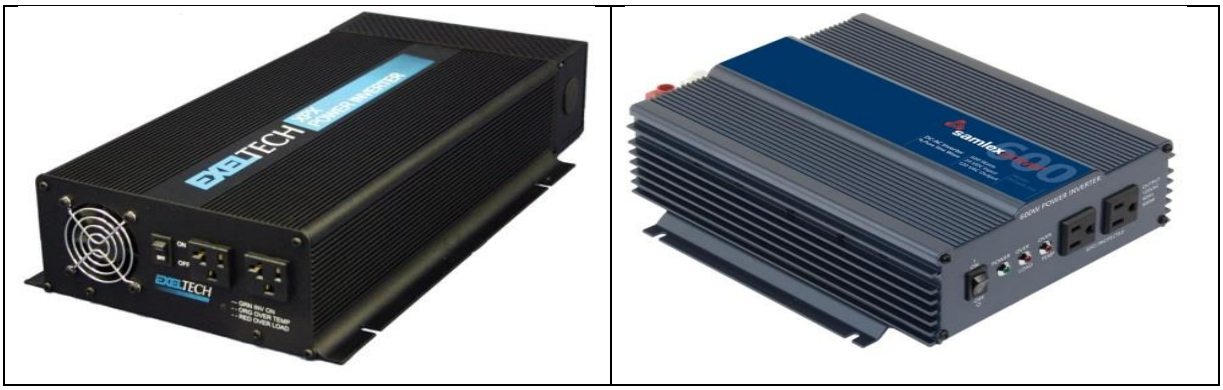
Inverter converts the variable solar panel DC output to AC. The inverter is must for using AC powered equipment.

9.4.1 Types and Specification

Single-phase system inverters are available in 500 VA to 7 KVA ratings with VDC input of 12/24/48 V and output of 220 Vac. Solar system inverters are normally categorized in following types:

9.4.1.1 Stand-Alone/ Off-Grid Inverter

Stand-Alone inverters are used in isolated system with battery backup where there is no access to utility grid. When PV voltage decreases it started drawing DC power from batteries. To access electricity all the time, a backup generator is used for charging batteries.



9.4.1.2 Grid-Tied Inverter

Grid-Tie inverter converts DC solar panel electricity to AC, which synchronizes with utility line to be added to utility grid. It shut down automatically upon the loss of utility grid and doesn't provide backup in absence of utility grid and solar power. This practice is not followed on residential and commercial projects in Pakistan.

9.4.1.3 Hybrid Solar Inverter

Hybrid solar inverter has dual function it can be used as off-grid system with back-up utility grid and grid-tie system with battery back-up. In Pakistan, residential and commercial projects have hybrid systems, which are off-grid with utility back-up.

Inverter without charge controller Inverter with built in charge controller

9.5 Batteries

For both residential and commercial projects solar system battery back-up is necessary. It could be single or multiple batteries to form a battery bank.

9.5.1 Types & Specification

Generally, there are different types of batteries which could be used in solar system. For solar power systems following batteries are used:

9.5.1.1 Lead Acid Battery

Lead acid battery uses lead plated cells with water and Sulphuric Acid in a mixed proportion as electrolyte. The batteries usually attached to solar panels are of 12V and 100/135/175/200 Amps. Small amperage batteries could also be used to charge directly with a 12V solar panel.

9.5.1.2 AGM (Absorbent Glass Matt) Battery

The electrolyte in these batteries is of a glass matt made by very thin woven glass fibers to increase surface; enough to hold sufficient electrolyte to increase the battery life. They are expensive then lead-acid battery but have long lifetime. AGM batteries of 12V and 100/150/200 Amps are available in market. Certain others amperage are also there but are usually in used condition.

9.5.1.3 GEL Battery

Gel or Deep-Cycle batteries have a silica gel as electrolyte and have low recharge voltage as compared to AGM and Lead-Acid. Its life expectancy is also longer than other mentioned batteries. A proper battery charger is used for such type of batteries otherwise low performance and failure will happen. There voltage and amperage specifications are 12V, 100/150/200 Amps. Other amperages are also available but are in used conditions and couldn't be reliable.

Batteries (Cells) are also available in 2V configuration which is normally used for commercial applications with different ampere ratings.

9.6 Solar Tracker

Solar tracker is used for solar panels to follow direction of sun. They are categorized on functional basis as passive and active tracker. Passive tracker uses compressed gas fluid to drive one side or the other. On the other hand, active tracker has a controller which responds to sun's direction. On basis of motion there are also two type's i.e. single axis tracker and dual axis tracker. Single axis moves back and forth in single direction and their motion includes vertical, horizontal, tilted and polar aligned. The dual axis continually faces the sun as they move in both directions.

9.6.1 Advantages

Systems with solar trackers generate more electricity than stationary arrangement due to an increased direct exposure to sunlight.

There are many different kinds of solar tracker, such as single-axis and dual-axis trackers, which can help you find the perfect fit for your unique jobsite. Installation size, local weather, degree of latitude, and electrical requirements are all important considerations that can influence the type of solar tracker suitable to the user's requirement.

9.6.2 Disadvantages

Solar trackers are slightly more expensive than stationary systems, due to the more complex technology and moving parts necessary for their operation.

Some ongoing maintenance is generally required, though the quality of the solar tracker can play a role in how much and how often this maintenance is needed.

10 RESIDENTIAL & COMMERCIAL SOLAR SYSTEMS

The electrical load and usage of residential and commercial system vary because residential usage is mostly same whereas in commercial systems usage depends upon the activities being performed in the particular location and it also depends upon the type of equipment installed.

Normally residential system consists of single phase two wire system whereas commercial systems are 3 phase 4 wire. Solar panels, inverters, batteries and charge controllers also vary for residential and commercial applications because the components designed for residential system may not be suitable for commercial applications and vice versa.

Commercial systems are normally used for following purposes in Pakistan:

a) Water pumping from tube wells.

b) Buildings electrification.

c) Auxiliary power sources for power plants startup.

d) Power source for remote BTS (Base Transceiver Station) locations of telecom companies.

Residential systems are normally installed to get electricity during the hours of load shedding and in some cases these systems are also used in daytime instead of WAPDA for uninterruptable supply

11 LOAD CALCULATION

Load calculation is very important before solar system installation. If the load is not calculated correctly, then appropriate system will not be installed hence user will get low performance. The power ratings of appliances are written on their stickers or their manuals. In general, the power ratings of common appliances are stated below for reference:

POWER RATINGS	
Appliance	**Power Consumption *(WATTS)***
Ceiling Fan	120
Tube Light (Choke)	80
Energy Saver Bulb	25
Air Conditioner (1-Ton)	950-1,100
Television 32"	120
LCD TV 32"	90
LED TV 32"	60
Iron	1,000
Pedestal Fan	85
Exhaust Fan 12"	60
PC	150-200
Refrigerator (varies with size)	150-300
Deep Freezers (varies with size)	250-400

12 HOW TO CALCULATE LOAD

Total Load for a small household can be calculated as under:

Equipment	Quantity	Load/unit (W)	Total Load (W)
Fans	3	120	360
Energy Savers	5	25	125
Refrigerator	1	300	300
Total			**785**

After the calculation of load, the solar system power to be selected is 20-25% more than the calculated load. Like described above by adding 20% it will become 942W. So 1000W solar panels will be good.

12.1 Selection of Components

12.1.1 Solar Panels

Solar panel selection is core of the system installation. The panel selection is also dependent upon the efficiency which varies company to company. If you are living in a region where temperature in summer is above 38 degrees then mono-crystalline panels is used. And if it is maximum of 35 degrees or maybe 38 degrees then poly-crystalline is better.

12.1.2 Charge Controller

Charge controller selection depends on solar panel power and battery bank voltages. For instance, to calculate the charge controller for 1000W panels and you have 24V battery bank then 1,000W/24V= 41.67Amps as solar panel never gives 100% output so the generally it is calculated at 80% of the total solar panel watts i.e. 800W/24V=33.3 amps. So you can install 40A charge controller. Moreover, to select between MPPT and PWM, if your solar panels are of voltages like 12/24/48V then PWM is a good option which is cheaper than MPPT. For PWM your battery bank voltages should be equal to the solar panel voltages. MPPT is more efficient and draws maximum energy from PV panels as required but expensive than PWM.

For small systems like 500W-1500W with 24V or 48V battery bank PWM controller is good choice. For Systems greater than 1500W then MPPT has better performance.

12.1.3 Inverter

Selection of inverter in solar system is based on the type of system you are installing. For residential and commercial use, the inverter used is hybrid with battery bank and also takes power from utility gird. Local manufactured UPS can also be used. In market, UPS having complete sine wave and better output are available. For 1000W PV system the inverter preferred is of 1000W 24VDC. Inverters are available in different power ratings and with a lot of models from different manufacturers. For single-phase systems inverters are available in 500 VA to 7 KVA ratings with Vdc input of 12/24/48 V and output of 220 Vac.

12.1.4 Battery

Battery selection is very important for residential and commercial use as system backup depends on battery bank. The batteries available in market are Lead-Acid, AGM and Gel technology. They are different in prices and life expectancy. For lead acid an extra maintenance is required to check every 15-20 days their water level. As example of 1000W system 100Amps two batteries are good enough. If you go for more amperes then it will take longer time to charge and in absence of solar energy, electricity from utility grid is required for charging.

13 KEY FACTORS

There are some key factors which should be taken care of in order to get proper efficiency and response of solar system. The details of these factors are explained below:

Panel Cleaning: There should be some proper schedule for the cleaning of solar panels to remove debris because if not cleaned properly efficiency of solar panels decreases with the passage of time.

Panel Direction: The direction of solar panels is also very critical in order to utilize maximum sunlight for conversion into electrical energy, usually solar tracker is used which rotates solar panels with respect to sun, optimizing the conversion of sunlight into electricity. Normally in Pakistan panels are placed in south-west facing direction.

Shading: Another key factor for solar systems is shading. Normally the shade of panels installed in front falls on panels installed in the back row, which reduces the efficiency of solar system, keeping this in view the space between solar panels should be chosen so that shading should be eliminated.

Temperature: High temperature also effects solar system efficiency, so panels should be placed in such a manner that there is efficient airflow to control temperature in hot weather. Normally panels are installed close to roof for good airflow.

Mounting: The mounting structure of solar panels should be fabricated properly so that it can bear the maximum wind pressure and solar panels remain intact in their place. Solar panels should be properly bolted to mounting structure to avoid any accident in case of high-speed winds.

14 INSTALLATION OF SOLAR SYSTEM

Following factors are to be considered while installing solar system:

14.1 Area required for PV panels.

Area required of PV system depends on what size of PV panels you are installing in that case it differs to panel size as well as system size. For residential system of 1000W approximately area required is 250 sq yards. As the system increases the required area will also increase.

14.2 System Installation

PV panels are either connected in parallel or series depending upon the open circuit voltage (Voc), short circuit current (Isc) of panels and PV input voltage and maximum amperes of charge controller. Consider a PV panel having Voc= 44.9V and Isc = 6.87A. Using MPPT charge charger controller with specification of PV input 150V, Output to battery 12/24 and 30A charging current for such specification of panel pair of maximum three panels are to be connected in series and then pairs are to be connected in parallel. For PWM charge controller having PV input 140V, output to battery 24V and 30A charging current with above mentioned specification of panels, the battery bank must be of 24V and in this case good practice is that all four panels are to be connected in parallel as PWM charge controller will fetch maximum of 24V and discard rest of the power

- PV panels direction should be in south-west

- The panel should be installed in a way that front row panel's shade does not affect the second row
- The length of wire between PV panels and charge controller should be minimum
- The wire gauge should be proper
- The charge controller and battery bank shouldn't be place in above 30 degrees temperature

14.3 Protection

Certain protection steps should be taken to avoid any accident or damage to system components.

- Proper amperage breakers should be installed in between battery bank and charge controller i.e. input from battery bank and output to charge controller to avoid unconventional current flow which usually damages the charge controller
- Breakers could also be installed in between PV panels and charge controller if charge controller is of less tolerance so that the excess flow doesn't damages the controller
- Solar panels plugs should be properly insulated
- The PV panel wires and battery bank wires should be tightly inserted in charge controller to avoid loss of energy and component damage

14.4 Maintenance

For better performance and long lasting of system few general maintenance steps are to be taken in consideration, which includes:

- Cleaning of PV panels with semi-wet cloth in the evening time regularly. Moreover, it should be done with soft hands to avoid any damage to PV panels
- If battery bank is of Lead-Acid batteries, then every 15-20 days check the water level
- Terminals of batteries should be checked regularly to avoid any loose connection, Heating or sometimes fungus growing on terminals

15 SUPPORT ORGANIZATIONS

Different public and private sector organizations providing technical support in the areas of Alternate Energy Systems can be contacted for detailed technical assistance required for making an investment decision towards installation of appropriate alternate energy systems including Solar Power Systems. Furthermore, detailed education and training for skill enhancement of resources managing installation and operations of Alternate Energy Systems can also be availed from these institutions.

The contact details of these institutions are listed below;

Serial	Organization	Address	Phone	Website
1.	Alternative Energy Development Board (AEDB)	2nd Floor, OPF Building, Shahrah-e-Jamhuriat, G-5/2, Islamabad	051-9222360-61	www.aedb.org
2	Pakistan Council Of Renewable Energy Technologies (PCRET)	Plot No. 25, H-9, Islamabad. 6 KM Off Main Raiwind Road, Thokar Niaz Baig, Lahore.	051-9265271 042-35321782	www.pcret.gov.pk
3.	Pakistan Industrial Technical Assistance Centre (PITAC)	234 Ferozepur Road, Lahore	042-99230699	www.pitac.gov.pk
4.	Technology Up-gradation & Skill Development Company (TUSDEC)	State Cement Corporation Building, Kot Lakhpat Lahore	042-111000143	www.tusdec.org.pk

5.	Technical Education & Vocational Training Authority (TEVTA)	TEVTA Secretariat, 96-H, Gulberg Road, Lahore	042-99263055	www.tevta.gop.pk
6.	Al-Khwarizmi Institute Of Computer Sciences (KICS), UET Lahore	G.T Road, Lahore	042-99029450	www.kics.edu.pk
7.	Pakistan Solar Association (PSA)	9 Egerton Road, Lahore.	0300-8470865	www.pakistansolarassociation.org
8.	Renewable & Alternative Association Of Pakistan (REAP)	Plot 140, Street No. 9, Sector I-10/3, Islamabad.	051-4100084 0300-5221718	www.reap.org.pk

16 LIST OF SOLAR SUPPLIERS / VENDORS

Contact details of some of the suppliers of Solar Energy Systems are given below;

Serial	Supplier	Address	Phone
1.	Solar Sigma Ltd.	Plaza No. 31-A, PWD, Main Express highway, Islamabad	051-5421006
2.	A. R. Brothers	4-D, 1st Floor, Mahmood Plaza, Fazal-ul-Haq Road, Blue Area, Islamabad	051-2605698 0333-5533362
3.	SPOT Pvt. Ltd.	#238, Street 8, Industrial Area, I-9/3, Islamabad	051-4432848 051-8358170
4.	Energy Bros (Pvt.)) Limited	57-C Valancia Town, Lahore	0334-0469000
5.	Alpha Solar	17-N, Johar Town, Lahore	042-35227136 0321-5149491
6.	Shaheen Solar	16 Hall Road, Lahore	042-37211390
7.	REON Energy	01 Canal Bank, Near Jail Road Underpass, Gulberg-II, Lahore	0302-8241857

8.	SIMTEX	C-5-E Sunset lane-2, Phase-2 (ext), DHA, Karachi	021-35386004 0332-2572227
9.	Pakistan Solar Services	Office # 9, 3rd Floor, B.B. Shopping Mall, Opposite NED University, Block-1, Gulistan-e-Johar, Karachi	021-34160010 0300-2731340
10.	SE Solar Energy	1st Floor Taj Mahall Market Jinnah Road, Rawalpindi	051-5750571 0313-8875674
11.	Solaris Engineering SMC Pvt. Ltd.	P-39, Ravi Market, Susan Road, Faisalabad	041-8710013 0312-7775155
12.	Solar Master	94-Garden Town, Sher Shah Road, Multan	061-6538182-3 0300-8545551

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