Solar Off- Grid Power Plant System

For

Village electrification

Of

Village : Dageria Dist: Dahod.

<u>Designed, supplied ,Installed and commissioned by</u>

Topsun Energy Limited

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1. Introduction

Solar off-Grid power Plant is the best and viable electricity source where the conventional grid based electricity has not been able to reach in remote rural areas and small settlements. The State Electricity Boards (SEBs) often consider such locations financially not viable due to the high cost of laying transmission lines coupled with low power demand resulting in low returns.

On the contrary, even in many of the so-called electrified villages and small towns, quite a few houses may not have been connected to the grid. Many a time, the grid supply is highly erratic with planned and unplanned power cuts. Consequently, industrial applications in such areas suffer a lot of hardships due to the lack of assured power supply. As a result, while raw material and manpower are available in the rural areas, industrial activities are not getting established over there either due to lack of power supply or its unreliability. As a result, such areas remain trapped in the vicious cycle of lack of power supply and undevelopment!

A Solar off-Grid Power plants is a system that provides electric supply to the household appliances as well as typical industrial equipment's where conventional grid electricity is not available. A typical Solar off-grid power plant consists of a solar panel array, Battery banks, charge controllers and Invertors, where in daytime electricity generated from Solar PV array is utilized by load directly while excess generation is stored in battery banks for night time utilization. A typical functioning of solar off-grid power plant is illustrated in **Figure 1.**

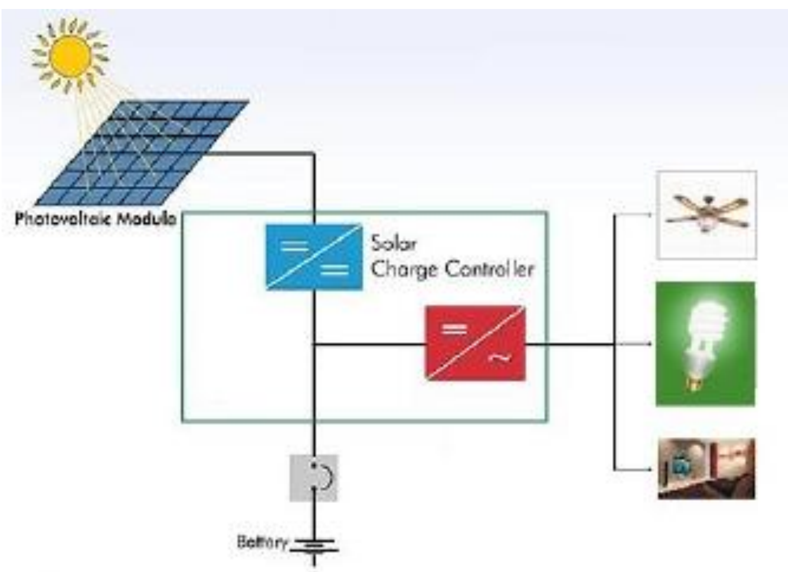


Figure: 1

2. Identification of the project site

Many rural and semi-urban areas in the country face long disruptions in power supply on a daily basis. Whenever a power shortage occurs, the State Electricity Boards (GSEBs) simply shuts down the rural feeders affecting normal life and bringing industrial and other productive activities to a standstill. Usually, there is no way to even correctly guess when power would be restored. The situation in places without power is still worse, but in this project a location already having a measurable and established demand for power was proposed to be covered so that the investigation could concentrate on the performance and management aspects of the RE power supply system rather than concentrating on finding ways to consume the power generated.
Many potential locations having electrified homes and established small scale economic activities like flourmills, workshop for tractors and two wheelers, agro processing, handicraft manufacturing etc. exist in all states. For logistical reasons a site either in Gujarat, M.P. or Rajasthan was to be selected for this first project. A location based on power demand, biomass and solar insolation availability and other essential needs like presence of a reputed NGO to help organize the end users into a nuclear unit who would manage power generation, distribution and revenue generation and post project sustainability was proposed to be identified through a survey. Selecting a site in an underdeveloped needy area would ensure long-term system utilization.

2.1 Significance of the present project

The project aimed at developing and establishing a new power supply – distribution system, first in a place where an unfulfilled demand already exists, utilizing the sun, diesel Genset, biomass and the rarely available grid electricity to provide high quality power on demand. The concept of users owning the responsibility for managing both the aspects the system i.e. generation and marketing is totally new for the simple village users.
In the past also such installations have been made; but without adequate external monitoring and appropriate guidance and support, many a time they have failed to meet the planned objectives. Through this project, it is aimed at making a thorough study of technical, economic and social aspects of a typical decentralized village power supply system. The outcome would be very much helpful in designing and installing suitable decentralized energy systems for remote rural/tribal areas.

2.2 Site Survey

Seven villages in Gujarat and MP were surveyed to study the feasibility of installing stand-alone renewable energy power supply system. The villages fall under Dahod and Panchamahal districts of Gujarat and Jabua district of MP. The villages were identified in consultation with the NGOs operating in the three districts. Tribal people who depend on agriculture or employment as labourers for livelihood inhabit almost all the villages. Of the surveyed villages, one is completely unelectrified while in others power supply is limited to some segments only.

The salient features of the surveyed villages are given below:

Village: Dageria: taluka – Jhalod, dist Dahod (Gujarat)

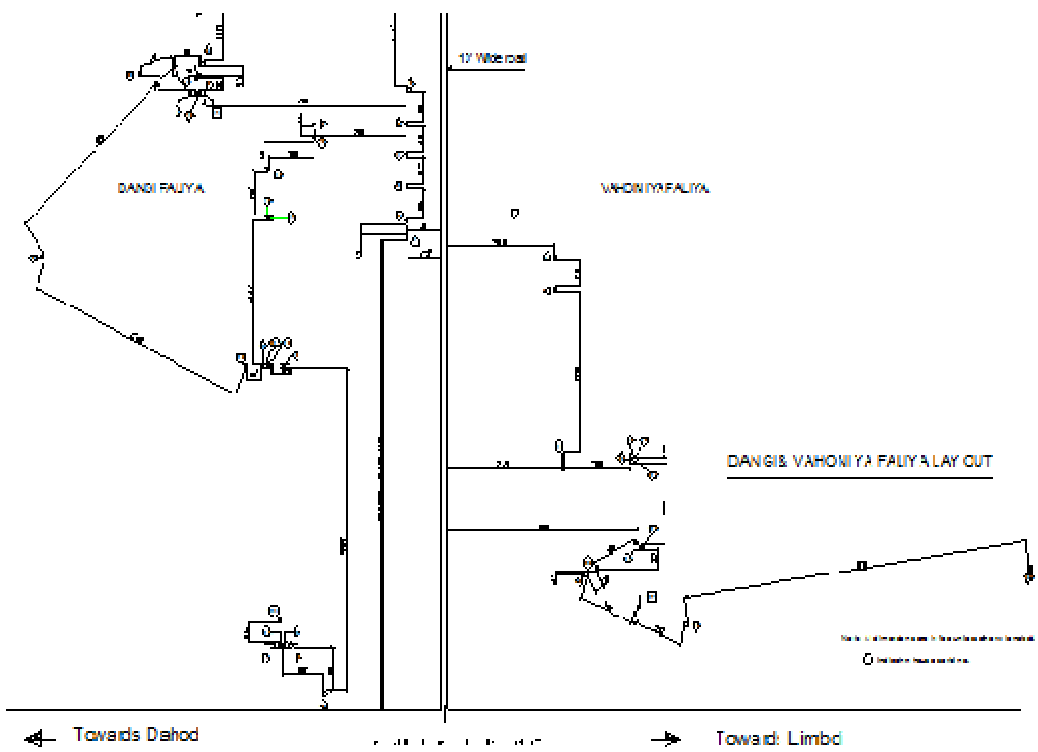
Village Dageria falls under the group panchayat of Mirakhedi in Jhalod taluka of Dahod distrcit. It is located 14 Kms from Dahod and is linked by motorable road. It has a population of 1400, mostly belonging to Bhil community. The village has 260 houses mostly scattered out of which about 75 houses are unelectrified. Out of the unelectrified houses 50 houses fall under one cluster, for which detailed data has been collected. The village has one primary school and two anganwadis. It has a small milk cooperative society. The daily milk collection from the surveyed cluster is about 80L /day. There are about 200 animals in the cluster comprising of cows, buffaloes, bullocks, calves and goats/sheep. Detailed survey of the unelectrified cluster known as Dangi faliya has been done.

N.M Sadguru water and development foundation, a NGO based at Dahod has undertaken various developmental activities in the village like organizing women self-help groups, water shed management, bio gas plant construction etc. There are three family bio gas plants and two solar lanterns in the village.

Since the people live near their land, the houses are scattered. The inter house distance varies from 50ft to 300 ft. The actual lay out has been worked out based on measurements.

Village Dageria in Dahod District, Gujarat with highly scattered clusters of houses

The lay out of the houses in village Dageria



To summarize –
Village Dageria was selected for project identification after surveying six villages in Gujarat and Madhya Pradesh with the help of local NGOs. Dageria is located in Dahod taluka inhabited by mostly tribal people. The houses are highly scattered falling under different clusters. Most of the houses are unelctrified and such clusters were selected for project implementation. The local NGO, Sri Sadguru Water and Development Foundation located at Dahod were closely involved in village identification and counseling with the villagers about the project.

After discussions with the villagers about the project and its benefits and the future plans, they unanimously agreed for the implementation of the project in their village and formed a *Soura Urja Samiti* for coordinating with SPRERI and Sri Sadguru Water and Development Foundation during the implementation of the project and thereafter its operation and maintenance.

Out of the electrified houses in various clusters, 55 houses were selected for under phase I of the project for covering under the SPV network. Four clusters were planned for power pack system and 12 houses for home light system.

3. System Design

From the detailed survey of the village, it was obvious that a centralized power pack system is not feasible to supply power to all the identified houses of Dageria. The houses were scattered, a typical lay out of dwellings often seen in the tribal areas of Dahod district. After careful planning, the houses were segregated into few clusters with nearest houses coming under one cluster. However, within the clusters the inter housing distances varied widely. Even after accommodating the houses under one or other cluster, some remote houses were still left out of the cluster planning which had to be covered under a different scheme.
Considering all these aspects, four pack systems were conceptualized each comprising of a set of SPV panels, battery bank, charge controller, inverter, power meter, junction box etc for four clusters. Those houses which did not come under any of clusters were planned to be covered under individual home light system.
Individual systems were designed based on the number of houses, lighting load, inter house distances etc. After discussing with the beneficiaries and M/S Sadguru Foundation it was planned to provide two CFL lamps of 11W to each of the beneficiaries which will be installed in two rooms of each house. The location of the lamp would be decided by the beneficiary. Usually the tribal houses will have a large entry room (drawing room?) and a kitchen attached with a store room. Many a time the cattle are located in a corner of the large room itself. In most of the cases one bulb was provided each in the large room and the kitchen. The power pack (inverter/battery system) would be set up in one of the houses which has adequate space and is secure. The owner of the house would be the care taker of the power pack and would monitor it's operation (switching on /off).

The design details of the of the SPV system for Dageria is given below:

3.1. Solar PV Modules:

- Array capacity: Depends on numbers of houses covered by each power pack comprising of Topsun make PV modules
- System Volts: 12V
- Total modules in parallel: Depends on the numbers of panels

3.2. Module Mounting Structure

- The solar PV Modules are to be installed & fixed with the module mounting structures with appropriate size Nickel-plated nuts & Bolts.
- The array supporting structure are made of hot dipped galvanized MS angles of size not less than 50mmx50mmx5mm in size. The minimum ground clearance of the lowest part of the module structure shall be of 500mm.
- The structure shall be designed to allow easy replacement of any module. The angle shall be fixed to **min 25 to max 30 degree** from ground plane to support in conditions in western India. Each leg of the structure shall be fixed on RCC concrete foundation structure around the legs, round or square min. 1 foot in diameter or 1.5 feet diagonal.
- The structure shall be designed such that there shall be no need of welding or complex machinery for installation at the site.

3.3. Junction Boxes

- The junction Boxes shall be dust & preferably waterproof and made of rust free material like thermoplastic, PVC etc. The terminals will be connected to copper lugs or bus bars of proper sizes with **min 30A current** carrying capacity. The junction boxes will be having suitable cable entry points fitted with cable glands of appropriate sizes for both incoming and outgoing cables. Suitable markings shall be provided on the connectors or bus bars for easy identification and cable ferrules will be fitted at the cable termination points for identification. Each main junction box shall be fitted with appropriate rating blocking diode if not accommodated in Solar Modules.
- It shall provide proper isolation from the mounting surface and among the connectors of group arrays.

3.4. Battery Bank

- There will be one battery bank comprising of numbers of cells of each 2V/appropriate ampere hours depending upon the required autonomy. The batteries should be of tubular type and low maintenance type and shall have long service life. **SMF batteries are not preferable** due to their degradation in hot weather conditions in summer.

Battery specifications are given below:

Container	:	Polypropylene, co-polymer, hard rubber
Terminals	:	Made of lead alloys suitable for bolted connection.
Electrolytic	:	Battery grade sulphuric acid.
Self-discharge	:	Less than 3 % per month at 30 degree.

Life expectancy : 1500 cycle duty at 27 degree at 80% depth of discharge

Voltage	: 2V x required Nos.
Approval	: DOT, Defense, ERTL, SEC or ETDC
Service life	: Should perform satisfactorily for a minimum period of 5-6 years under operating conditions as mentioned.

3.5. Inverter

- The Inverter used should be highly efficient based on PWM MOSFET Design with facility to Grid connectivity for charging in case required in monsoon or in case of failure of charge controller.

  Inverter specification are given below:

Nominal capacity	: Depends on the power pack and preferably true sine wave type
Input voltage	: 12 V DC nominal
Output voltage	: 230V 50Hz 1Φ
Regulation	: 200 % for 30 seconds
O/P frequency	: 50Hz ± 1%
Efficiency	: Preferably > 80-90% from NL to FL at 0.8 PF
Total Harmonic Distortions	: < 5%
Indications	: Mains ON, Inverter ON, Low Battery, Overload, charging, Full Battery etc
Protections	: Protection against Surges & Spikes, Overload, Short-circuit, Battery low, Reverse Battery
Audio Fault Indication	: Low Battery, Overload by buzzer or speaker

3.6. Charge controller Unit:

- The charge controllers installed should be capable of handling the peak output current of solar Array, Array reversal, Battery reversal, and short circuit on Battery side.

  Specifications of Charge controller are as given below:

Nominal Volts	: 12V
Max. Charging Current	: 30A
Other functions	: Charge Equalization logic
Indications	: Charging ON LED
Protections	: Against short CK.T, Deep Discharge, Over charge, Solar Array, Reversal, Battery Reversal
Mounting	: Preferably Wall Mount
Connections	: Clear Indications for SPV ARRAY & Battery connections

3.7. Cables & wiring:

All cables to be used from SPV Modules to Junctions BOX shall not be less than 2.5 Sq. mm individual as per ISI standards and it should be PVC insulated and run underground at least 3feet deep in suitable PVC pipes waterproofed from array to the inside of the House.

The cables shall be tinned copper conductors of suitable cross sections with PVC insulations and two-core type with one core having BLACK and the other Core having RED color.

Length of cables were selected such that the overall electrical energy loss in any section of cable or wire is not less than 3% under the designed operating conditions.

All cables were crimped and/or soldered for making connections and shall be supported for the proper flow of cabling by suitable cable ties and compression glands wherever they go in and out of any junction box.
In case of in house wiring, the wires would run in PVC pipes or PVC sanction pipes with suitable cable size and insulations as per ISI standards. No wire will be left open for AC wiring. Suitable switches will be provided for each device to be operated on AC.
In case of cabling from one house to another, it is recommended that the cables used are under grounded at least 3-4 feet deep while distributing AC lines from inverters. A suitable wire gauge with preferably **armored type cable is recommended**. If there are farms on the ways of cabling it becomes difficult to do any maintenance in case of cable fault while the crops are being grown. So it is recommended that in such cases the lines may be distributed over the top of the farms to houses by steel wires with suitable supports as necessary.

3.8. Compact Fluorescent Lamps (CFL) fittings 11W (AC):

All the fittings of CFL shall be of reputed make and should possess the parameters as below.
Parameters of CFL fittings:

Enclosure	:	ABS Plastic body with Transparent Acrylic/polycarbonate enclosure on LAMP with back reflector preferably Aluminum foils.
Volts	:	230V± 5% AC
Frequency	:	50Hz ± 5 %
Lamp type	:	CFL 11W 4 pins type ….*2 pins Type not to be used as it has half the life*
Efficiency	:	> 80%
Blackening	:	Not more than 2 % after 1000 cycles of ON/OFF
Other Feature	:	With Super bright LED to work as night Lamp
Switch type	:	Three way; Load on, Night Lamp and OFF positions
Light Lumen	:	Not < 900 Lumens

Fittings should be detachable for mobility and serviceability with male connector having reverse polarity protection .The fittings should be wall or Ceiling mount type and of light weight to suit the interiors of the house.

3.9. Battery / Inverter Rack:

There shall be provided suitable rack, properly ventilated and convenient to check the battery conditions, topping up water in batteries, check all the indications of Inverter etc.
It should have proper weight handling capacity not less than 400 Kg. The design to be made at the later stage by the supplier depending on the type, make of battery and inverter he offers.
3.10. Danger Plates:

The contractor shall provide danger plates wherever required at least measuring 200mm x 200mm in size, made of mild steel sheet with the writing in the local language.

3.11. Lightning protection & earthing: (may be optional)

3.12. Warranty:

Solar Module : Performance warranty of 10 years,

Battery : One year from the date of supply

Battery : 2 years, against manufacturing defects to be repaired or replaced as necessary.

Electronics items : 2 years against manufacturing defects to be repaired or replaced as necessary.

3.13. Compressive Maintenance Contract (CMC):

The manufacturer will also provide additional information about the CMC of the system and conditions of warranty as necessary along with price list for major components and with validity of prices.

3.14. Tool kits:

Necessary toolkits have been provided along with the each power plant for any routine maintenance or immediate repair.

4. System Installation and training

As planned earlier, in each of the clusters one of the beneficiary's houses had been identified for installing the battery-inverter system, after looking into the safety and security factors.

The required number of SPV panels, storage batteries, cables, inverter system, charge controller, etc were unloaded in the respective clusters at the identified beneficiary's house.

Cabling through PVC pipes under process

Team of technical person's f from SPRERI was deputed to supervise the installation work. The concerned staff of the NGO, Sadguru foundation and the semi-skilled persons from the Soura Urja Samiti of Dageria were present throughout the installation work. The system installation was done in different stages as below:

4.1 SPV array mounting structure installation:

The SPV panels supporting structure was made of hot dipped galvanized MS angles of size 50mmx50mmx5mm. The structure was designed such that the specific number of panels designed for each cluster would fit into it. The minimum ground clearance of the lowest part of the module structure was maintained at not less than 500mm.

The solar PV Modules were installed & fixed with the module mounting structures with appropriate size Nickel-plated nuts & Bolts. The structure was fixed in such a way that the SPV panels would be facing south in each cluster at an angle of 25 degree to horizontal.

Since the soil at Dageria is highly stony, some modifications were made in the method of anchoring the SPV panels to the ground. The angle iron structural holding the panels was fixed to a 100 mm GI pipe at the diagonal mid-point. The central supporting pipe was fixed on a 40 cm x 40 cm cement concrete foundation structure around the leg and 1meter below the ground level.

Since the site is remote and y, all fittings were designed so as to avoid any welding work during the installation.

4.2 Installation of the cables and poles with junction boxes:

The cables made of tinned copper conductors of 2.00 Sq mm with PVC insulations and two-core type with one core having BLACK and the other Core having RED color were used for inter connections throughout the system.

The SPV panels of 12 V, 40Wp were connected in parallel in each array with the cables of above specifications. The same was used to connect the SPV Modules to Junctions BOX in each cluster. The PVC insulated cables and were laid underground 3 feet deep embedded in ISI standard PVC pipes and the entire length was waterproofed, from array to the inside of the House.

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Length of cables were selected such that the overall electrical energy loss in any section of cable or wire is not less than 3% under the designed operating conditions.

All cables were crimped and/or soldered for making connections and supported for the proper flow of cabling by suitable cable ties and compression glands wherever they went in and out of any junction box.

In case of in house wiring, the wires would run in PVC pipes suitable for the cable size. Two points were provided in each house for using two CFL lamps of 220V– 11 watts, with suitable switches.

Forty MS poles of 5-meter length (in two segments of 3 meter – 75 mm Φ and 2 meter 50 mm Φ) were used for connecting the houses in each cluster through the power packs. Each pole was buried under ground up to 1 meter with adequate concrete support. The exposed portions were painted with anti-rust painting. Inter pole cable connections as well as inter house cable connections were strengthened with the support of steel wires to avoid sagging.

Cables passing through pole – supported by steel wires to avoid sagging

Weatherproof PVC junction Boxes were used for connections in each power pack system. The terminals used were of 30A current carrying capacity. The junction boxes had suitable cable entry points fitted with cable glands of appropriate sizes for both incoming and outgoing cables. Connectors were suitable marked for easy identification and cable ferrules were fitted at the cable termination points for identification. Each main junction box was fitted with appropriate rating blocking diode.

The CFL lamp fitting inside the house – anchored on to the wooden beam

Installation of Inverter, Charge controllers and Batteries

Quasi sine wave inverters - 500 W, 12 V I/P and 230 V O/P were used in all the power packs coupled with charge controllers of 12 V DC and 10 A to 40 A , depending upon the power pack rating . The charge controllers would not only monitor the battery charging level, but also protect against short circuit, deep discharge, over charge, solar array reversal, battery reversal. The Inverters have also the option of grid connectivity for charging if required. They are equipped with indicators for Mains ON, Inverter ON, Low Battery, Overload, charging, Full Battery etc as well as protection against Surges & Spikes, Overload, Short-circuit, Battery low, Reverse Battery.

Deep cycle - tubular batteries were installed I each power pack as per the design of each power pack as mentioned in chapter 3. Six nos. 2 Volt cells were connected in series to get the total output of 12 V and the designed ampere-hours in each of the power pack.

Battery- inverter units being installed on specially designed safety racks

Specially designed racks with appropriate covers were used for supporting the inverter – charge controller - battery system to protect the system from dust as well as the provide safety to the users/ operator. The systems were installed in one of the previously selected houses at a safe part of the house, protected from dust and water. An extra power point was provided in these houses to install an additional CFL lamp over the power pack system for operation and inspection of the system.

5. CFL Lamps

Two CFL lamps each of 11 W capacities of standard make were installed in each house under different clusters with separate switches. As far as possible, the CFL lamps were wall mounted in each of the houses from safety point of view.

5.1 Home light system

Remote and scattered houses, which could not be, connected by power pack system, home light systems were provided. The package consisted of a 40 Wp SPV panel fixed on to a pole connected to a battery of 12 V 40 AH capacity from which two CFL lamps were supplied with DC power.

A photograph of the SPV panel of the home light system

Provided to an isolated house

The CFL lamp fixtures had inbuilt inverters to covert the DC power into AC power. Twelve remote houses were provided with the individual home light system.

Unlike the power pack system, in the case of home light system the individual owners of the system were the operators of their respective units. They had the option to switch on and switch off the system as per their will. However, the switching on /off time was ensured to match with those of the power pack units.

5.3 Energy meters

In each power pack system, an energy meter was installed to measure the power consumption of the respective cluster. This would also help in evaluating the system performance of different clusters over different periods during the year. This could also help in collecting the tariff from the users on a prorate basis.

Photograph of the Energy meters installed in each power pack

5.5 Earthing connections

In each power pack from the safety point of view, earthing connections were made as per the standard norms of the grid connections. A two meter deep hole was dug and earthing wires with appropriate copper plate were laid with charcoal and common salt.

Earthing connection being done at one of the power packs

The beneficiaries in whose residences power packs were installed were advised to ensure that daily some water is allowed to be soaked at the earthing point to ensure the wetness of the soil underneath for effective earthing.

"The final view"

A view of the SPV array in the background of the beneficiary's house and power carrying cables

All smiles, with the job finished satisfactorily -Members of the installation team-

The installation work was completed by the end of September 2007 and a trial run was conducted for a couple of days and the system was found to work satisfactorily. The installation work which lasted for about a fortnight and completed smoothly was the outcome of a perfect coordination between the villagers of Dageria, the installation staff of our company and the officers and staff of M/S Sadguru foundation and engineers of SPRERI. All the members worked like a single unit and strived for completing the job to every one's satisfaction.

Training on measuring the battery gravity to assess its performance

Each of the beneficiary was briefed in details about the Dos and Don'ts to be followed for the proper functioning of the system like not to tamper with the wiring, not to use any other bulb other than the CFL lamps provided to them, to switch off their lights whenever not required during the scheduled power supply hours etc.

Each of the four beneficiaries responsible for the safety of the power packs located in their houses were trained on how to switch on and switch off the power pack as per the agreed power supply schedule hours, to dust the up the inverter – battery rack regularly, to clean the SPV array regularly. Similarly, each of the home light system owners was also briefed to keep their battery pack and the SPV panel clean.