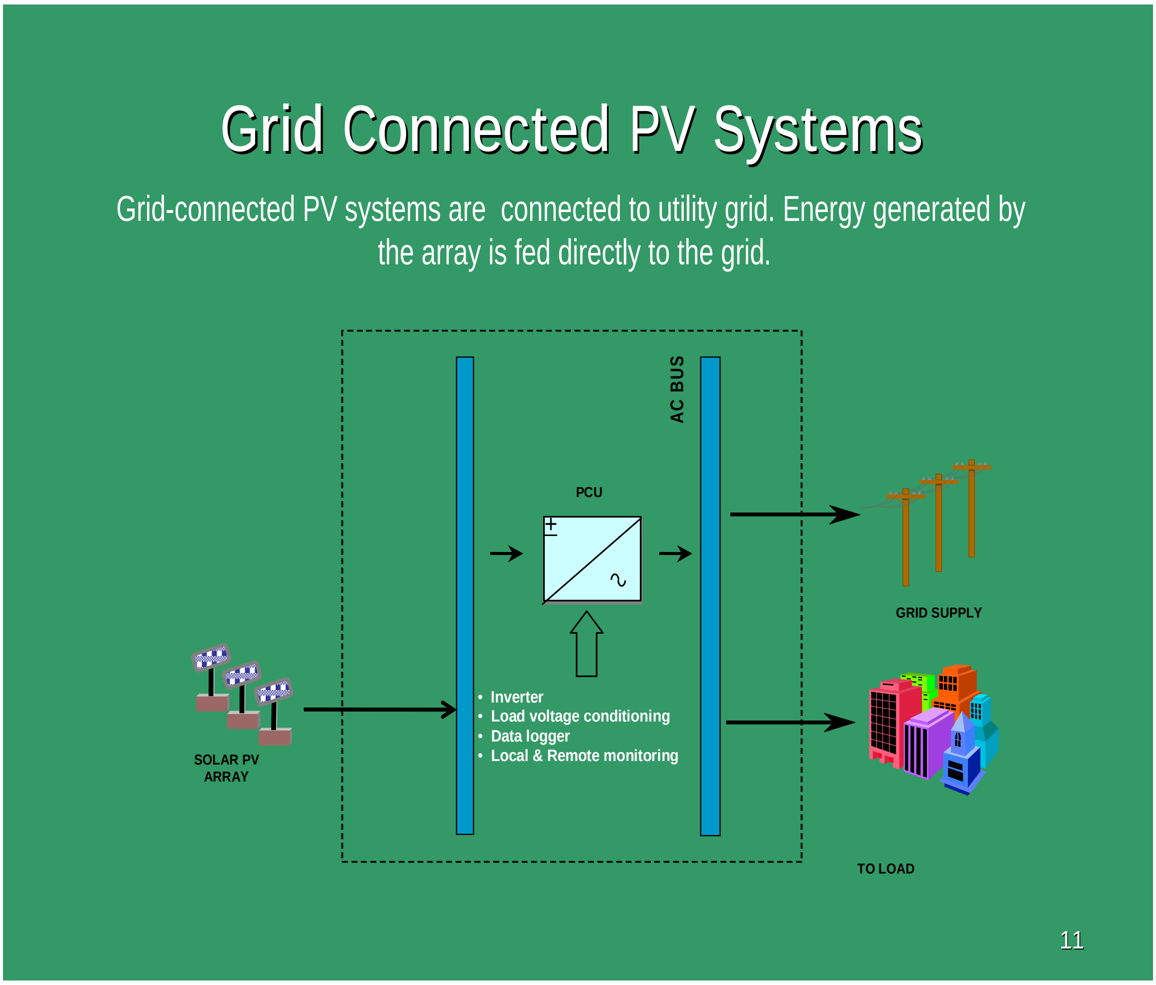
REPORT OF SUBGROUP-I
ON
GRID INTERACTIVE
ROOFTOP SOLAR PV SYSTEM



Central Electricity Authority
New Delhi
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C O N T E N T S

LIST OF ANNEXURES AND EXHIBITS TO REPORT OF SUBGROUP-I

A. ANNEXURES:

B. EXHIBITS:

EXECUTIVE SUMMARY

1. A Task force was constituted by MNRE under the chairmanship of Chairperson, CEA to look into the technical issues related to feasibility of the integration of solar power plant with thermal/hydro and interconnectivity of rooftop solar PV system with the grid. This task force in its meeting held on 18-06-2009 constituted a Subgroup-I to look into metering and interconnectivity of roof top solar PV system with the grid. The Subgroup-I comprised of the following members.

   i) Shri SM Dhiman, Member(GO&D), CEA -Chairman
   ii) Shri Puneet Goel, Director, Ministry of Power
   iii) Shri MK Raina, ED, NHPC
   iv) Shri Jitendra Sood, Energy Economist, BEE
   v) Shri CVSN Murthy, AGM, BHEL, Bangalore.
   vi) Shri SK Sangal, ED, CEL
   vii) Shri S Ramesh, Chief Engineer, KPCL
   viii) Shri Vivek Singla, GM, NDPL
   ix) Shri Alok Gupta, Chief Engineer(DP&D), CEA-Member Secretary

2. The sub-group met on 15th July, 2009 in CEA and deliberated upon the metering and interconnectivity issues.

3. The report is prepared with an aim to provide ready solutions for roof top solar PV systems for commercial, industrial and residential complex installations and individual consumer houses to feed full or part of the house load. However these can be extended for non-roof top solar photovoltaic systems as well.

4. The following type of modules of grid interactive roof top Solar PV system have been considered by the sub-group for various applications depending upon grid supply availability and the redundancy the consumer needs.

S.No	Exhibits	Description
1	Exhibit-I	Grid interactive Solar PV System without Battery.
2	Exhibit-II	Grid interactive Solar PV System with full load Battery backup.
3	Exhibit -III	Grid interactive Solar PV System with Partial load Battery backup
4	Exhibit -IV	Grid Interactive Solar PV System With Full Load DG Backup
5	Exhibit -V	Grid Interactive Solar PV System With Partial Load DG Backup
6	Exhibit -VI	Grid Interactive Solar PV System With Full Load Battery and DG Backup
7	Exhibit -VII	Grid Interactive Solar PV System With Partial Load Battery and DG Backup

5. The report covers equipment to be used, functional description, type of schemes metering arrangements, software and control requirements, selection of cables, earthing requirements, technical particular of meters, schematic diagrams, voltage levels, power quality issues such as harmonics , ripples, compliance to regulations, capacity, area coverage, implementation mechanism, islanding protection, etc. The report also gives the bill of material for typical ratings from few kW to 50kW systems as also a model technical specification (volume-II) which can be readily used by DISCOM/consumer.

6. The various types of metering and tariff philosophies prevalent in the world were studied by the Sub-group. It is gathered that under solar power mission Generation Based Incentive(GBI) based on entire solar generation is being considered irrespective of what consumer consumes. This generation would be treated as deemed export to the grid.

7. The report also indicates a sample calculation to arrive at the capacity of the roof top solar PV system, battery and inverter.

8. A group comprising of officers from CEA, BHEL and NHPC has been entrusted the task of preparing a feasibility report and identifying sites for installation of solar PV plant at Leh and Kargil. Feasibility report is under preparation and shall be submitted separately.

9. The Sub-group has also prepared a detailed project report for roof top solar system to be installed at CEA’s headquarters at Sewa Bhawan, RK Puram, New Delhi as a demonstration project which is also enclosed along with Technical Specifications of Grid interactive Rooftop Solar PV system for some project. The DPR and the Technical specification could also be used for similar solar PV rooftop systems.

REPORT OF SUB GROUP -I
ON
GRID INTERACTIVE ROOFTOP SOLAR PV SYSTEM

1 BACKGROUND:

1.1 Several cities and towns in the country are experiencing a substantial growth in their peak electricity demand. Municipal Corporations and the electricity utilities are finding it difficult to cope with this rapid rise in demand and as a result most of the cities/towns are facing severe electricity shortages. Various industries and commercial establishments e.g. Malls, Hotels, Hospitals, Nursing homes, etc., housing complexes developed by the builders and developers in cities and towns use diesel generators for back-up power even during the day time. These generators capacities vary from a few kilowatts to a couple of MWs. Generally, in a single establishment more than one generators are installed; one to cater the minimum load required for lighting and computers and other emergency operations during load shedding and the others for running ACs and other operations such as lifts and other power applications. Under such conditions use of grid interactive roof top Solar Photovoltaic systems seem to be feasible solutions. Similar solar PV system can be employed in rural areas on vacant land to feed cluster of households where space is not a constraint and grid connectivity is not feasible as on today. The implementation of standalone system in such rural areas would give an opening to setting up of small scale industries.

1.2 In order to supplement ambitious capacity addition programme of Government of India solar power is being encouraged in our country. This will also reduce green house gas emission. The National Solar Mission envisages solar generation capacity addition of 20000 MW by the year 2020.

1.3 The main objective of installing solar photovoltaic device system in urban areas, industries and rural areas will be as follows:-

a To reduce the burden on conventional electricity in cities/towns facing shortage of power.

b To provide access to electricity to all rural households especially where grid connectivity is not a cost effective solution.

c To create awareness and demonstrate effective alternate solutions for community/institutional solar based systems in urban areas and industry.

d To save highly subsidized diesel in institutions and other commercial establishments including industry facing huge power cuts especially during day time.

e To reduce the burden on depleting fossil fuel resources such as coal and to reduce carbon emission.

f To provide a clean and environment friendly energy generation.

1.4 Accordingly a task force was constituted by MNRE under the chairmanship of Chairperson, CEA, to examine the technical issues related to feasibility of integrating solar power plants with thermal/hydro power plant and interconnectivity of solar rooftop system with the grid. The task force comprises of members from CEA, Ministry of Power, Ministry of Environment and Forest, MNRE, BEE, NTPC, NHPC, BHEL, CEL, RCEL, RRVUNL, GEDA. The first meeting of the task force was held on 18th June, 2009 at CEA office, New Delhi. During the meeting three sub-groups were formed to look into interconnectivity of solar rooftop system with the grid, integration of solar power plant with the existing thermal power plant and integration of solar power plant with the existing hydro plant.

2 CONSTITUTION OF SUB-GROUP-I:

2.1 The constitution of Subgroup-I on Grid Interactive Roof Top Solar PV System: is as follows:-

i. Shri SM Dhiman, Member(GO&D), CEA-Chairman
ii. Shri Puneet Goel, Director, Ministry of Power
iii. Shri MK Raina, ED, NHPC
iv. Shri Jitendra Sood, Energy Economist, BEE
v. Shri CVSN Murthy, AGM, BHEL, Bangalore.
vi. Shri SK Sangal, ED, CEL
vii. Shri S Ramesh, Chief Engineer, KPCL
viii. Shri Vivek Singla, GM, NDPL
ix. Shri Alok Gupta, Chief Engineer(DP&D), CEA-Member Secretary

3 TERM OF REFERENCE OF SUBGROUP-I:

3.1 To bring out guidelines on interconnection of roof top solar PV system one each for a commercial building and an independent house to the grid which shall include scheme, bill of material, specification, metering and safety aspects.

3.2 To look at voltage, frequency, harmonics, reliability, islanding and other related issues with regard to solar generation.

3.3 To prepare a Feasibility Report for installing solar plant in Leh and at CEA's Headquarters at Sewa Bhawan, New Delhi.

4 PROCEEDINGS OF SUB-GROUP-I:

4.1 The First meeting of the Subgroup-1 was held on 15th July 2009 in CEA office. The Minutes of first meeting of the Sub-Group I held during the meeting are enclosed at **Annexure-I.** The draft report prepared was also circulated to various members of subgroup as also to members of task force. The comments received were considered and discussed in the meeting of the Task Force held on 29.10.09 and report was finalized accordingly.

5 SCOPE:

5.1 These guidelines are prepared with an aim to provide an insight of the solar photo voltaic system for roof top systems for commercial, industrial and residential complex installations and individual consumer houses to feed full or part of the house load. However these can be extended for non-roof top solar photovoltaic systems as well. These guidelines, however, do not provide a comprehensive technical specification on photovoltaic systems.

5.2 These guidelines cover type of PV system to be used, functional description, connectivity, equipment used, harmonics, schematic diagrams, voltage levels, compliance to regulations, capacity, area coverage, implementation mechanism, islanding protection, safety and reliability etc

6 TYPE OF TECHNOLOGY FOR SOLAR CELLS:

6.1 The solar PV system shall be designed with either mono/ poly crystalline silicon modules or using thin film photovoltaic cells or any other superior technology having higher efficiency.

6.2 Three key elements in a solar cell form the basis of their manufacturing technology. The first is the semiconductor, which absorbs light and converts it into electron-hole pairs. The second is the semiconductor junction, which separates the photo-generated carriers (electrons and holes), and the third is the contacts on the front and back of the cell that allow the current to flow to the external circuit. The two main categories of technology are defined by the choice of the semiconductor: either **crystalline silicon** in a wafer form or **thin films** of other materials.

6.3 Crystalline Technology

a Crystalline silicon (c-Si) has been used as the light-absorbing semiconductor in most solar cells, even though it is a relatively poor absorber of light and requires a considerable thickness (several hundred microns) of material. Nevertheless, it has proved convenient because it yields stable solar cells with good efficiencies and uses process technology developed from the huge knowledge base of the industry.

b Two types of crystalline silicon are used in industry. The first is **mono crystalline**, produced by slicing wafers (up to 150mm diameter and 350 microns thick) from a high-purity single crystal boule.

c The second is **multi crystalline** silicon, made by sawing a cast block of silicon first into bars and then wafers. The main trend in crystalline silicon cell manufacture is toward multi crystalline technology.

d For both mono- and multi crystalline Si, a semiconductor homo junction is formed by diffusing phosphorus (an n-type dopant) into the top surface of the boron doped (p-type) Si wafer. Screen-printed contacts are applied to the front and rear of the cell, with the front contact pattern specially designed to allow maximum light exposure of the Si material with minimum electrical (resistive) losses in the cell.

e The **most efficient production cells** use mono crystalline c-Si with laser grooved, buried grid contacts for maximum light absorption and current collection.

f Some companies are using technologies that by-pass some of the inefficiencies of the crystal growth/casting and wafer sawing route. One route is to grow a ribbon of silicon, either as a plain two-dimensional strip or as an octagonal column, by pulling it from a silicon melt. Another is to melt silicon powder on a cheap conducting substrate. These processes may bring with them other issues of lower growth/pulling rates and poorer uniformity and surface roughness.

6.4 Thin film Technology

a The selected materials are all strong light absorbers and only need to be about 1micron thick, so materials costs are significantly reduced. The most common materials are **amorphous silicon** (a-Si, still silicon, but in a different form), or the **polycrystalline materials**: **cadmium telluride** (CdTe) and **copper indium (gallium) diselenide** (CIS or CIGS).

b Each of these three is amenable to large area deposition (on to substrates of about 1 meter dimensions) and hence high volume manufacturing. The thin film semiconductor layers are deposited on to either coated glass or stainless steel sheet.

c The semiconductor junctions are formed in different ways, either as a p-i-n device in amorphous silicon, or as a hetero-junction (e.g. with a thin cadmium sulphide layer) for CdTe and CIS. A transparent conducting oxide layer (such as tin oxide) forms the front electrical contact of the cell, and a metal layer forms the rear contact.

d **Amorphous silicon** is the most well developed of the thin film technologies. In its simplest form, the cell structure has a single sequence of p-i-n layers. Such cells suffer from significant degradation in their power output (in the range 15-35%) when exposed to the sun.

e Better stability requires the use of thinner layers in order to increase the electric field strength across the material. However, this reduces light absorption and hence cell efficiency.

f This has led the industry to develop tandem and even triple layer devices that contain p-i-n cells stacked one on top of the other. In the cell at the base of the structure, a-Si is sometimes alloyed with germanium to reduce its band gap and further improve light absorption. All this added complexity has a downside though; the processes are more complex and process yields are likely to be lower.

g In order to build up a practically useful voltage from thin film cells, their manufacture usually includes a laser scribing sequence that enables the front and back of adjacent cells to be directly interconnected in series, with no need for further solder connection between cells.

h As before, thin film cells are laminated to produce a weather resistant and environmentally robust module. Although they are less efficient (production modules range from 5 to 8%), thin films are potentially cheaper than c-Si because of their lower materials costs and larger substrate size.

i However, some thin film materials have shown degradation of performance over time and stabilized efficiencies can be 15-35% lower than initial values. Many thin film technologies have demonstrated best cell efficiencies at research scale above 13%, and best prototype module efficiencies above 10%. The technology that is most successful in achieving **low manufacturing costs** in the long run is likely to be the one that can deliver the highest stable efficiencies (probably at least 10%) with the highest process yields.

j Amorphous silicon is the most well-developed thin film technology to-date and has an interesting avenue of further development through the use of "**microcrystalline**" silicon which seeks to combine the stable high efficiencies of crystalline Si technology with the simpler and cheaper large area deposition technology of amorphous silicon.

k However, conventional c-Si manufacturing technology has continued its steady improvement year by year and its production costs are still falling too.

l The emerging thin films technologies are starting to make significant in-roads in to grid connect markets, particularly in Germany, but crystalline technologies still dominate the market. Thin films have long held a **niche position** in low power (<50W) and consumer electronics applications, and may offer particular design options for building integrated applications.

6.5 It would be seen from the table given below that crystalline solar modules are costlier but much more efficient than thin film modules and therefore have 92% share in the market. Typical cost of solar cell technologies are as follows, however the cost are further coming down worldwide.

6.6 **Approximate cost of Technologies**

	Technology type	**Current conversion efficiency (%)**	**Manufacturing cost ($ per watt)**	**Market share (%)**
A.	**Crystalline silicon**			**92**
A.1	Mono crystalline	17-23	2.40	**-**
A-2	Poly crystalline	15-18	2.15	
B.	**Thin film**			**8**
B.1	Amorphous silicon	6	1.35	**-**
B.2	Tandem micro crystalline	8.5	1.35	**-**
B.3	Cadmium telluride	11	1.15	**-**
B.4	Copper indium gallium diselenide	12	1.75	**-**

(Source : Power line vol.13-No.8-April, 2009)

7 EQUIPMENTS REQUIRED FOR GRID INTERACTIVE ROOF TOP SOLAR PV SYSTEM:

7.1 The grid interactive roof top solar PV system generally comprises the following equipment.

a Solar PV Power Source

b Inverter
c Charge Controller (only with system with batteries)
d Grid Charger(only with system with batteries)
e Batteries(Optional)
f Mounting Structure
g Power and control Cables
h Earthing equipment /material
i Junction Boxes or combiners
j Instruments and protection equipments

7.2 The functions of inverter, Charge controller and Grid charger can be built in one unit called power conditioning unit (PCU). Similarly inverter and charger can also be built in one unit. All control logics are built in inverter or PCU.

8 FUNCTIONAL DESCRIPTION:

8.1 SOLAR PV POWER SOURCE

a Photovoltaic solar system use the light available from the sun to generate electricity and feed this into the main electricity grid or load as the case may be. The PV panels convert the light reaching them into DC power. The amount of power they produce is roughly proportional to the intensity and the angle of the light reaching them. They are therefore positioned to take maximum advantage of available sunlight within siting constraints. Maximum power is obtained when the panels are able to 'track' the sun's movements during the day and the various seasons. However, these tracking mechanisms tend to add a fair bit to the cost of the system, so a most of installations either have fixed panels or compromise by incorporating some limited manual adjustments, which take into account the different 'elevations' of the sun at various times of the year. The best elevations vary with the latitude of the load location.

b The power generating capacity of a photovoltaic system is denoted in Kilowatt peak (measured at standard test conditions of solar radiation of 1000 W per m^2). A common rule of thumb is that average power is equal to 20% of peak power, so that each peak kilowatt of solar array output power corresponds to energy production of 4.8 kWh per day (24 hours x 1 kW x 20% = 4.8 kWh)

c Solar photovoltaic modules can be developed in various combinations depending upon the requirements of the voltage and power output to be taken from the solar plant. No. of cells and modules may vary depending upon the manufacturer prudent practice.

d The capacity and rating of Roof top SPV Power Source will depend on the load to be fed by it. The basic building block of PV technology is the solar “cell”. Numbers of cells are wired in series to provide one PV “module”. Many modules are linked together to form a PV "array". Many arrays are then wired to form a solar PV system to give the desired output. Roof top PV modules are sold commercially in the range of 10 watts to 100 watts power output.

e For the purpose of grid interactive roof top solar PV system of 0.5kW to 50 kW considered in the report, two PV modules of 160 watts and 80 watts consisting of 72 cells and 36 cells respectively have been considered. These modules of sizes other than above are also available in the market and can be used. These modules can be connected in series parallel combination to form PV arrays and PV systems.

f As a rule of thumb, the roof top solar PV modules will cover a maximum area in the range of $8m^2$ to $18m^2$ per kWp depending on the type of technology used and also depending upon the space available. The orientation would be generally towards south and inclination angle shall be the latitude of the location of the installation.

g The power delivered by an SPV power source will depend on PV module rating and isolation level of the location and environmental factors like dust, wind, velocity and temperature of the location. Knowing the rating of the SPV system (power source) only vis-a-vis load does not guarantee the deliverance of full power of the load. Some of the features of SPV technology & environmental factors which influence the performance of the power source are I-V Curve, Voltage of the SPV power source, Irradiance or light intensity, Temperature of the cells, Response of the light spectrum, and Orientation of the panel/array, Full Sun hours or Isolation /day. (isolation is a measure of solar radiation energy received on a given surface area in a given time. It is commonly expressed In the case of photovoltaic it is commonly measured as $kWh/(kW_p{\cdot}y)$ (kilowatt hours per year per kilowatt peak rating).

h With a view to encourage technology development and reduction in the cost of the PV power plant projects, the PV power project developers shall make effort to utilize the state of the art technology to set up the plants. They are expected to use large capacity and higher power output PV modules available for the specific technology used in setting up the power plant.

i **I-V Curve** The suppliers of the SPV power source shall provide the I-V Curve at standard condition of $1000W/m^2$ solar intensity at 25 Degree Centigrade and Air Mass (thickness of the atmosphere)) of 1.5. By looking at the I-V curve it shall be possible to know about the optimum power to be delivered by the SPV panel/array/source. In addition the peak hour behavior of current and voltage can also be estimated from the curve. A module which is rated at 17 volts will produce less than its rated power when used in a battery system. This is because the working voltage will be between 12 and 15 volts. As wattage (power) is the product of volts times amps, the module output will be reduced. For example: a 50 watt module working at 13.0 volts will produce

39.0 watts (13.0 volts x 3.0 amps = 39.0 watts).This is important to remember when sizing a PV system. An I-V curve is simply all of a module's possible operating points, (voltage/current combinations) at a given cell temperature and light.

j **SPV Voltage:** The voltage of the SPV power source is an important factor that affects the battery charging in case of system with battery. The voltage of the SPV Cell/Module/Panel decreases with the rise of its temperature, which increases or decreases @ 0.0024V/cell/degree Celsius. To charge a battery fully the voltage of the power source shall be better than 2.5V/cell. Considering this fact, the Voltage of the SPV panel at optimum power shall be such that the voltage delivered by it at the battery terminals shall be about 2.25V/cell.

k **Irradiance or Light intensity:** In actual field condition the irradiance may be different than the standard irradiance. The SPV modules or panels are designed at a standard irradiance of 1000 watts per meter square at 25° Celsius and AM (air mass) 1.5, which is called "ONE SUN" or peak irradiance. The current delivered by the SPV power source will decrease or increase but there would be no variation in the system voltage.

l Solar PV modules shall comply with the requirement of Bureau of Indian Standards (BIS) or IEC 61215 or other international standards and MNRE approved test centers.

m The PV power project developers are required to optimize generation of electricity in terms of kWh generated per kWp of PV capacity installed vis-à-vis available solar radiation at the site. This may be achieved through use of efficient electronics, lower cable losses, maximization of power transfer from PV modules to electronics and the grid, and by enhancing incident radiation by optional methods like seasonally changing tilt angles, etc.

n Before installing the PV solar system it shall be ensured that sun path is clear and not shaded by trees, roof gables, chimneys, buildings or other features of home such as cable antenna and the surrounding landscape. Roof top must be shake proof, flat concrete tiles and mission tiles roof.

o As a rule of thumb 15% generation may be deducted if system is to be located within 50 km. of the coast and 7% may be deducted if PV system is located in valley regions subject to fog conditions.

p Ideally, grid interactive systems do not require battery back up as the grid acts as the back-up for absorbing excess solar power and feeding the customer load in case of shortfall. However, to enhance the performance reliability of the overall systems, a minimum battery-back of one hr of load capacity could also be considered where grid supply is not reliable and erratic.

8.2 **INVERTER**

a The DC power produced is fed to inverter for conversion into AC. In a grid interactive system AC power is fed to the grid at 11 KV three phase systems or to a 415V three phases or 220/240 V single phase system line depending on the system installed at institution/commercial establishment or residential complex or single house consumer and load requirement. Power generated from the solar system during the daytime is utilized fully by powering the captive loads and feeding excess power to the grid as long as grid is available. In cases, where solar power is not sufficient due to cloud cover etc. the captive loads are served by drawing power from the grid. The inverter should always give preference to the Solar Power and will use Grid/DG power only when the Solar Power is insufficient to meet the load requirement.

b The output of the inverter must synchronize automatically its AC output to the exact AC voltage and frequency of the grid.

c In a solar PV system without battery or with battery the inverter continuously monitors the condition of the grid and in the event of grid failure; the inverter automatically switches to off-grid supply within 20 to 50 milliseconds. The solar system is resynchronized with the grid within two minutes after the restoration of grid. Grid voltage is continuously monitored and in the event of voltage going below a preset value and above a preset value, the solar system shall be disconnected from the grid within the set time. Both over voltage and under voltage relays shall have adjustable voltage (50% to 130%) and time settings (0 to 5 seconds).

d Over-voltage protection shall be provided by using Metal Oxide Varistors (MOVs) on DC and AC side the inverter.

e The inverter shall be so designed so as to operate the PV system near its maximum Power Point (MPP), the operating point where the combined values of the current and voltage of the solar modules result in a maximum power output.

f The inverter shall be a true sine wave inverter for a grid interactive PV system.

g In case of system with battery, inverter also monitors the, state of Battery Voltage, and performs switching operations to ensure that battery is charged continuously.

h The degree of protection of the indoor inverter panel shall be at least IP 31 and that of outdoor at least IP-55

8.3 CHARGE CONTROLLER

a Normally in a solar PV system with battery, battery is first charged from solar system through Charge Controller. A charge controller monitors the battery's state-of-charge to ensure that when the battery needs charge-current it gets it, and also ensures the battery isn't over-charged. Connecting a solar panel to a battery without a regulator seriously risks damaging the battery and potentially causing a safety concern.

b Charge controllers (or often called charge regulator) are rated based on the amount of amperage they can process from a solar array. If a controller is rated at 20 amps it means that you can connect up to 20 amps of solar panel output current to this one controller. The most advanced charge controllers utilize a charging principal referred to as Pulse-Width-Modulation (PWM) - which insures the most efficient battery charging and extends the life of the battery. Even more advanced controllers also include Maximum Power Point Tracking (MPPT) which maximizes the amount of current going into the battery from the solar array by lowering the panel's output voltage, which increases the charging amps to the battery - because if a panel can produce 60 watts with 17.2 volts and **3.5** amps, then if the voltage is lowered to say 14 volts then the amperage increases to **4.28** (14v X 4.28 amps = 60 watts) resulting in a 19% increase in charging amps for this example.

c Many charge controllers also offer Low Voltage Disconnect (LVD) and Battery Temperature Compensation (BTC) as an optional feature. The LVD feature permits connecting loads to the LVD terminals which are then voltage sensitive. If the battery voltage drops too far the loads are disconnected - preventing potential damage to both the battery and the loads. BTC adjusts the charge rate based on the temperature of the battery since batteries are sensitive to temperature variations above and below about 75 F degrees.

8.4 GRID CHARGER

In a grid interactive solar PV system with battery, a grid charger can also provided which charges the battery taking AC power from the Grid/DG in case solar power is not sufficient to charge the battery or battery voltage is very low. This may happen during the continuous cloudy days.

8.5 BATTERIES

In the technical specifications and DPR for Sewa Bhavan, battery system is not considered in view of reliability of grid power supply and has been kept as optional item. In case battery system is also envisaged generally low maintenance. Lead Acid batteries are provided wherever required. Generally, the batteries are provided are of 2V cells connected in series to reach the system voltage. Battery shall be suitable for charging from SPV system as well as from the grid in case of grid interactive system and with SPV system alone in case of stand alone system.

8.6 MOUNTING STRUCTURES:

a Hot dip galvanized iron mounting structures may be used for mounting the modules/ panels/arrays. These mounting structures must be suitable to mount the SPV modules/panels/arrays on the roof top, on the ground or on the poles/masts, at an angle of tilt with the horizontal in accordance with the latitude of the place of installation.

b The following may be ensured about the mounting structure :

i The Mounting structure shall be so designed to withstand the speed for the wind zone of the location where a PV system is proposed to be installed (Delhi-wind speed of 150 kM/ hour). It may be ensured that the design has been certified by a recognized Lab/ Institution in this regard.

ii The mounting structure steel shall be as per latest IS 2062: 1992 and galvanization of the mounting structure shall be in compliance of latest IS 4759.

8.7 POWER AND CONTROL CABLES:

a Power Cables of adequate rating shall be required for interconnection of :

- Modules/panels within array
- Array & Charge Controller
- Charge Controller & Battery
- Charge controller & Loads Including Inverter (if used) & between load & inverter.

b The cable shall be 1.1 grade, heavy duty, stranded copper/aluminium conductor, PVC type A insulated, galvanized steel wire/strip armoured, flame retardant low smoke (FRLS) extruded PVC type ST-1 outer sheathed. The cables shall, in general conform to IS-1554 P+I & other relevant standards.

c The minimum size of 11 kV power cables shall be chosen taking into account Fault level contribution to the system and full load current. However, power cables size for 415 V systems shall be chosen taking into account the full load current & voltage drop. The allowable voltage drop at terminal of the connected equipment shall be max. 2.5% at full load. The derating factors viz. group duration of temp. duration shall also be considered while choosing the conductor size.

d Control Cables

i. The cable shall be 1.1 grades, heavy duty, stranded copper conductor, PVC type A insulated, galvanized steel wire/strip armoured, flame retardant low smoke (FRLS) extruded PVC type ST-1 outer sheathed. The cables shall, in general conform to IS-1554 P+I & other relevant standards.

ii. The permissible voltage drop from the SPV Generator to the Charge controller shall not be more than 2% of peak power voltage of the SPV power source (generating system). In the light of this fact the cross-sectional area of the cable chosen is such that the voltage drop introduced by it shall be within 2% of the system voltage at peak power.

iii. All connections should be properly terminated, soldered and/or sealed from outdoor and indoor elements. Relevant codes and operating manuals must be followed. Extensive wiring and terminations (connection points) for all PV components is needed along with electrical connection to lighting loads.

8.8 EARTHING EQUIPMENT/MATERIAL

a Earthing is essential for the protection of the equipment & manpower. Two main grounds used in the power equipments are :

- System earth
- Equipment earth

b System earth is earth which is used to ground one leg of the circuit. For example in AC circuits the Neutral is earthed while in DC supply +ve is earthed.

c In case of equipment earth all the non-current carrying metal parts are bonded together and connected to earth to prevent shock to the man power & also the protection of the equipment in case of any accidental contact.

d To prevent the damage due to lightning the one terminal of the lightning protection arrangement is also earthed. The provision for lightning & surge protection of the SPV power source & Charge controller is required to be made.

e In case the SPV Array can not be installed close to the equipment to be powered & a separate earth has been provided for SPV System, it shall be ensured that all the earths are bonded together to prevent the development of potential difference between ant two earths.

f Earth resistance shall not be more than 5 ohms. It shall be ensured that all the earths are bonded together to make them at the same potential.

g The earthing conductor shall be rated for the maximum short circuit current. & shall be 1.56 times the short circuit current. The area of cross-section shall not be less than 1.6 sq mm in any case.

8.9 JUNCTIONS BOXES OR COMBINERS

Dust, water and vermin proof junction boxes of adequate rating and adequate terminal facility made of fire resistant Plastic (FRP) shall be provided for wiring. Each solar shall be provided with fuses of adequate rating to protect the solar arrays from accidental short circuit.

8.10 INSTRUMENTS AND PROTECTION EQUIOPMENTS

Necessary equipments as per prudent practice shall be provided in addition to those specifically mentioned in this report.

9 REQUIREMENTS FOR CONNECTIVITY WITH THE GRID

9.1 TYPE OF SCHEMES AND CONNECTION ARRANGEMENTS:

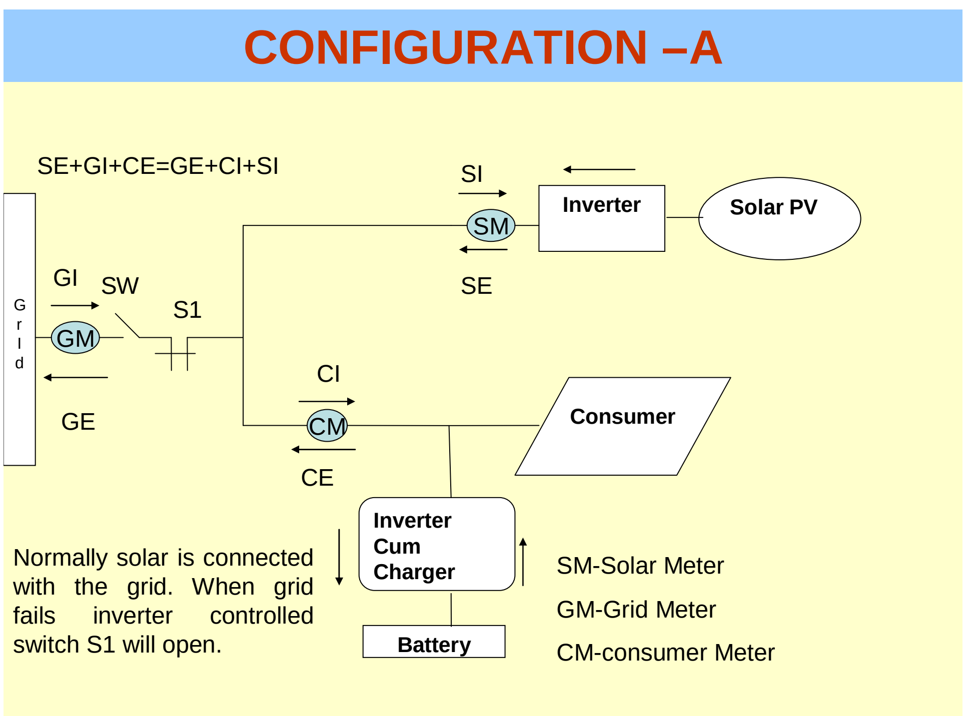
a The rooftop solar system can be a standalone system as well as grid interactive system. In this report the Sub-Group has considered only the grid interactive system. In the grid interactive system also there can be a number of schemes depending upon the reliability of supply the consumer needs.

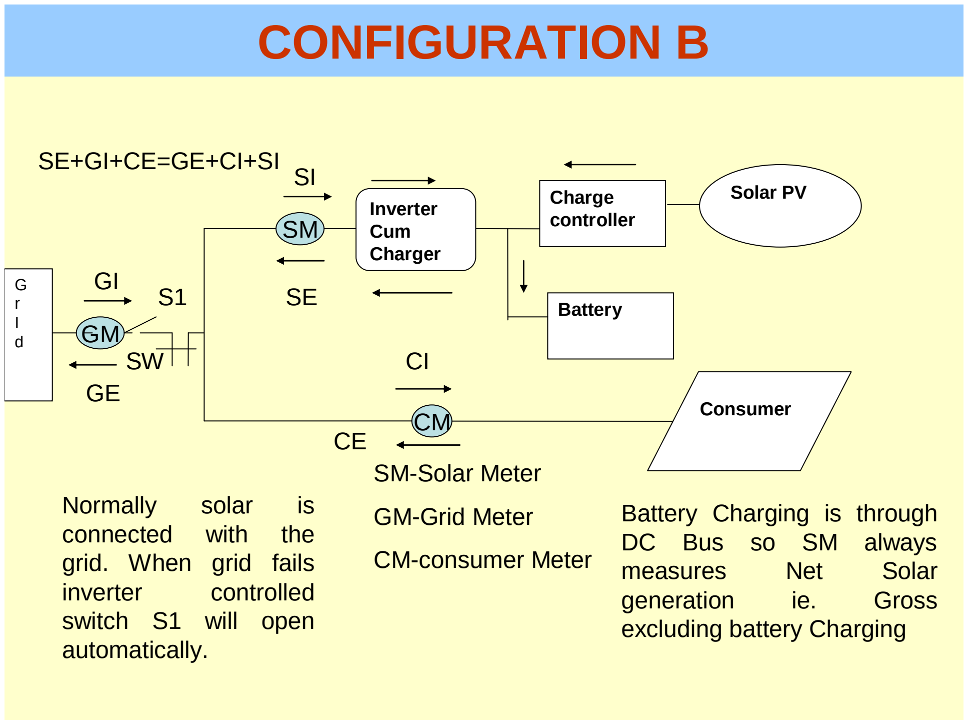
b Wherever the battery is not envisaged, the solar system can be directly connected to consumer AC bus and the total energy of the solar system will be supplied to consumer/grid depending upon the requirement of the consumer. The scheme for grid interactive rooftop solar system without battery system is shown in Scheme-I(Exhibit-I).

c In case where battery is also envisaged, the scheme of connection for solar PV system will depend upon the way the battery is charged. There are two possible ways of charging battery. First one is where there is AC coupling i.e. first the DC produced by solar is converted into AC and battery is connected through a charger which converts AC into DC. This arrangement is shown in **Configuration-A**. In this arrangement as long as grid is available the solar system, consumer, and battery system will be interactive up with grid. In case of grid failure solar system, battery system and consumer load would be disconnected form grid and solar will be connected to battery and AC loads through another route. This arrangement has been finalized with the premise that normally consumer and battery system will take supply from gird. This scheme is envisaged in Europe where feed in tariff is employed. However the only difference proposed here is regarding the positioning of the solar meter(SM). In the scheme in vogue in Europe for feed in tariff the SM is towards the grid side and does not record the energy drawn by the consumer /battery during grid failure. In the suggested scheme as per configuration-A, during grid failure also it measures the solar generation including the energy drawn by battery and the consumer load.

d In the second arrangement, solar system directly charges the battery through charge controller i.e. DC coupling (**Configuration-B).** In this arrangement the AC system is not involved to charge the battery and battery will always be connected to solar system. In case, battery is discharged due to any reason whatsoever solar system will first charge the battery and the excess generation from the solar will be fed into grid. This scheme would not reflect the true gross generation produced by the solar PV system and hence not considered.

e In case battery system is envisaged, it is proposed to adopt **Configuration A.**





f Based on above two configurations system without battery and system with battery (Configuration A) following schemes of grid interactive roof top Solar PV system has been considered by the sub-group for various applications depending upon grid supply availability and the redundancy that the consumer wants.

Sl No	Schemes	Description
1	Scheme-I	Grid interactive Solar PV System without Battery.
2	Scheme-II	Grid interactive Solar PV System with full load Battery backup.
3	Scheme-III	Grid interactive Solar PV System with Partial load Battery backup
4	Scheme-IV	Grid Interactive Solar PV System With Full Load DG Backup
5	Scheme-V	Grid Interactive Solar PV System With Partial Load DG Backup
6	Scheme-VI	Grid Interactive Solar PV System With Full Load Battery and DG Backup
7	Scheme-VII	Grid Interactive Solar PV System With Partial Load Battery and DG Backup

g The above schemes are briefly discussed

i. **Scheme-I : Grid interactive roof top solar PV system without battery**

This is a simplest scheme of the grid interactive rooftop solar system. In this arrangement inverter which is heart of the entire solar system continuously supervises the grid condition and in the event of grid failure or under voltage or over voltage, the solar system is disconnected by the circuit breaker /auto switch provided in the inverter. Since there is no back up in the solar system, it cannot supply the consumer load in the event of grid failure because the load is continuously varying in nature. **Block diagram of the scheme is shown in scheme-I (Exhibit-I)**

ii. **Scheme-II: Grid interactive roof top solar PV system with full load Battery back up.**

In this scheme when the grid is available consumer loads will be fed from grid side and solar system is connected to grid through its inverter. Solar is continuously feeding the grid. In this arrangement battery and inverter cum charger (which may be available in the consumer house) is also shown. The DC generated form solar is first converted to AC and than it is connected to other equipments/grid. When grid fails automatic disconnection from the grid side takes place and solar is connected to battery system and AC consumer load. **Block diagram of the scheme is shown in Scheme-II (Exhibit-II).**

iii. **Scheme-III: Grid interactive roof top solar PV system with partial load Battery back up**

Under this scheme also, the basic operation will be same as given in for scheme-II but bus splitting is necessary in the even of grid failure so as to supply critical loads as battery back up is not sufficient to feed the entire consumer load. In the event of grid failure or under voltage or over voltage, inverter will disconnect the grid supply as also the non-emergency loads. Solar and battery system shall be feeding emergency loads only. Battery system shall be charged if battery is not fully charged. **Block diagram of the scheme is shown in Scheme-III (Exhibit-III).**

iv. **Scheme-IV: Grid interactive roof top solar PV system with full load DG backup system**

All the equipment envisaged in the Scheme-I would be provided in this scheme as well, however, in addition there is second line of defense and DG set is also envisaged because in some parts of the country, the grid supply is not very reliable and is erratic. The operation of this scheme would be similar to scheme-I A but in addition provision is kept for consumer DG set. In case the failure of utility grid the solar PV system shall be disconnected form the grid and DG shall start. Once DG is started the solar system shall also be connected to the AC bus after synchronization with the DG set. DG set will be automatically disconnected in the event of grid supply is restored. **Block diagram of the scheme is shown in Scheme-IV(Exhibit-IV).**

v. **Scheme-V: Grid interactive roof top solar PV system with partial load DG Backup system**

Under this scheme also, the basic operation will be similar to that under Scheme-IV. Only AC bus segregation in the consumer premises would be necessary to supply critical loads during grid failure. **Block diagram of the scheme is shown in Scheme-V(Exhibit-V).**

vi. **Scheme-VI: Grid interactive roof top solar PV system with full load Battery and DG backup system**

In this arrangement solar PV system will remain connected with the utility grid as long as supply from the grid is available. In the event of supply failure or low voltage or over voltage solar system will be disconnected from the grid and DG system will start. Once the DG set is started and solar generation is possible the solar system shall be again connected to the system. In the event of restoration of grid supply the solar system shall be again connected to main grid. All the control operations shall be performed by the inverter connected to solar system. **Block diagram of the scheme is shown in Scheme-VI (Exhibit-VI).**

vii. **Scheme-VII :Grid interactive roof top solar PV system with partial load Battery and DG backup system**

The scheme will be similar to Scheme-VI. Only AC load segregation will be done in case of grid failure. **Block diagram of the scheme is shown in Scheme-VII (Exhibit-VII).**

h In Europe where feed into tariff based the system is envisaged, the first scheme is more popular. In USA and Canada the metering arrangement is based on net metering and the second scheme is generally envisaged **The Committee has suggested that we should adopt. Configuration – A where battery system is envisaged.**

i The above schemes have been considered with the premise that solar system is installed by individual consumer. There can be a case where solar company or a service provider implements a solar system and makes contract with the distribution utility and supplies number of consumers. In that case solar system shall be connected to utility bus instead of consumer bus. The connection point shall be utility bus. The metering arrangement for the same will be similar otherwise.

j The control scheme for sequence of operations of various equipments is a matter of detail engineering and can be prepared in consultation with the supplier of the solar PV module and inverter.

k The DG and its associated equipments shall not in scope of supplier ,however in case DG system is envisaged by the consumer necessary hardware and controls to disconnect and connect DG set shall be provided in inverter and wiring shall be done by the solar PV supplier.

l Block diagram has been made to illustrate the connection diagram and metering arrangement and does not show all wires, breakers, fuses, disconnecting switches and lightening arrestors which are required to be provided for safe and efficient operation by supplier of PV system.

9.2 METERING PHILOSOPHY AND REQUIRENTS

a Metering is required to measure the following energy transactions besides measurement of DC battery voltages, DC current, AC system voltages and currents , frequency etc

i. Solar Gross Generation
ii. Consumer load consumption
iii. Export of energy to the Grid
iv. Import of energy from the Grid
v. Export from DG to Grid

b There are two basic philosophies of metering prevalent in the world when utility grid is connected with solar generating source and feed the load.

- Net metering or Market rate net metering
- Feed in tariff metering

c Net Metering:

i. Net metering is an electricity policy for consumers who own (generally small) renewable energy facilities, such as wind, solar power or home fuel cells. Net metering means measurement of net energy consumption by the load from a system. If a consumer load is connected to two generating sources and one is infinite grid and other is a small generating source such as solar described above their may be following options depending upon the size of the small source and time of use

ii. Generated power by the small source is in excess of the load at a particular moment. In this case surplus power from this source will be fed into the grid if it is a grid interactive system.

iii. Generated power by the small source is less than the power required by the load. In this case the extra power to meet the consumer load will be taken from grid.

iv. At the end of month the billing of the consumer by the distribution company is done based on the net energy import from the grid. Under net metering, a distribution company receives credit for net energy supplied to the consumer load in case it is import and pays to the developer of the small source if there is net export to the grid.

v. In this case the tariff has to be same for export as well as import of energy as the billing is done on net energy basis.

vi. In some parts of USA and Canada, credit for the export is adjusted on predefined period of say six months or year and adjusted in running bills. No incentive is given for net export beyond the defined period. However it is learnt that gradually they are also shifting towards feed in tariff.

d **Feed in tariff Metering**

i. It is a different method of providing power to the electricity grid that does not offer the price symmetry of net metering, making this system a lot less profitable for home users of small renewable energy systems.

ii. Under this arrangement, practice is to have two uni-directional meters are installed—one records electricity drawn from the grid and the other records excess electricity generated and fed back into the grid. The above functionality can also be achieved with having one meter having separate export and import recording registers.

iii. The user pays retail rate for the electricity they use, and the power provider purchases their excess generation at its avoided cost (wholesale rate). There may be a significant difference between the retail rate the user pays and the power provider's avoided cost.

iv. Germany and Spain, on the other hand, have adopted a price schedule, or Feed-in Tariff (FIT), whereby customers get paid for any electricity they generate from renewable energy on their premises. The actual electricity being generated is counted on a separate meter, not just the surplus they feed back to the grid.

v. In Germany, for the solar power generated, a feed-in tariff of more than 3 times the retail rate per kWh for residential customers is being paid in order to boost solar power (figure from 2006). Wind energy, in contrast, only receives around a third of the retail rate because the German system pays what each source costs.

vi. Feed in tariff is in vogue except in some parts of USA and Canada

e Metering arrangement in Indian Context:

i. The various type of metering and tariff philosophies prevalent in the world were studied by the group and it was considered that Generation Based Incentive (GBI) based on entire solar generation would be appropriate to encourage consumer to implement roof top solar PV systems. Under this arrangement, both on the solar power consumed by the operator and solar power fed into the grid feed in tariff be provided. The two inverter based scheme (Configuration A) as described above is recommended for systems where battery is envisaged as in configuration-B the solar meter(export) measures net generation i.e. gross generation minus battery charging by solar. In cases where battery is not envisaged the scheme-I would be applicable.

ii. Suggested metering scheme for solar PV systems is shown in block diagram of each schemes annexed herewith. Meters would have to install as per above.

iii. Metering scheme indicated herewith is only for guideline purpose and applicable scheme would be as per the metering scheme finalised by the appropriate Electricity Regulatory Commission.

iv. Metering requirements shall be as per Regulations on “Installation and Operation of Meters“.

v. If the tariff is different for different time slots in a day, the Time of Use metering arrangement would be required to be provided and facility for recording export and import in the meter for each time slot shall be required.

vi. Technical particulars of meters are given in **Annexure-II**.

9.3 VOLTAGE LEVELS:

a Though rooftop systems shall be generally connected on LV supply, large solar PV system may have to be connected to 11 kV system. Following criteria have been suggested for selection of voltage level in the distribution system for ready reference of the solar suppliers.

i. Up to 10 KW PV system supply Low Voltage single phase supply shall be provided.
ii. Thereafter up to a level of 100 kW PV system, three phases low voltage supply shall be provided.
iii. In case load is more than 100 kW and does not exceed 1.5 MW, SPV system connection can be made at 11 kV level.
iv. In case load is more than 1.5 MW PV system and does not exceed 5 MW, SPV system connection can be made at 11kV/33 kV/66kv level or as per the site condition.

b Utilities may have voltage levels other than above, DISCOMS may be consulted before finalization of the voltage level and specification be made accordingly.

c The voltage variation in various power supply systems shall be ±10%

d The solar PV system for above 11 kV systems is not considered in these guidelines because the same may not be feasible on roof top due to space limitation and operational problems.

e In the roof top solar system, the grid interconnection is generally made to low voltage single phase or three phase system. For large PV system for commercial installation having large load, the solar power can be generated at low voltage levels and stepped up to 11 kV level through the step up transformer. The transformers and associated switchgear would require to be provided by the SPV supplier.

9.4 COMPLIANCE TO REGULATIONS ON METERING AND GRID CONNECTIVITY:

CEA has notified regulations on “Installation and Operation of Meters”, grid connectivity and technical standards of grid connectivity which stipulates the various technical requirements such as accuracy class of meters, level of harmonics and other requirements. The developer of solar power shall ensure that requirement of these Regulations shall be complied with. Non-compliance to these regulations will be dealt with requisite provisions of the ACT.

9.5 POWER QUALITY REQUIREMENTS:

a DC INJECTION INTO GRID:

i. The injection of DC power into the grid shall be avoided by using an isolation transformer at the output of the inverter.

ii. Various standards and guidelines define the maximum DC component that feed-in electricity from grid-feeding inverters may possess. The following is the practice followed by few countries.

Standard designated as:	**Standard applicable in:**	**threshold values**
IEC 61727	Thailand	1% (of rated AC current)
IEEE 1547	USA	0.5% (of rated AC current)
EN 50438	Europe	Not specified
IEEE 929	Thailand (until 2008)	0.5% (of rated AC current)
UL 1741	USA	0.5% (of rated AC current)
AS 4777	Australia	0.5% (of rated AC current)
VDE 0126-1-1	Germany	1 A
Synergrid C10/11	Belgium	1% (of rated AC current)
DK5940	Italy	0.5% (of rated AC current)
G83	United Kingdom	20 mA (recommended)

iii. BIS are aligned to IEC standards as such it is suggested that IEC 61727 may be followed in Indian environment. It is also proposed by the committee that CEA may approach BIS to develop standards for solar systems covering power quality requirements for solar systems.

b RIPPLE CONTENT ON DC SIDE

i. The most common meaning of ripple in electrical science, is the small unwanted residual periodic variation of the direct current (dc) output of a power supply which has been derived from an alternating current (ac) source. This ripple is due to incomplete suppression of the alternating waveform within the power supply.

ii. PV modules shall produces Pure DC Voltage and Current without any ripple. The inverter operation will influence the voltage on the DC side, so will have a backlash on the PV generator voltage. Depending on the inverter topology and with or without transformer, the ripple on the DC side may appear very different. Even an old style transformer inverter has some very low AC 2x50Hz ripple on the DC side. That's due to the energy flow in the inverter.

iii. A transformer-less inverter has no galvanic separation between AC and DC side. The voltage to ground is influenced by AC and depending on the topology of the inverter even full AC sin wave on the DC side (on top of DC voltage level - measured to earth) or for other topologies, there will be no AC ripple on DC side.

iv. There is no standard available for ripple control, it is proposed that the ripple content must not exceed 3% based on products literature.

c **HARMONICS ON AC SIDE:**

i. Harmonic distortion is caused principally by non-linear load such as rectifiers and arc furnaces and can affect the operation of a supply system and can cause overloading of equipments such as capacitors, or even resonance with the system leading to overstressing (excessive voltage & current). Other effects are interference with telephone circuits and broadcasting, metering errors, overheating of rotating machines due to increased iron losses (eddy current effects), overheating of delta connected winding of transformer due to excessive third harmonics or excessive exciting current.

ii. The limits for harmonics shall be as stipulated in the CEA Technical standards On Grid Connectivity which are as follows:

- Total Voltage harmonic Distortion= 5%
- Individual Voltage harmonics Distortion=3%
- Total Current harmonic Distortion=8%

iii. Utilities must procure sufficient number of harmonic measuring instruments for carrying out measurements at regular intervals near the source of harmonics generation.

d **VOLTAGE UNBALANCE**

The Voltage Unbalance at 33 kV and above shall not exceed 3.0%

e **VOLTAGE FLUCTUATIONS**

(i)The permissible limit of voltage fluctuation for step changes which may occur repetitively is 1.5%.

(ii)For occasional fluctuations other than step changes the maximum permissible limits is 3%.

(iii) The limits prescribed in (i) and (ii) above shall come into force not later than five years from the date of publication of these regulations in the Official Gazette.

9.6 **COMMUNICATION INTERFACE:**

a The communication must be able to support

- Real time data logging
- Event logging
- Supervisory control
- Operational modes
- Set point editing

b The following parameters shall also be measured and displayed continuously.

- Solar system temperature
- Ambient temperature
- Solar irradiation/isolation
- DC current and Voltages
- DC injection into the grid (one time measurement at the time of installation)
- Efficiency of the inverter
- Solar system efficiency
- Display of I-V curve of the solar system
- Any other parameter considered necessary by supplier of the solar PV system based on prudent practice.

c Data logger system must record these parameters for study of effect of various environmental & grid parameters on energy generated by the solar system and various analysis would be required to be provided through bar charts, curves, tables, which shall be finalized during approval of drawings.

d The communication interface shall be an integral part of inverter and shall be suitable to be connected to local computer and also remotely via the Web using either a standard modem or a GSM / WIFI modem.

e The bidder must supply all the required hardware to have this web based SCADA operational such that the system can be monitored via the web from distribution company office. Full fledged SCADA is recommended for Solar PV plants above 25 kW.

9.7 PROTECTIONS AND CONTROL

a In addition to disconnection from the grid (islanding protection) on no supply, under and over voltage conditions , PV systems shall be provided with adequate rating fuses, fuses on inverter input side (DC) as well as output side (AC) side for overload and short circuit protection and disconnecting switches to isolate the DC and AC system for maintenance.

b Fuses of adequate rating shall also be provided in each solar array module to protect them against short circuit.

c There could always be possibility of something being wrong with the automatic disconnection system of the invertor and it continues to put electricity to the grid in the event of grid failure or the planned shutdown of the distribution feeder by the distribution company. In such case to avoid any accident, a manual disconnect switch beside automatic disconnection to grid would have to be provided to isolate the grid connection by the utility personnel to carry out any maintenance. This switch shall be locked by the utility personnel during the planned shutdown of the utility's feeder. Locking of the switch may be required only under shutdown.

d Following protections shall also be provided to ensure safe and efficient operation and shall include the following:

- Avoiding Battery overcharging (in case of SPV system with battery)
- Avoiding Battery over discharge(in case of SPV system with battery)
- Battery over load protection(in case of SPV system with battery)
- Ground fault protection system.
- Any other protection as per manufacturer's prudent practice for safe and efficient protection.

10 ACCEPTANCE OF SYSTEMS AND PERFORMANCE EVALUATION

a The installer must verify that the system has been installed according to the manufacturer's procedures. A checkout procedure should be developed to ensure an efficient and complete installation.

b A system can be checked with some common test equipment to verify proper installation and performance. A key to keeping the system testing simple is to do the tests on cloudless days. Clouds can cause fluctuations that confound evaluation of the results.

11 SYSTEM DOCUMENTATION:

It is essential that the owner have complete documentation on the system. System documentation should include an owner's manual and copies of relevant drawings for whatever system maintenance might be required in the future.

12 TECHNICAL PARTICULARS, SPECIFICATION AND BILL OF MATERIAL:

a Two PV modules are considered here one comprising cells forming a 160 watt module and another 80 watt module. Technical particular of module Type-160 (160 watts) and Module Type-80 (80 watts) are indicated in **Annexure-III**.

b Bill of material for suggested ratings (0.5kW to 100 kW) of Roof top PV system is indicated in **Annexure-IV.**

ANNEXURE-I

MINUTES OF THE FIRST MEETING OF SUB GROUP I – INTERCONNECTIVITY OF SOLAR PHOTO VOLTAIC ROOF TOP SYSTEMS WITH THE GRID HELD ON 15-07-2009.

First meeting of the Sub Group-I regarding Interconnectivity of Solar Photo Voltaic Roof Top System with the Grid was taken by Member (GO&D), CEA at 10.30 hours on 15th July, 2009 at CEA, Sewa Bhawan, R.K. Puram, New Delhi. List of participants is enclosed.

2. Member (GO&D), CEA, welcomed the participants to the meeting and stated that a National Solar Mission has been envisaged to ensure rapid and large scale diffusion of solar energy technologies in the country. National Solar Mission envisages setting up of grid inter active solar capacity of about 20,000 MW by 2020 & about 1 lakh MW by 2030. Among various applications, grid interactive Solar Power generation will be one of the important applications. A Task Force has been constituted under the Chairperson, CEA to examine inter-alia, technical issues relating to feasibility of integrating solar based plants with thermal/hydro electric power plants and connectivity of Solar rooftop systems and other Solar Plants with grid. In the first meeting of Task Force held on 18th June, 2009, three Sub Groups were constituted to look into various aspects related to setting up of solar power plants in India. The terms of reference of the Sub Group- I headed by Member (GO&D) CEA is to bring out guidelines on interconnection of Solar roof top system for the commercial and domestic buildings to the grid which would include scheme, bill of material, specification, metering as well as safety aspect. This Sub Group would also look at voltage, frequency, harmonics, reliability, islanding and other related issued with regard to solar generation. Member (GO&D), CEA has also been requested to prepare a feasibility report for installing solar plant in Leh & Ladakh Region.

4. Subsequently M/s. BHEL and M/s. CEL made presentations regarding their experience of setting up of Solar Power Plants in the country covering all aspects including manufacturing, installation and operation etc. During the presentation it was seen that M/s. BHEL has implemented solar PV System at the following places-

- Lakshadweep - aggregating capacity of 1 MWp at various islands (8x100 + 1x150 +2x50 KW)
- Andaman & Nicobar - (2x50 KW)
- Sunderaban (WB)- 490 kWp at six Islands & 55 kWp under progress,
- Ranchi - 620 kWp (2.2 to 5.5 kW packages fo tribal school & hostels)
- Punjab - 200 No. SPV each of 1800 Wp for water pumps
- Chattisgarh- 220 kWp village electrification system ranging from 1 to 6 kWp

- APTRANSCO- Vidyut Soudha-Hyderabad – 100 kWp

M/s. BHEL indicated that synchronization of SPV with grid needs to be with digital phased locked type to ensure continuous tracking and better loop response. Inverter output needs to be for larger window so far as voltage (330 V to 460 V, L-L) and frequency (47Hz to 52 Hz). M/s. BHEL indicated that meter must record both the export and import from the grid and has to be very accurate. It was indicated that output DC voltage can vary from 48 V DC to 800 V DC depending upon peak power rating of the array. The junction box for field cable termination needs to be IP 65 rated. The SCADA must be able to support

- Real time data logging
- Event logging
- Supervisory control
- Operational modes
- Set point editing

M/s. CEL in their presentation intimated that they have installed number of solar PV Plants both off and grid interactive of various capacities and they are pioneer in the implementation of solar PV system. They have got accredition from various agencies. M/s. CEL indicated that inverter efficiency of about 94% - 98% available in the market and Grid Interactive solar PV system must have the following features:

- Maximum power Point Tracking (MPPT)
- Balancing of 3 phases
- Automatic sleep mode operation at night to minimize unnecessary losses.
- On Board data logging & LCD DISPLAY
- Remote access facility via telephone network.

M/s. CEL also indicated scheme arrangement for 1 MW solar PV Plant which can generate 16 MU (16 million units) per year, improve the grid voltage and will meet the peak load as well. M/s CEL indicated that both bi-directional meter (1 meter) and unidirectional (2 meter) may be installed.

M/s. NDPL also shared their experience on their two solar plants one 14.85 KW and another 3.96 KW which they have installed in their training institute at CENPEID at Rithala. M/s. NDPL also intimated that they are planning to install 1 MW plant at Keshav Puram which is sent for DERC approval.

NDPL indicated that it intends to add 50 MW of grid interactive SPV Power Plants at consumer rooftops for 10,000 consumers @ 5 KW per consumer. The space requirement will be 700-800 Sq. feet each. For this, a policy incentive is required and suggested the following regulatory policy support –

- Capex subsidy of 50% on grid interactive roof top system

- Long term loan at 8% to the end consumer (say 10-20 years)
- 100% tax rebate on income for export of solar energy to the grid.
- Energy buy back by utility at a cost of Rs. 6.37 per unit.

Chief Engineer (DP&D) intimated that metering is not a very complicated issue. CEA regulation on metering takes care of metering from such system and can be finalized by the appropriate electricity regulators. However, the metering scheme shall be formulated in the report of Sub-Group-I.

4 The following emerged from the discussion :

1 A number of grid interactive Solar Photo Voltaic (SPV) Power Plants have been operational in the country for more than 10 years successfully.

2 Grid interactive SPV PPs of capacities 200 KW and less are normally interactive to the grid on low voltage whereas capacities more than 200 KW are interactive to the grid at 11 KV through a step up transformer however there are no fixed norms.

3 In the case of small DG Grid, the capacity of the SPV should not be more than one third of the size of the grid for stable operation of grid. Installation of batteries for storage and back up is advisable for better regulation of frequency and quality of power.

4 The cost of procurement and installation of SPV Power Plants in the last 5 years has come down significantly to about Rs. 16-19 Crores per MW from the earlier cost of Rs. 25 Crore per MW. The cost is likely to come down further with increase in the demand for SPV Power Plants.

5 Normally the cost break up of SPV Power Plant is of the order of:

- SPV Module 60%
- Inverter 10%
- Balance Equipments 30%

6 In case of use of batteries, the cost of the power plant will increase by 30-40%. The cost of battery is avoidable in case of connection with the infinite grid and the grid supply is reliable.

7 There are only few companies manufacturing inverters to suite the application in the country and therefore, generally inverters are being imported by the manufacturer of SPV.

8 The SPV Power Plants are supplied with state of the art SCADA and various protection along with monitoring of the entire SPV system.

9 The level of total harmonic generation from the SPV Power Plant must be limited to 3% only.

10 In place of single inverter, a number of inverters can be used to avoid the higher size cable and to improve the redundancy in the system.

11 The representative of Indian Semiconductor Association (ISA) informed that there is shortage of silicon material and Indian manufactures are importing almost all of the silicon material being used in India. A total of about 400-500 MW capacity for manufacturing SPV Cells is available in India. We have to augment the manufacturing capacity in next 5 years to achieve the target of 1000 MW generation from SPV Plants.

12 A small group comprising of following officers to study the system of Leh and Laddakh for installation of SPV Plants and to bring out a feasibility report was formed:

- Shri Puneet Goel, Director, MoP
- SE, RE, J&K
- Shri C.V.S.N Murthy, AGM, BHEL
- Shri Y.K. Khanduja, DM, NHPC
- Shri R.K. Verma – Director, CEA

This group would meet frequently to finalize SPV system for Leh and Ladakh and submit feasibility report to sub group I. This would be a part of the report of the sub group I. Shri R.K. Verma, Director would coordinate the activities of sub group.

13. The representative from J&K requested to install off grid SPV Power Plants at following locations which would also be looked into by the above group:

- Nyoma
- Zamskar
- Nobra
- Darass

14. Member (GO&D), CEA stated that separate guidelines may be prepared for various capacities of SPV Power Plants such as for capacities upto 1 kW, for capacities between 1 and 10 kW & for capacities more than 10 kW.

15. It was decided that BHEL / CEL/ NDPL/ ISA would provide the draft specifications for all the items of SPV Power Plants including safety aspects to CEA as per above for finalizing the specifications of the SPV Plant within a week time.

The meeting ended with vote of thanks to the chair.

List of Participants

Central Electricity Authority

1. Shri S.M. Dhiman, Member (GO&D) In chair
2. Shri Alok Gupta, Chief Engineer (DP&D)
3. Shri R.K. Verma, Director (DP&D)
4. Shri T.K. Saha, Director (DP&D)
5. Shri Vivek Goel, Dy. Director (DP&D)
6. Shri M.S. Sodhi, AD (DP&D)
7. Shri Raghbar Singh, AD (DP&D)
8. Shri Praveen Kamal, AD (DP&D)

Ministry of Power

Shri Puneet Goel, Director

N.H.P.C.

1. Shri M.K. Raina, ED
2. Shri Y.K. Khanduja, DM

B.E.E.

Shri Jitendra Sood, Energy Economist

NDPL

Shri Vivek Singla, GM

C.E.L.

Shri S.K. Sangal, ED
Shri R.K. Jain, AGM

K.P.C.L.

1. Dr. Tandan, MD
2. Shri Murli Dhar Rao, TD
3. Shri S. Ramesh, CE
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Annexure-II

TECHNICAL PARTICULARS OF SINGLE PHASE 10-60 or 20-80 Amp ENERGY METERS

1.0 FUNCTIONAL SPECIFICATION:

1.1	Applicable IS	IS 13779 or IS 14679 depending upon accuracy of meters.
1.2	Regulations	CEA Regulations on " Installation and Operation of Meters:" ,2006
1.3	Accuracy Class Index	1.0 or better up to 650 V
1.4	Voltage	415 Volt(P-P), +20% to -40% Vref, however the meter should withstand the maximum system voltage i.e. 440 volts continuously.
1.5	Display	a) LCD (Six digits),pin type
1.6	Power factor range	Zero lag –unity- zero lead
1.7	Display parameters	a) Display parameters : LCD test, KWH import, KWH export, MD in KW export, MD in KW import, Date & Time, AC current and voltages and power factor (Cumulative KWH will be indicated continuously by default & other parameters through push-button) b) Display order shall be as per **Annexure-A**
1.8	Power Consumption	Less than 1 Watt & 4VA in Voltage circuit and 2 VA for Current circuit
1.9	Starting current	0.2 % of Ib
1.10	Frequency	50 Hz with + / - 5% variation
1.11	Test Output Device	Flashing LED visible from the front
1.12	Billing data	a) Meter serial number, Date and time, KWH import, KWH export, MD in KW (both export and import), History of KWH import and export, & MD(both export & import) for last 6 billing cycles along with TOD readings. b) All these data shall be accessible for reading, recording and spot billing by downloading through optical port on MRI or Laptop computers at site.
1.13	MD Registration	a) Meter shall store MD in every 30 min. period along with date & time. At the end of every 30 min, new MD shall be compared with previous MD and store whichever is higher and the same shall be displayed. b) It should be possible to reset MD automatically at the defined date (or period) or through MRI.

		c) Manual MD resetting using sealable push button is an optional.
1.14	Auto Reset of MD	Auto reset date for MD shall be indicated at the time of finalizing GTP and provision shall be made to change MD reset date through MRI even after installation of meter on site.
1.15	TOD metering	Meter shall be capable of Time of use metering for KWH, and MD in KW with 8 time zones (programmable on site through CMRI)
1.16	Security feature	Programmable facility to restrict the access to the information recorded at different security level such as read communication, communication write etc
1.17	Memory	Non volatile memory independent of battery backup, memory should be retained up to 10 year in case of power failure
1.18	Software & communication compatibility	a) Optical port with RS 232 compatible to transfer the data locally through CMRI & remote through PSTN / Optical fiber / GSM / CDMA / RF / any other technology to the main computer. b) The Supplier shall supply Software required for CMRI & for the connectivity to AMR modules. The supplier shall also provide training for the use of software. The software should be compatible to Microsoft Windows systems (Windows 98 system). The software should have polling feature with optional selection of parameters to be downloaded for AMR application. c) Copy of operation manual shall be supplied. d) The data transfer (from meter to CMRI / AMR equipment) rate should be minimum 1200 bps. e) The Supplier shall provide meter reading protocols.
1.19	Climatic conditions	a) Refer IS: 13779 or IS: 14697 for climatic conditions. b)The meter should function satisfactorily in India with high end temperature as 60ºC and humidity up to 96%.
1.20	Meter Sealing	As per CEA Regulations, Supplier shall affix one Utility /buyer seal on side of Meter body as advised and record should be forwarded to Buyer.
1.21	Guarantee / Warranty	10 Years.
1.22	Insulation	A meter shall withstand an insulation test of 4 KV and impulse test at 8 KV

1.23	Resistance of heat and fire	The terminal block and Meter case shall have safety against the spread of fire. They shall not be ignited by thermal overload of live parts in contact with them as per the relevant IS.
1.24	Battery	Lithium with guaranteed life of 15 Years
1.25	RTC & Micro controller	The accuracy of RTC shall be as per relevant IEC / IS standards
1.26	P.C.B.	Glass Epoxy, fire resistance grade FR4, with minimum thickness 1.6 mm
1.27	**Power ON/Off hrs:**	Along with billing history parameters, meter shall log monthly ON/ Off hrs as history.
1.28	**Tamper Logging**	Last 200 events of Magnetic tamper; single wire tamper and top cover tamper shall be logged in memory along with Occurrence and restoration event data. Logic of defining tamper and OBIS code shall be agreed before supply of meter.
1.29	**Protection against HV spark**:	Meter shall continue to record energy or log the event, incase it is disturbed externally using a 35KV spark gun/ ignition coil.

2. TAMPER & ANTI-FRAUD DETECTION/EVIDENCE FEATURES

The meter shall not get affected by any remote control device & shall continue recording energy at least under any one or combinations of the following conditions:

2.1	I/C & O/G Interchanged	Meter should record forward energy
2.2	Phase & Neutral Interchanged	Meter should record forward energy
2.3	I/C Neutral Disconnected, O/G Neutral & Load Connected to Earth.	Meter should record forward energy
2.4	I/C Neutral disconnected, O/G Neutral Connected To Earth Through Resistor & Load Connected To Earth.	Meter should record forward energy
2.5	I/C Neutral connected, O/G Neutral Connected To Earth Through Resistor & Load Connected To Earth.	Meter should record forward energy
2.6	I/C (Phase & Neutral) Interchanged, Load Connected To Earth.	Meter should record forward energy
2.7	I/C & O/G (Phase or Neutral)	Meter should record forward energy

	Disconnected, Load Connected To Earth.	

3.0 INFLUENCE PARAMETERS

The meter shall work satisfactorily with guaranteed accuracy limit under the presence of the following influence quantities.

a) External magnetic field – 0.5 Tesla.
b) Electromagnetic field induction,
c) Radio frequency interference,
d) Vibration etc,
e) Waveform 10% of 3rd harmonics,
f) Voltage variation,
g) Electro magnetic H.F. Field,
h) D.C. immunity test,

ANNEXURE A

DISPLAY SEQUENCE FOR THE PARAMETERS

A **Default Display:**

Cumulative KWH to be displayed continuously without decimal

B On-demand Display:

After using pushbutton the following parameters should be displayed.

1. LCD test
2. Date
3. Real Time
4. Current MD in kW
5. Current kW generated by solar system
5. Last month billing Date
6. Last month billing KWH reading
7. Last month billing Maximum Demand in KW
8. Last month billing Maximum Demand in KW occurrence Date
9. Last month billing Maximum Demand in KW occurrence Time
10. Instantaneous AC Current and Voltages

Note: The meter display should return to Default Display mode (mentioned above) if the 'push button' is not operated for more than 6 seconds.

Annexure-III

TYPICAL TECHNICAL PARTICULARS OF SOLAR MODULES (160 AND 80 WATTS)

Electrical Parameters	Module-160	Module-80
Maximum Power Rating $P_{max.}$ (Wp)*	160.0	80.0
Minimum Power Rating P_{min} (Wp)*	150.0	75.0
Rated Current I_{MPP} (A)	4.45	4.45
Rated Voltage V_{MPP} (V)	36.0	18.0
Short Circuit Current I_{sc} (A)	5.00	5.00
Open Circuit Voltage V_{oc} (V)	44.0	22.0

Physical Parameters		
No. of Cells(Nos)	72	36
Physical Dimension (mm) (L x W x T)	1580 x 805 x 42	1200 x 550 x 35
Weight (Kg)	14.2	7.4

Environmental Rating	
Nominal Operating Cell Temperature (NOCT ** (^{0}C)	49 ±2
Maximum permitted module temperature (^{0}C)	-40 to + 85
Maximum permissible system voltage (V)	1000
Relative Humidity at 85^{0}C (%)	85
Temp. Co-efficient of the short-circuit current	+ .0004/K
Temp. Co-efficient of the open-circuit voltage	- .0034/K

* Under Standard Test Conditions (STC):
Air Mass : AM 1.5 Irradiance : 1000 W/m^2 Cell Temperature : 25^{0}C

** Nominal Operating Cell Temperature (NOCT) at :
Wind Speed :1m/s Irradiance : 800 W/m^2 Ambient Temperature : 20^{0}C

Annexure-IV

Technical Particulars of Solar PV System-0.5 kWp to 50 kWp

DC output of PV Array (KWp)	0.5	1	3	5	10	25	50
Area required (square feet)	75	150	450	750	1500	3750	7500
No. of cells in one PV module	36	36	72	72	72	72	72
DC rating of one module (W_P)	80	80	160	160	160	160	160
Connection configuration	Cells are connected in series to form one PV module.						
Rated DC current of one module	4.45	4.45	4.45	4.45	4.45	4.45	4.45
Rated DC voltage of one module (Vmpp)	18	18	36	36	36	36	36
No. of PV module in one array (all in series)	2	2	5	5	5	10	10
Max. DC output voltage of Array (Volt)	36	36	180	180	180	360	360
No. of Arrays	4	7	4	7	14	16	32
Rating of inverter(KVA)	0.6	1.1	4	6	12	30	60
Nominal AC output voltage(volt)	240	240	240	240	440	440	440
Variation In Output Voltage	±1%	±1%	±1%	±1%	±1%	±1%	±1%
Nominal frequency(Hz)	50	50	50	50	50	50	50
Grid Frequency variation	±3%	±3%	±3%	±3%	±3%	±3%	±3%
No. of phases/ wire	½	½	½	½	¾	¾	¾
AC output voltage range(Grid)	-20% to 15%						
Power Factor Range	0.8 lag to unity						
Minimum Efficiency of Inverter (%)	94	94	94	94	94	94	94
No load Losses of Inverter(max)	1%	1%	1%	1%	1%	1%	1%
DC Injection into Grid(max)	1%	1%	1%	1%	1%	1%	1%
Ripple content on DC side	3%	3%	3%	3%	3%	3%	3%
Total Voltage harmonic Distortion(AC side)	5%	5%	5%	5%	5%	5%	5%
Individual Voltage harmonic Distortion(AC side)	3%	3%	3%	3%	3%	3%	3%
Total Current harmonic Distortion(AC side)	8%	8%	8%	8%	8%	8%	8%

No. of AC& DC distribution board	1	1	1	1	1	1	1
No. of AC distribution Board	1	1	1	1	1	1	1

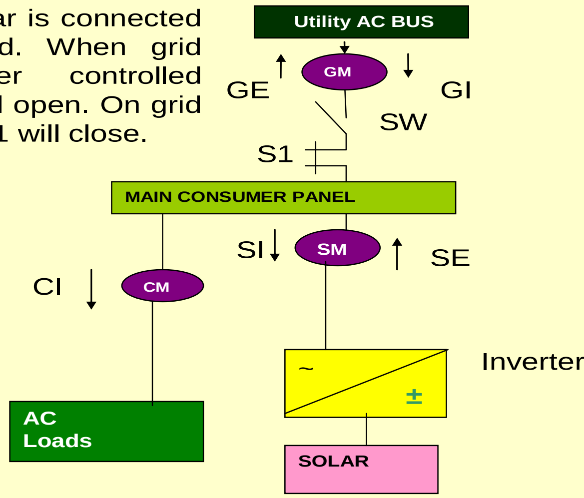
Note: Manufactures may offer module of different size than 160 watt in that case the configuration may differ slightly.

EXHIBIT-I

SCHEME-I

GRID INTERACTIVE SOLAR PV SYSTEM WITHOUT BATTERY

Normally solar is connected with the grid. When grid fails inverter controlled switch S1 will open. On grid restoration S1 will close.



SM-Solar Meter

GM-Grid Meter

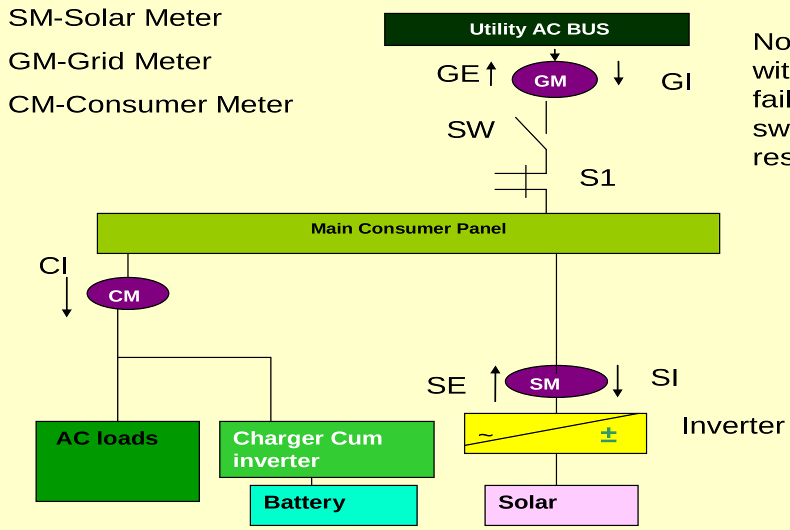
CM-Consumer Meter

- Tariff for operators of solar roof top devices shall be based on feed tariff fixed by Regulator, both on solar energy consumed by operator and the solar energy fed into the grid i.e SE.

- CI-Consumer Energy Import
  GI-Import of Energy from Grid
  GE-Export of Energy to the Grid
  SE- Export of energy from solar system
  SI- Import of energy by solar system
  SW –Manual Lockable switch for distribution feeder maintenance by the distribution company.

EXHIBIT-II

SCHEME-II
GRID INTERACTIVE SOLAR PV SYSTEM WITH FULL LOAD BATTERY BACKUP
(Based on Configuration-A)



Normally solar is connected with the grid. When grid fails inverter controlled switch S1 will open. On grid restoration S1 will close.

- Tariff for operators of solar roof top devices shall be based on feed tariff fixed by Regulator, both on solar energy consumed by operator and the solar energy fed into the grid i.e SE.

- CI-Consumer Energy Import
  GI-Import of Energy from Grid
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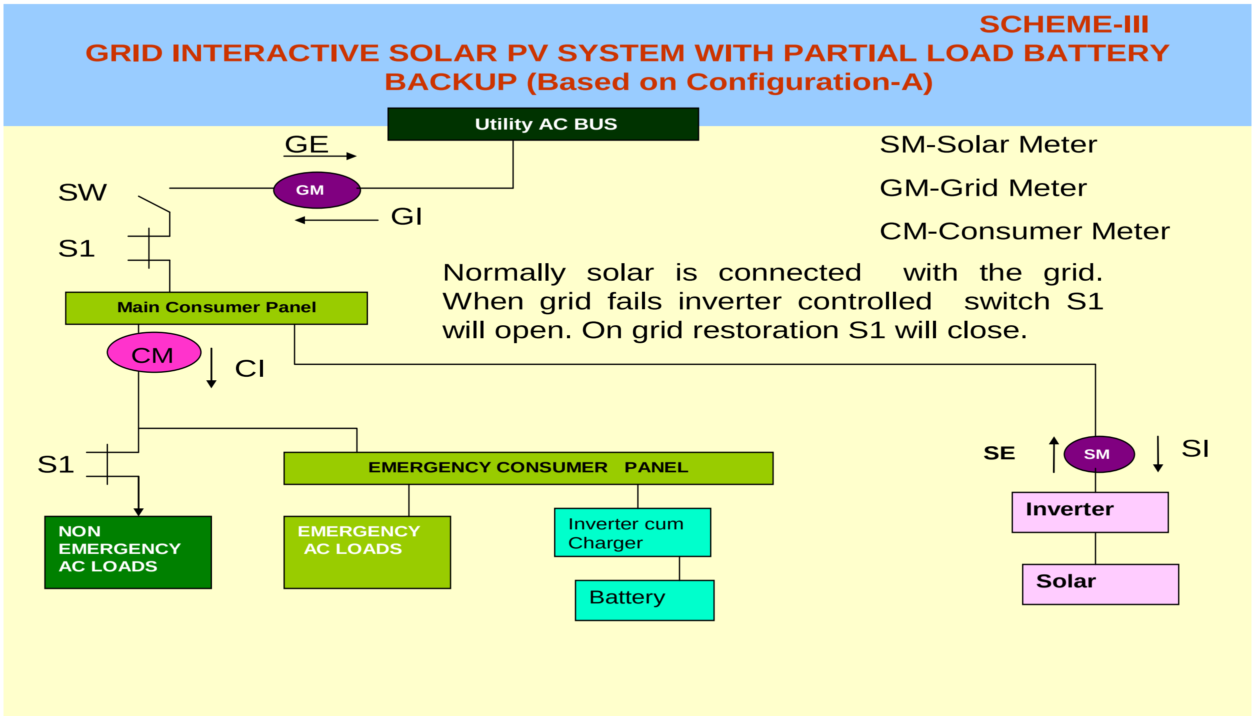
EXHIBIT-III



- Tariff for operators of solar roof top devices shall be based on feed tariff fixed by Regulator, both on solar energy consumed by operator and the solar energy fed into the grid i.e SE.

- CI-Consumer Energy Import
  GI-Import of Energy from Grid
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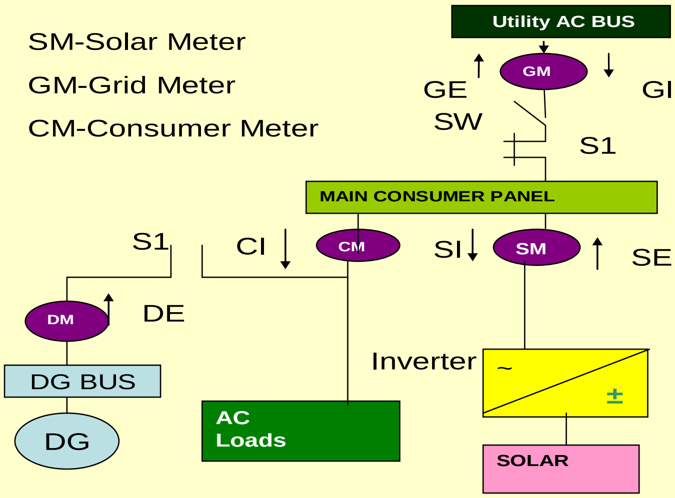
  SI- Import of energy by solar system
  SW –Manual Lockable switch for distribution feeder maintenance by the distribution company.

EXHIBIT-IV

SCHEME-IV

GRID INTERACTIVE SOLAR PV SYSTEM WITH FULL LOAD DG BACKUP



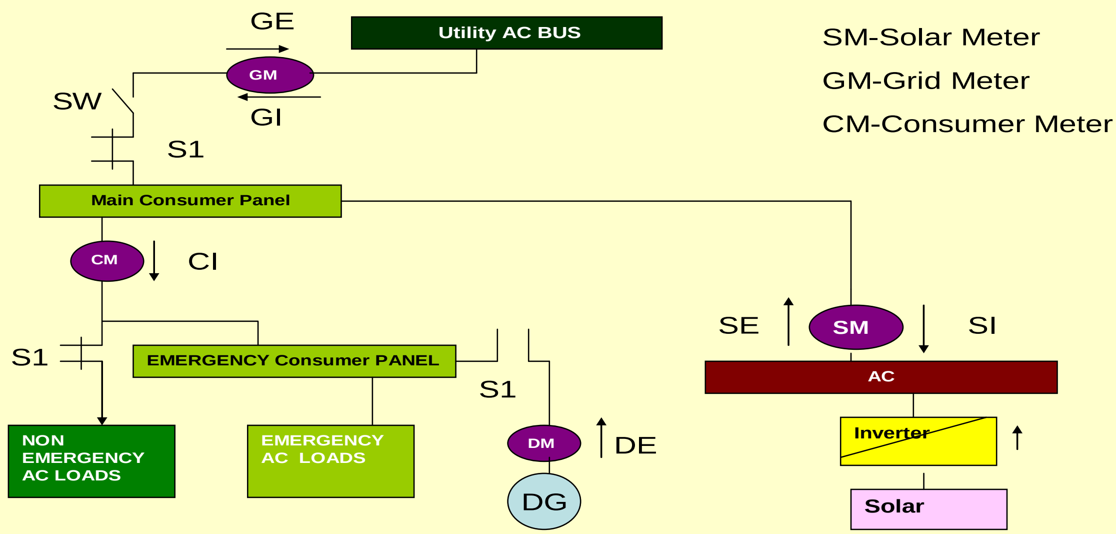
Normally solar is connected with the grid. When grid fails normally closed contact and normally open contact of inverter controlled switch S1 will open and close respectively.

- Tariff for operators of solar roof top devices shall be based on feed tariff fixed by Regulator, both on solar energy consumed by operator and the solar energy fed into the grid i.e SE.

- CI-Consumer Energy Import
  GI-Import of Energy from Grid
  GE-Export of Energy to the Grid
  SE- Export of energy from solar system
  SI- Import of energy by solar system
  SW –Manual Lockable switch for distribution feeder maintenance by the distribution company.

EXHIBIT-V

SCHEME-V
GRID INTERACTIVE SOLAR PV SYSTEM WITH PARTIAL LOAD DG BACKUP

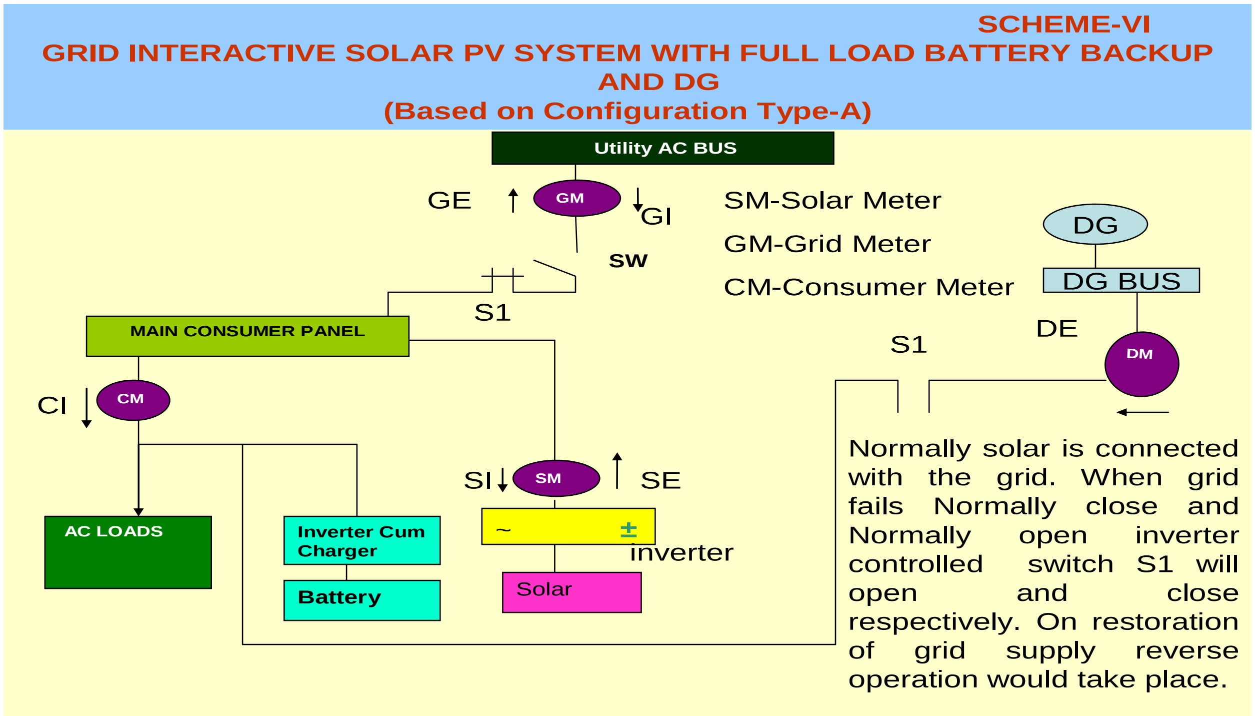


Normally solar is connected with the grid. When grid fails Normally close and Normally open inverter controlled switch S1 will open and close respectively. On restoration of grid supply reverse operation would take place.

- Tariff for operators of solar roof top devices shall be based on feed tariff fixed by Regulator, both on solar energy consumed by operator and the solar energy fed into the grid i.e SE.

- CI-Consumer Energy Import
  GI-Import of Energy from Grid
  GE-Export of Energy to the Grid
  SE- Export of energy from solar system
  SI- Import of energy by solar system
  SW –Manual Lockable switch for distribution feeder maintenance by the distribution company.

EXHIBIT-VI



- Tariff for operators of solar roof top devices shall be based on feed tariff fixed by Regulator, both on solar energy consumed by operator and the solar energy fed into the grid i.e SE.

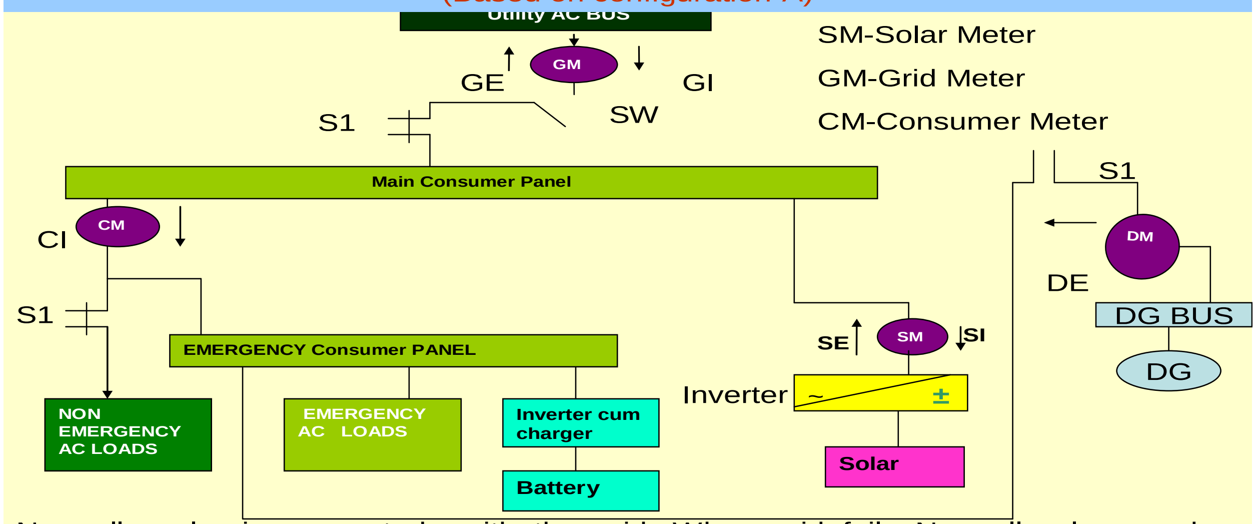
- CI-Consumer Energy Import
  GI-Import of Energy from Grid
  GE-Export of Energy to the Grid
  SE- Export of energy from solar system
  SI- Import of energy by solar system
  SW –Manual Lockable switch for distribution feeder maintenance by the distribution company.

EXHIBIT-VII

SCHEME-VII

GRID INTERACTIVE SOLAR PV SYSTEM WITH PARTIAL LOAD BATTERY BACKUP AND DG

(Based on configuration-A)



Normally solar is connected with the grid. When grid fails Normally close and Normally open inverter controlled switch S1 will open and close respectively. On restoration of grid supply reverse operation would take place.

- Tariff for operators of solar roof top devices shall be based on feed tariff fixed by Regulator, both on solar energy consumed by operator and the solar energy fed into the grid i.e SE.

- CI-Consumer Energy Import
  GI-Import of Energy from Grid
  GE-Export of Energy to the Grid
  SE- Export of energy from solar system
  SI- Import of energy by solar system
  SW –Manual Lockable switch for distribution feeder maintenance by the distribution company.