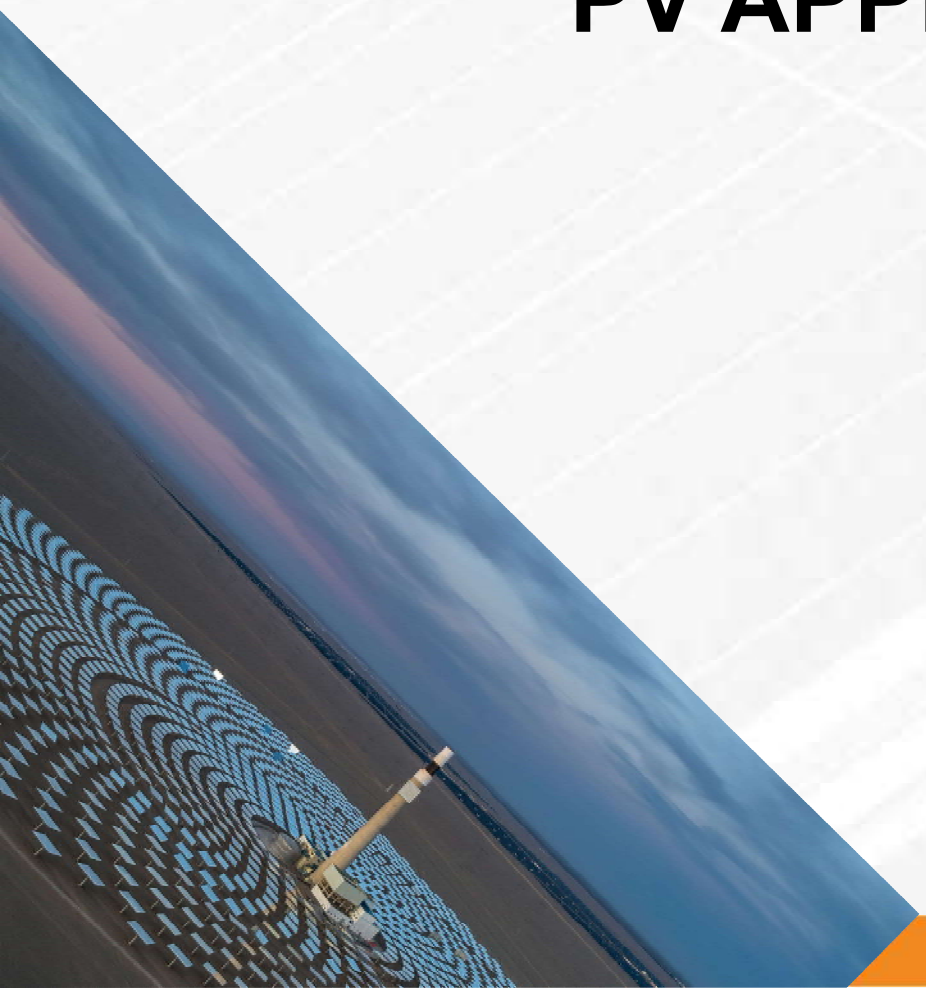
Module Outline

RESIDENTIAL AND RURAL PV APPLICATIONS



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Relevance and Background

Solar PV has several advantages at different application areas. But the major advantage it has over conventional power sources is its capability of distributed generation, practically to the user's consumption point. By making maximum use of solar technology, the efforts of a government to provide electrical power to such remote populations would yield high and desirable results, mainly in the countries where a major part of the population still lives in remote rural areas. Extending the conventional power grid to such areas has the challenges of very high costs, lower revenues, and hence less or no profitability. All governments have limited resources and may have other pressing priorities.

One requirement for such solar applications to be adopted on a mass scale in rural areas is the availability of standard products and power plant designs. Such standardization has helped many countries to speedily promote off-grid PV. A large number of suppliers of solar products and power plants should be available locally in the rural areas who can design and install suitable systems.

Because off-grid PV systems are still costly and capital intensive, as compared to on-grid systems, mainly due to the presence of batteries, these may still require budgetary support as well as easy financing options from government agencies. Once the proper scale of operation is achieved, these systems would become affordable without any external financial support.

Theme – Project Management
Competency – Project Development (DRE)
Code of the Module – T03C06M17

Learning Outcomes

At the end of the presentation, the participants will be conversant with the:

- Challenges of providing conventional power supply in rural and remote areas
- Suitability of solar energy as a solution to reach rural and remote areas
- Different solar standard products useful for such areas and applications

An overview of solar solutions possible to address the various energy needs of rural population would equip participants with the necessary exposure to plan relevant schemes and programs using solar solutions and products for these communities' economic growth.

Method of Delivery

Duration	Resource Code	Resource Delivery
60 min.	M17 L01	Lecture on Residential and Rural PV Applications

M17 L01: Lecture Presentation

The MS PowerPoint presentation mainly provides an overview of different solar energy products and systems, against the backdrop of the challenges of extending the conventional power grid to rural areas.

The first set of slides provides glimpses of various solar solutions for different sectors such as health services, education, electrification, irrigation, and so on. This is followed by information on the major solar products that can be standardized for meeting these needs in rural areas, such as solar pumps and solar-based mini-grids, in addition to lanterns, home lighting systems and streetlights.

Solar power packs are discussed in detail with their components, types and salient features because these are very versatile in meeting various energy needs.

The last section focuses on deployment of these products and systems, and the necessary inputs required from stakeholders, mainly the government. This brief discussion would help the participants understand the value addition by different solar interventions to improve the economic and social scenario of the rural population.

Key Topics to be Covered

1 Challenges with Conventional Grid Power to Rural Areas
2 Suitability of Solar PV for Rural Areas
3 Solar PV Solutions for Meeting Energy Demand
4 Deployment Models and Requirements
5 Support Requirement from Government

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1 Introduction

Electrical energy has become an integral part of our day-to-day life, and more and more applications like transport and cooking are now being converted to use electricity. We need electricity for our domestic, commercial and industrial sectors. However, those living in rural or remote areas do not have the luxury of 24x7 power supply. They either get no power, or the supply is unreliable and irregular.

2 Challenges with Conventional Grid Power to Rural Areas

Grid operators find it difficult and uneconomical to extend the regular power grid to remote populations, whose requirement is low in comparison with the urban population, and therefore provide less revenue to the supplier. It is very costly to deploy and maintain grid electricity in tough terrains such as mountains, valley, island etc. Extreme events such as flood, storms, cyclones etc further increases the cost and effort to maintain the electricity supply with safety and at times suffer from long downtime. Running a fossil-based energy source such as diesel gensets not only add extra to cost burden, but also create localised air pollution and high decibel noise worsening the living condition in the neighbourhood.

3 Suitability of Solar PV for Rural Areas

In such situations, the possibility of local generation nearer the user points is the best solution and solar PV completely fits this requirement. versatility of solar power system allows local generation of electricity for consumption or storage in battery. Solar power plants can be established within a very short period as compared to conventional power plants, and practically generates power throughout the year. Grid deployment in a tough terrain with sparse population becomes uneconomical due to low demand and high deployment cost. Modular nature of solar PV allows users to have a power generating system designed according to their needs in a much economical way. To harness the advantages of solar PV, it is important that the off-grid applications are well understood, and products are designed to suit needs of the users. The variability of solar energy can be addressed through providing storage solutions, which are an integral part of off-grid products and systems.

4 Solar PV Solutions for Meeting Energy Demand

Standard solar products should be considered as energy solution for various sectors in rural areas. For example, in addition to lighting applications, solar PV can also be used to run other applications such as telecommunications in health clinics or schools. Local farmers could use solar pumping applications. It has been proven globally, that once reliable power reaches rural areas, many new enterprises develop as they can have power for longer working hours and to run different machinery or equipment. This helps develop the area with increased economic activity.

The following table provides a summary of some major solar PV solutions available for different sectors in rural areas.

Rural Sector	Needs	Solutions
• Lighting	• Home lighting • Street lighting	• Home lighting systems • Solar lanterns • Solar streetlights
• Rural Electrification	• Rural electrification	• Solar mini-grids providing AC power for local distribution grid
• Education/Information	• Lighting/running equipment in schools. • Power for TVs • Mid-day meals • Teaching through smart mobile apps • Use of smart boards	• Lighting/other power solutions for schools • Solar power for TVs • Solar cookers • Off-grid solar to provide electricity to run electrical / electronic appliances
• Health	• Primary Health Centres in rural areas without power	• Power for lighting/equipment • Vaccine refrigerators (medical fridge) • Solar hot water systems
• Irrigation	• Adequate water supply for irrigation	• Surface pumping systems • Submersible pumping
• Telecommunication	• Reliable power for telecom systems	• Custom designed solar power packs for equipment used in different types of telecommunications like in wireless, very small aperture terminal satellites, very high frequency transmitters
• Rural Banking	• Reliable day long power for rural bank branches	• Solar power packs to power lights and computers
• Enterprises	• Reliable power for running rural enterprises	• Solar power packs to power equipment • Solar mini-grids
• Agriculture	• Grain and Fruits drying • Irrigation to crops • Post harvest storage • Milk transport, storage and processing	• Solar dryers • Solar based cold storages • Solar milk chillers • Solar water pumps

Some of the above standard products have been explained briefly below:

4.1 Solar Lanterns

Solar lanterns are very useful when the light source needs to be portable. These lanterns have the required capacity solar module, which charges the battery inbuilt in the lantern during the daytime for 4-6 hours of use in the evenings. There are some models that can also be used as stationery reading lamps. The lanterns have LED lights and maintenance-free small. the solar charge controller built in the lantern carries protective devices for overcharge and discharge to make it safe for use and last long.

4.2 Home Lighting Systems

Home lighting systems can be designed in different configurations, and as the name suggests, can be used in homes for lighting as well as for operating fans. The solar panel can be mounted permanently or can have a detachable arrangement, so that during the day it can be kept in the open on the roof or on the ground nearby with or without the mounting structure provided with the system. The battery here is normally a stationary battery inside the house for its protection, which can be low maintenance or totally maintenance-free depending on the design and required capacity.

The loads in these systems that run on solar-charged batteries can be for different combinations of light and fans as required for the household. The capacity of the module and the battery depends on the load requirement, and the system is provided with switches to operate individual loads as necessary for the required durations.

4.3 Solar Streetlights

Solar streetlights are independently standing solar lights normally on a pole or at a high location, which can illuminate the surrounding area during the whole or part of the night based on the battery charging that happens during the daytime with the solar module. These streetlights have inbuilt electronics and voltage sensing mechanisms so that they operate automatically during dusk to dawn. All the other necessary protections are also built into a single unit, known as electronic control unit (ECU).

It is possible to design a streetlight to vary the light intensity during the night. This would reduce the required capacities of the solar module and battery, and thereby the overall cost.

4.4 Small and Medium Power Packs

Solar power packs allow for need-based flexible use of electricity to power the load during high demand and low or no sun hours. These power packs can be designed in different capacities ranging from a few kilowatts to a few hundred kilowatts. such power packs can be configured to get charged from multiple sources such as grid, solar, wind, DG sets etc. The common components of off-grid solar power packs include the solar module, mounting structure, solar charge controller, battery, inverter, cables and accessories, and electrical connection hardware.

The operation of solar packs is very simple, where the battery is charged during the resource available and then discharged to support the load as necessary. Solar modules of any technology can be installed either on the rooftops or on the ground within the premises, while the battery and other electronics

are normally housed in an enclosure which is inside the building where all the loads are to be supported.

Some common configurations of off-grid solar power packs are listed below.

- **Stand-Alone PV System with Storage:** Here the only source to charge the battery is solar energy, so the battery bank needs to be of a higher capacity than the daily requirement so that even on some non-Sun days, all the loads can be supported, even without solar charging on that day. Such higher capacity battery banks can be of 1-2 days or even 7 days depending on the criticality of the load operation and the available budget. This is defined as autonomy - the time during which the load can be met with the battery alone, without any solar inputs, starting from a "full charged" battery state, and is measured in 'number of days'.
- **AC-PV Hybrid System with Storage:** This system will have one more source to charge the battery in addition to solar energy. This enables the designer to have the lowest possible autonomy days, or it can even be without any autonomy. The system can be designed as per the solar charging needs vis-à-vis non-solar use. Therefore, such power packs may have smaller solar arrays and/or smaller batteries, depending on the design, and hence are less costly.
- **AC-PV Hybrid System with Storage and Manual Switchover to DG:** Just like the above hybrid solar power pack this has more than one energy source, but also has the possibility of shifting all the loads to the available diesel generator (DG) in case of emergencies. This shifting of loads can be manual or automatic. This further increases the reliability of the system but also can add to the operation cost in case of higher DG operation hours.
- **DG-PV Hybrid System with Storage:** This type of power pack uses a DG as a complementary energy source to charge the battery when solar is insufficient.

4.5 Solar Water Pumps

Another very important use of solar energy in rural areas can be for pumping water. Such solar water pumps normally do not have any energy storage device like batteries and can operate only during sunshine hours. Such configurations also match the water requirement, as during the rainy season when solar radiation is minimal, water pumping is not necessary, at least for irrigation. Along with solar modules and the motor-run pump, the set also includes a variable frequency drive (VFD) so that the pump can easily handle water quantities based on the available solar radiation intensity.

Solar water pumps can be stand-alone or grid-connected. Under each category, they can be of surface/open well type or submersible, and therefore mobile/transportable or stationary.

The pump powered by solar, can be of capacity from 1 HP up to 10 HP. There are special DC pumps in the market, which can directly operate on solar modules or as an alternative the existing AC pump can also be supported on solar through an inverter and a VFD. The total head is divided into suction and delivery head. The solar pump capacity can be designed based on the total head and the total

water quantity required to be delivered at that head. This is important so that only the necessary solar modules are deployed, thereby saving on costs.

The requirement for water pumping for irrigation depends upon season and crops. The grid-connected solar pumps feed the electricity into the grid during non-pumping hours thus utilising the installed capacity. There can be different business models built around these grid-connected solar pumps depending on the grid quality, the schemes in the region, and the cropping pattern. In small villages or hamlets solar pumps can also be used to lift potable water to an elevated tank and thereafter distribute tap water through gravity to all the households. Similarly individual households can use solar pumps to pump water from ground storage to rooftop tanks.

To increase the return on the investment in solar pumps there are different models used worldwide where the ownership is shared among many individuals. For example, a group of farmers can own the pump and share the use of the same for their farms. Such pumps can be designed to be portable and can be moved to the application area when required. The concept of sharing solar pumps among farmers makes maximum use of solar energy as well as makes them affordable to individual users.

4.6 Solar Mini-grids

Solar-based mini-grids are decentralized electricity distribution systems that rely primarily on solar energy to provide power to small communities or remote areas. These mini-grids combine solar

energy generation with energy storage and distribution technologies to create reliable and sustainable solutions for supply of electricity to communities that are not connected to the national grid. As with other solar applications, they can positively impact education, healthcare, economic activities, and overall quality of life in these regions, contributing to achieving the United Nations' Sustainable Development Goal of providing universal access to affordable, reliable, and modern energy services, thereby promoting inclusivity and reducing energy poverty.

Key features of solar mini-grids are:

- The primary source of electricity in these mini-grids is solar PV panels, which capture sunlight and convert it into electricity, making them an eco-friendly and renewable energy source.
- Unlike centralized power plants, mini-grids generate electricity close to the point of consumption. This reduces transmission losses and improves overall efficiency.
- To ensure stable and continuous power supply, solar mini grids incorporate energy storage systems such as batteries, which store excess electricity generated during sunny periods, allowing communities to access electricity even during cloudy or night-time conditions.
- The electricity generated and stored within the mini grid is distributed through a localized network of power lines and transformers. The distribution infrastructure is tailored to meet the specific needs of the community it serves.
- Mini-grids can be designed to suit the energy demands of a particular community, making them scalable and adaptable. As the community grows, the mini-grid's capacity can be expanded accordingly.
- For remote communities, extending the national grid can be expensive and time-consuming. Solar mini-grids offer a cost-effective solution, particularly when compared to diesel generators or other fossil fuel-based alternatives.
- Solar mini-grids help reduce greenhouse gas emissions, combat climate change, and minimize environmental impacts associated with traditional fossil fuel-based energy sources.
- In many cases, solar mini grids are owned and operated by the communities they serve or local entrepreneurs. This fosters a sense of ownership and involvement, promoting sustainable management and maintenance of the systems.

5 Deployment Models and Requirements

Special efforts are necessary to deploy these products and systems as they are to be installed in rural and remote areas, the purchasing power, transport facilities, and sales and service infrastructure are limited. Also, the requirements are different for effective promotion of solar products and power packs in these areas.

As the standard products can be centrally manufactured and installed locally, the requirement is mainly of forming standard designs to begin with, transportation to remote areas, and local servicing capabilities.

The components of the solar power packs can be centrally manufactured, but need to be designed, installed and serviced locally. local capacity building can be the solution for smooth operation, maintenance and servicing of the system. Safety and product standards need to be laid out correctly and followed strictly to avoid any accidents due to these power generating components and plants.

6 Support Requirement from Government

Government agencies need to make available financial assistance as necessary in different forms like subsidies or low interest loans. Long-term and transparent policies and programs need to be in place for population to make use of such schemes. Capacity building initiatives need to be undertaken extensively in these areas to build local capacity as community involvement is a must to give them a feeling of ownership and responsibility.

In the long run the government must also consider promoting and enabling national or local manufacturing or assembly of these systems. Similarly, to promote private investment in such areas there must be well designed regulations so that all stakeholders' interests are protected, and more investors come forward to reduce the burden on government funds.