Components of photovoltaic system

A photovoltaic system basically consists of : Cells, Modules and Arrays.

Cells

A solar cell is a device which converts solar energy into electrical energy. In a production line one expects variation in the performance of cells processed in a batch. The performance of processed cells is not identical and hence cells of nearly similar current-voltage characteristic are sorted out for connection in a module.

Modules or Panels

A module consist of:

- a support board to which the solar cells are affixed
- an encapsulating cover with high optical transmission; and
- a supporting frame designed to facilitate connection of modules in closely packed arrays. The modules should be tugged and easy to handle during the assembly of arrays. Commercial modules range in power out puts from 1 to 40 watts under AM1condition of insulation.

Array

A photovoltaic array is a structure, which houses and supports the solar panels or modules in a photovoltaic system.

In the case of system using concentrators, the definition of the array would include focusing and cooling equipment.

Dimensions of cells and modules :

A.Dimension of cells

For space applications solar cells are normally rectangular (2 CM x 2 CM or 2 CM x 4CM or 2 CM x 6 CM). For space applications rectangular cells provide high panel packing efficiency. To conserve ground space solar cells for terrestrial application should also be rectangular if used in very large quantities. Commercially available solar cells are silicon solar cells and are circular, hexagonal and rectangular. The circular cells vary in diameter and have AM1 efficiency ranging from 10 to 40%. Hexagonal cells with 6.25 CM between parallel sides are also available. Rectangular solar cells of 6 M x 2 CM are commercially available with AM1 efficiency of 12%.

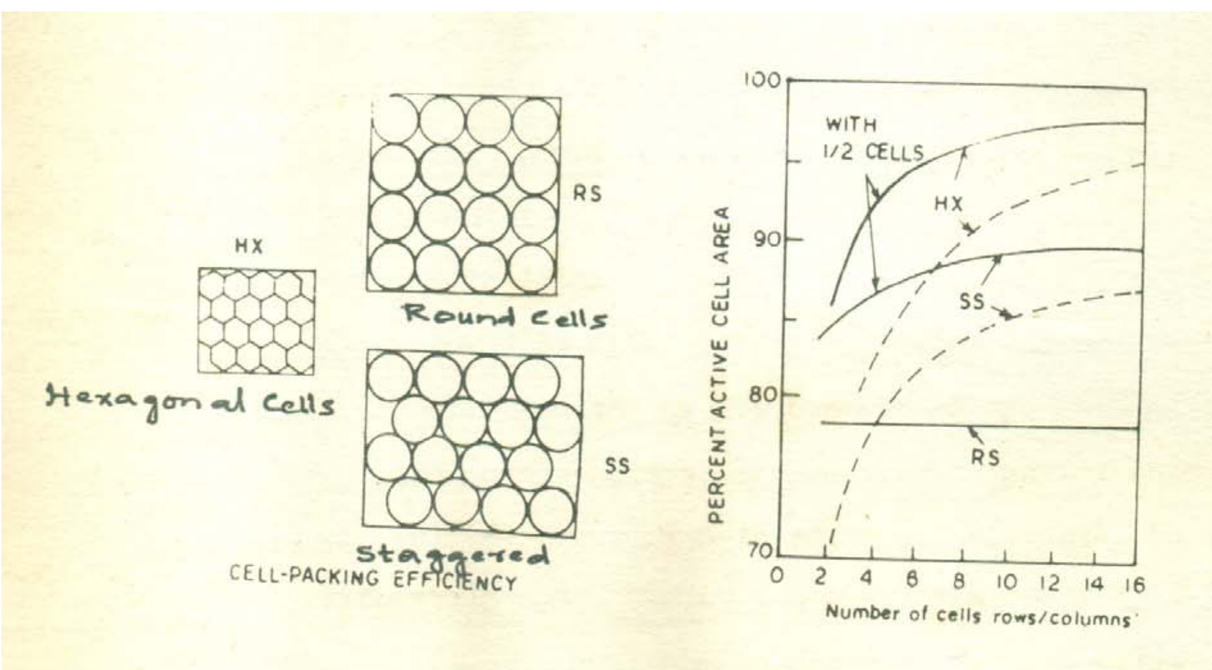
As the size of the individual cell increases, the collected photocurrent in the cell increases correspondingly. Commercially available round solar cells are cells are as large as 10 CM in diameter and can deliver 2.15 Amperes at 0.45v under AM1 condition if insulation. The cells have a conversion efficiency of around 12%.

B) **Packing efficiency of cells in modules**

Modules are rectangular. In order to utilize the maximum module surface area it is necessary that the solar cell packing efficiency on the module be high. The packing efficiency is defined as the percentage ratio of active cell area in a module to the module total area. By increasing the module size the, the ratio of border area to active area can be reduced and so improvements can be made in the overall module packing efficiency. The use of large modules might also represent savings in installation costs though this may cause difficulties in replacement at the time of module replacement. The packing efficiency of a module is a function of:

- the number of cell per rows/column
- the geometry of the cell[2]
- solar cell spacing required for the electrical interconnection of the cells.

Fig.6 Shows the effect of solar cell shape and module size on the packing efficiency within a square module with cells in direct contact with one another. It is to be seen that the solar cell packing efficiency increases with increasing module size, though a point of diminishing return is reached when the number of the cells in a row is 15. Hence the module size depends upon the size of the cell used.



As an approximation it can be stated that:
Size of the module $\approx$ 15 x diameter of the cell
Half cells fill out end spaces when staggered pack is used. A slight gain in packing efficiency is obtained by utilizing half cells.

Typical values of the percentage of areas lost in round and hexagonal cells are given in Table.

Table
Lost area %

	Round cell	Hexagonal cells
Border frame	6-8%	6-8%
Interspaces	10%	2%
½ cell spaces	3%	3%
Interconnect-spaces	3-5%	4-6%

The above values are for 120 cm x 120 cmmodules with 7.5 – 10 CM diameter cells.
Therefore overall packing efficiency of 75-85% is achievable. Reduction in border area can further improve the efficiency.

Modules efficiency

For a module of given dimensions and using solar cells of given conversion efficiency and operating characteristics, the electrical voltage and current rating of the module would depend upon the number of cells and their method of interconnection.

In order to obtain the desired operating current and voltage values, series parallel combinations of cells are necessary in the module. The module peak power depends upon the module area and the module efficiency. Under AM1 conditions of insulation:
Module peak power = module (CM^2) x 100 mW/CM^2 x η_{mod} where η_{mod} is module efficiency .

The module efficiency η_{mod} depends upon:

- packing efficiency of the cells in the module
- encapsulated cell efficiency, which in turn depends upon:
  * cell efficiency at rated temperature and insulation
  * cell mismatch efficiency

* optical transmission efficiency
* cell operating temperature efficiency

The module efficiency η_{mod} for a variety of commercially available modules with circular cells, varies from 6% for smaller panels of about 2 watts to about 8% for larger modules of about 30 watts peak power out put. With square and rectangular cells the module efficiency is high and in some cases it is about 12%.

storage batteries

In isolated system away from the grid, batteries are used for storage of excess solar energy converted into electrical energy. To be economically attractive, the storage of solar electricity requires a battery with a particular combination of properties:

- Low cost
- Long life
- High reliability
- High overall efficiency WH output/WH input
- Low self discharge
- Minimum maintenance

Types of batteries:

There are many types of batteries potentially available for use in PV systems. These are:
a) lead- acid, b) nickel –cadmium, c) nickel-metal-hydride, d) rechargeable alkaline manganese, e) lithium-ion, f) lithium-polymer, g) redox batteries. At present most commonly used is lead-acid.