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Micro-grid for distribution of electric energy in an Island

Virendra Kumar Maurya[1], Rituraj Jalan[1], Agarwal HP[1], Dharmendra Pal[2*]

1. Department of Electrical Engineering Shekhawati Engineering College Dundlod Rajasthan, India
2. Department of Physics, BBD National Institute of Technology and Management, BBD University Campus, Lucknow -227105, India

***Correspondence to**: Dharmendra Pal, Department of Physics, BBD National Institute of Technology and Management, BBD University Campus, Lucknow -227105, India

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ABSTRACT

The photovoltaic (pv) power technology uses semiconductor cells (wafers), generally several square centimeters in size. The "photovoltaic effect" is the basic physical process through which a PV cell converts sunlight into electricity. In this paper we develop a micro-grid for distribution of electric energy in an Island .Where other sources of electricity are not easy to install and are costly also. The results given here are purely analytic & applicable.

1. INTRODUCTION

To induce the electric field within a PV cell, two separate semiconductors are sandwiched together. The "p" and "n" types of semiconductors correspond to "positive" and "negative" because of their abundance of holes or electrons [1]. When the p-type and n-type semiconductors are sandwiched together, the excess electrons in the n-type material flow to the p-type, and the holes thereby vacated during this process flow to the n-type (Figure 1, 2 and 3). (The concept of a hole moving is somewhat like looking at a bubble in a liquid. Although it's the liquid that is actually moving, it's easier to describe the motion of the bubble as it moves in the opposite direction.) Through this electron and hole flow, the two semiconductors act as a battery, creating an electric field at the surface where they meet (known as the "junction") [2,3].

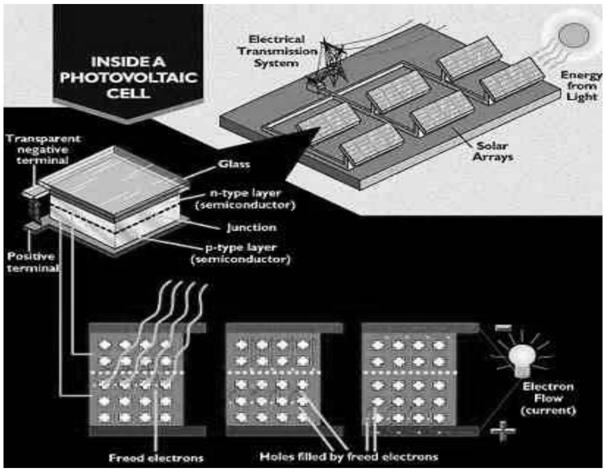

Figure1
General over view of PV cell

2. SOLAR PHOTOVOLTAICS (SPV)

Solar photovoltaic (SPV) is the process of converting solar radiation into electricity using a device called solar cell [4]. A solar cell is a semi-conducting device made of silicon or other materials, which, when exposed to sunlight, generates electricity. Factors affecting magnitude of electric current:
1. Intensity of the solar radiation
2. Exposed area of the solar cell
3. Type of material used in fabricating the solar cell
4. Ambient temperature

2.1. Advantages of the photovoltaic power

Major advantages of the photovoltaic power are as follows:
1. Short lead time to design, install, and start up a new plant.
2. Highly modular, hence, the plant economy is not a strong function of size.
3. Power output matches very well with peak load demands.
4. Static structure, no moving parts, hence, no noise.
5. High power capability per unit of weight.
6. Longer life with little maintenance because of no moving parts.
7. Highly mobile and portable because of light weight.

2.2. Solar photovoltaic in India

India is implementing perhaps the most number of pv systems in the world for remote villages. About 30 MW capacity has already been installed, with more being added every year [5-8]. The country has a total production capacity of 8.5 MW modules per year. The remaining need is met by imports. A 700 kW grid connected PV plant has been commissioned, and a 425 kW capacity is under installation in Madhya Pradesh. The state of West Bengal has decided to convert the Sagar Island into a PV island. The island has 150,000 inhabitants in 16 villages spread out in an area of about 300 square kilometers. The main source of electricity at present is diesel, which is expensive and is causing severe environmental problems on the island. The state of Rajasthan has initialed a policy to purchase PV electricity at an attractive rate of $0.08 per kWh. In response, a consortium of Enron and Amoco has proposed installing a 50 MW plant using thin film cells. When completed, this will be the largest PV power plant in the world. The studies at the Arid Zone Research Institute, Jodhpur, indicate significant solar energy reaching the earth surface in India. About 30 percent of the electrical energy used in India is

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for agricultural needs. Since the availability of solar power for agricultural need is not time critical (within a few days), India is expected to lead the world in PV installations in near future.

2.3. Interesting fact

One of the attractive features of the pv system is that its power output matches very well with the peak load demand. It produces more power on a sunny summer day when the air-conditioning load strains thegrid lines. Power usage curve in commercial building on a typical summer day is shown in Figure 4.

2.4. PV cell technology

In making comparisons between alternative power technologies, the most important measure is the energy cost per kWh delivered. In pv power, this cost primarily depends on two parameters, the photovoltaic energy conversion efficiency, and the capital cost per watt capacity [9]. Together, these two parameters indicate the economic competitiveness of the pv electricity (Fig.5). The conversion efficiency of the photovoltaic cell is defined as follows:

$$\eta = \frac{\text{Electrical power output}}{\text{Solar power impinging the cell}}$$

3. SOLAR CELL

PV cell is a light sensitive two-terminal N-P junction made of semiconducting material such as silicon. Ptype and N-type semiconductor and a solar cell are shown in Figure 3 and 4 respectively [10].

3.1. Solar cell construction

Constructing a solar cell involves following important steps:

1. *General design criteria*
2. *Crystal growth:* High purity electronic grade material is obtained in polycrystalline ingots.

Impurities should be less than 1 atom in 109, i.e. less than 1018 atoms per m3. This starter material has to be made into large single crystals using one of the techniques mentioned below

1. *Czochralski technique*
2. *Zone refining*
3. *Ribbon growth*
4. *Vacuum deposition*
5. *Casting*
3. *Slice treatment*
4. *Modules and arrays*

3.2. Limits to PV cell efficiency

1. Top surface contact obstruction (loss ~3%)
2. Reflection at top surface (loss ~1%)
3. Photon energy less than band gap (loss ~23%)
4. Excess photon energy (loss ~33%)
5. Quantum efficiency (loss ~0.4%)
6. Collection efficiency
7. Voltage factor FV (loss ~20%)
8. Curve factor FC (loss ~4%)
9. Additional curve factor A (loss ~5%)
10. Series resistance (loss ~0.3%)
11. Shunt resistance (negligible, ~0.1%)
12. Delivered power (Si cell 10 to 14%)

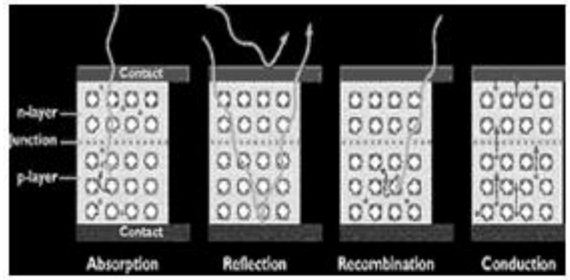

Figure 2

p-n-Types Array

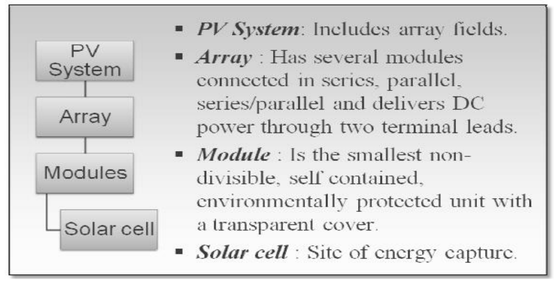

Figure 3

Hierarchical arrangement of elements of PV System

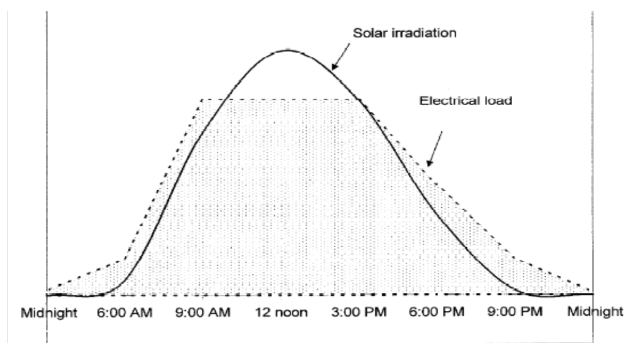

Figure 4

Power usage curve

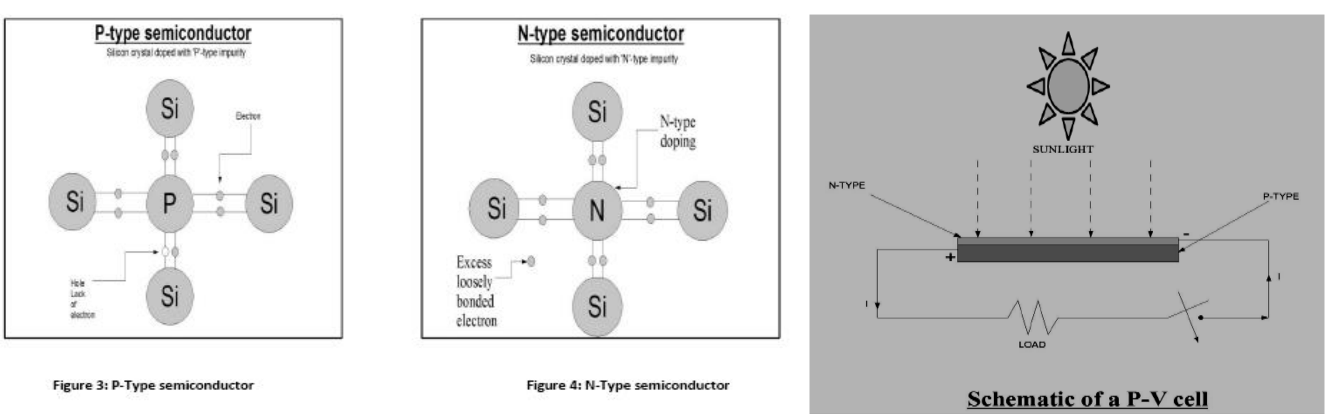

Figure 5 (a,b,c)

chematic of a PV cell

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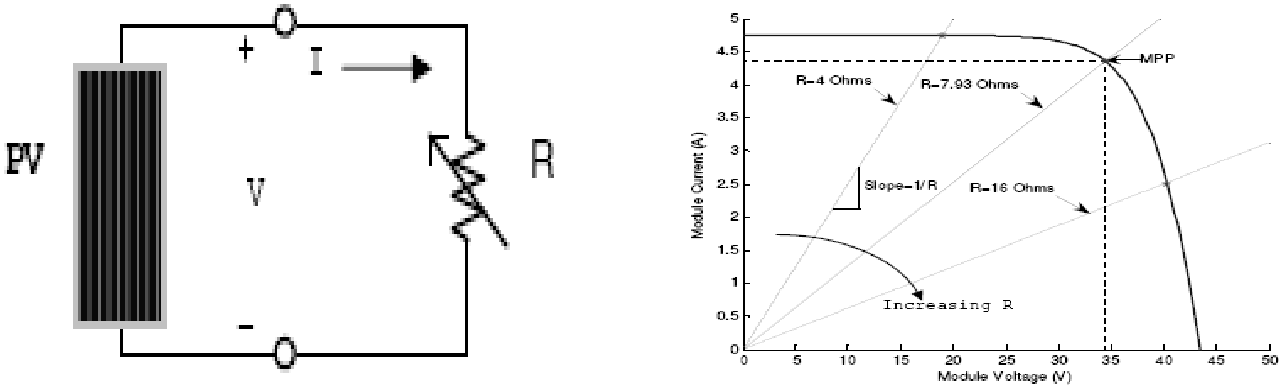

Figure 6

(a) PV module is directly connected to a (variable) resistive load, (b) I-V curves of BP SX 150S PV module and various resistive loads Simulated with the MATLAB model (1KW/m2, 25oC)

3.3. Experimental Analysis of Photovoltaics

To calibrate a solar photovoltaic array and determine its characteristic curve. A PV module is directly coupled to a load, the PV module's operating point will be at the intersection of its *I–V* curve and the load line which is the *I-V* relationship of load. For example in Figure 6, a resistive load has a straight line with a slope of *1/Rload* as shown in Figure 6. In other words, the impedance of load dictates the operating condition of the PV module. In general, this operating point is seldom at the PV module's MPP, thus it is not producing the maximum power. A study shows that a direct-coupled system utilizes a mere 31% of the PV capacity [11]. A PV array is usually oversized to compensate for a low power yield during winter months. This mismatching between a PV module and a load requires further over-sizing of the PV array and thus increases the overall system cost [11-13]. To mitigate this problem, a maximum power point tracker (MPPT) can be used to maintain the PV module's operating point at the MPP. MPPTs can extract more than 97% of the PV power when properly optimized [9]. This chapter discusses the *I-V* characteristics of PV modules and loads, matching between the two, and the use of DC-DC converters as a means of MPPT. It also discusses the details of some MPPT algorithms and control methods, and limitations of MPPT [14].

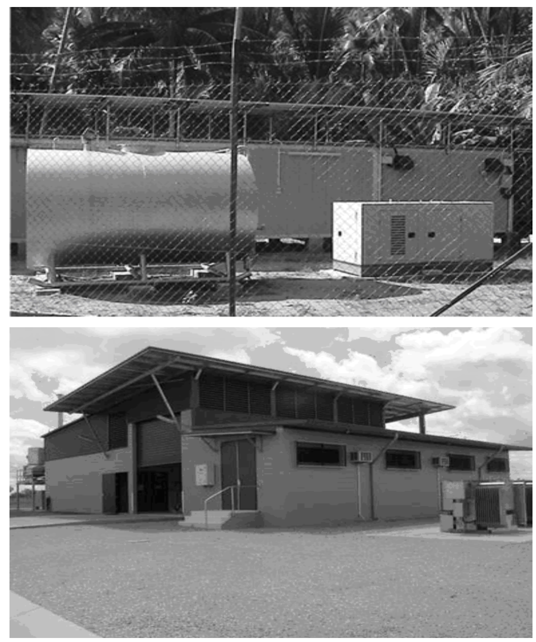

Figure 7

(a) Solar Hybrid Power Station [TNB, Malaysia],
(b) Rural Community Power Station [Ergon Energy , Australia]

3.4. Scope of rural electrification

There are many different interpretations and classifications in use today to describe rural and/or remote areas for the purposes of discussing methods of electrification (Fig.7). Some useful examples are as follows: [15]

3.4.1. By density and concentration or clustering – setting the context of the environment or geography

Small communities, villages or even towns remote from other habitation, Dispersed households, farms and enterprises of low density over wide areas or regions, Community clusters or villages surrounded by lower density dispersed households, Communities on the same land mass but separated by physical obstacles such as mountainous terrain, or on islands separated by water [16].

3.4.2. By energy use

By power and energy (or load factor=f(energy/power)) and load profile,
By application: household, commercial enterprise, institution, agricultural processing, etc.

3.4.2.1. By choice and method of energy provision

- Reticulated electricity, connected to some form of larger grid, or a local micro grid,
- Reticulated/piped fuel such as natural gas, LPG, fuel oil, diesel,
- Transported fuel such as natural gas, LPG, fuel oil, diesel, by land or sea transport,
- Reliance on renewable energy products such as hydro, solar photovoltaic (PV), wind, waves, tides.

The most suitable method of electricity provision (technology, institutional model, etc) will usually depend on the combination of the geographic context, the consumer need, and the possibilities that are available and affordable to provide the energy requirements. Therefore, the most appropriate solutions in one place might be quite unsuitable in another. Clusters and communities that are very remote from other habitation are generally supplied by some form of centralized local generation, or via a connection to a larger but somewhat remote grid.

If centralized local generation is the system chosen for such communities or clusters, then these will be larger than the isolated generation systems used for individual consumers, and are likely to be diesel, gas or fuel oil generators, supplemented by renewable methods if these are available, such as hydro driven generators or hybrid (wind, PV, battery) systems. These community supply systems are often called Micro Grids, as they often include small grid systems radiating from the generation source, often at low voltage or they can be stepped up to medium voltage (11kV, 22kV) for distribution to customers further away from the community centre. SWER technologies are discouraged on these micro grid networks due to the impact of phase imbalance on small generators. In contrast, evenly or widely dispersed households and farms, are generally supplied by small single customer systems, with little or no opportunity for interconnection. These days such supply systems are primarily smaller diesel generators with a growing number of hybrid (wind, PV, battery) systems supplemented by a fuel based generator at peak times. If, as an alternative to local generation, network interconnection is available and adopted, then appropriately low cost, limited capacity systems are required. The choice between alternatives is usually made on a financial basis taking into account capital construction costs, losses, and operating/maintenance costs. Where fossil fuel based generators are selected, the costs of the selected fuel is generally the dominant cost driver. The greatest uncertainty arises in areas of mixed types of electrification (load magnitude, density and clustering), where no single technology is distinctly better than the alternatives, and small changes in the assumptions about power and energy forecasts affect the ranking of alternative technologies and business models. Technical innovations for grid connected supplies include: [17]

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- Electronic voltage regulators, such as switched reactors and compensators, Unified Power Flow Controllers (UPFC) at Medium Voltages, and applied to long, weak networks at 3 phases, or SWER lines to improve power quality for all customers over the entire feeder length.
- Single- to three-phase converters.
- Reliability improvement techniques such as lightning surge reduction, earthing improvements for SWER, improved insulation co-ordination and insulator materials, greater use of covered conductors, multiple reclosers linked with intelligent SCADA systems for monitoring and fault response.
- Small capacity, multi-terminal HVDC systems might change distribution technology significantly. Substantial reductions in losses and costs have been achieved already in VSC technology HVDC systems with extruded polymer cables. Techniques for a DC version of LV distribution, with electronic voltage controllers and inverters, are being developed [18].

The global average air temperature at the surface of the Earth has increased by about 0.74 ºC over the past century, and is likely to continue rising [1]. Human activities such as burning fossil fuels cause emission of the greenhouse gases (mainly carbon dioxide) that contribute to global warming. Electricity generation is one of the major contributors to environmental problems. Thus, development of clean energy sources becomes increasingly important to the global environment. Furthermore, we human beings are challenged by the depletion of fossil fuel reserves. Green energy sources that allow for sustainable development are therefore becoming more interesting. Our present standard of living can only be maintained by tapping sustainable sources of energy such as solar power, wind power, hydro power, wave power, geothermal power, tidal power, biomass, and others. The way energy is generated and supplied will undergo a fundamental change. As most sustainable energy is harvested as electricity, innovations in electric power conversion technology are crucial for the economic feasibility of the use of Sustainable energy. This work investigates how sustainable electricity generators such as fuel cells and photo voltaic and appropriate storage elements like batteries and super capacitors (also named ultra capacitors) are best integrated in energy systems suitable for domestic application. Power electronic converters provide the electrical interface between the sources, storage, and loads, and the availability of reliable and low-cost converters will accelerate the deployment of sustainable energy systems [19]. From a power electronic point of view, fundamental research topics in the above context are

- novel converter topologies,
- converter control and modeling,
- means for energy storage,
- system power flow management,
- power quality control,
- public utility interconnection system,
- generator control and protection, etc.

4. MODELING AND SIMMULATION

4.1. Pv cell

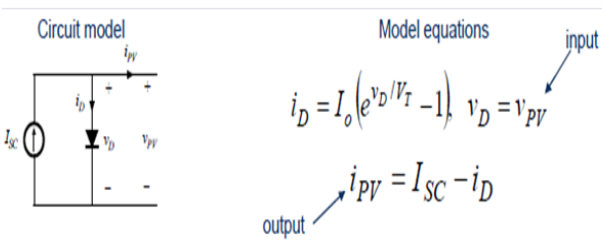

Figure 8

Pv cell

$$i_{PV} = I_{SC} - i_D$$

Where I_{pv} =output, I_{sc}= insolation current , I_D = diode current

Now fig.9 shows the I-V characteristic and p-v characteristic at the different insolation at 1000W/m^2 ,800W/m^2,600W/m^2,

4.2. Result: 1000W/m^2

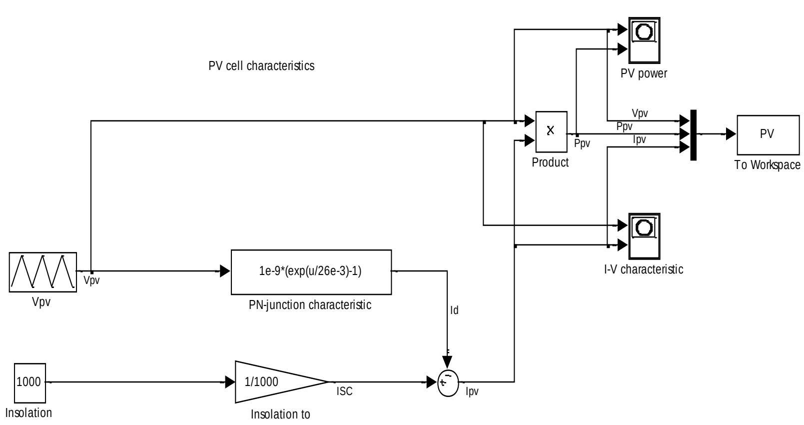

Figure 9

Modeling and Simulation

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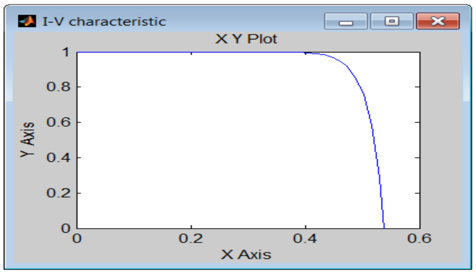
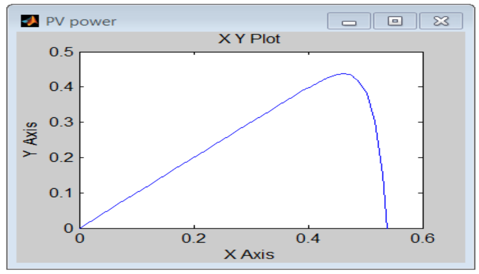
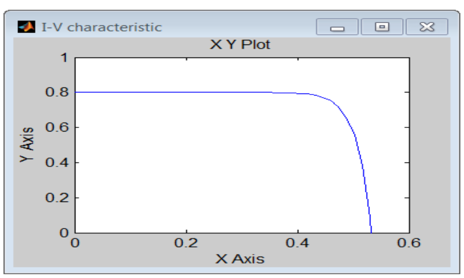
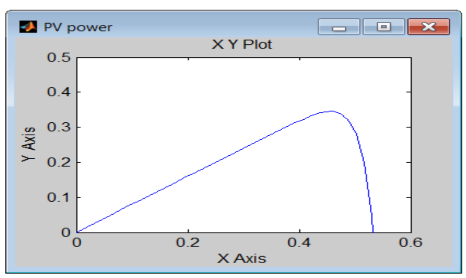




Voltage	Power	current
0.012	0.012	1
0.026	0.026	1
0.04	0.04	1
0.054	0.054	1
0.068	0.068	1
0.18	0.18	0.999999
0.194	0.194	0.999998
0.208	0.207999	0.999997
0.222	0.221999	0.999995
0.236	0.235998	0.999991
0.474	0.434799	0.917297
0.488	0.41885	0.858299
0.502	0.380121	0.757214
0.516	0.301353	0.584017
0.53	0.152252	0.287268

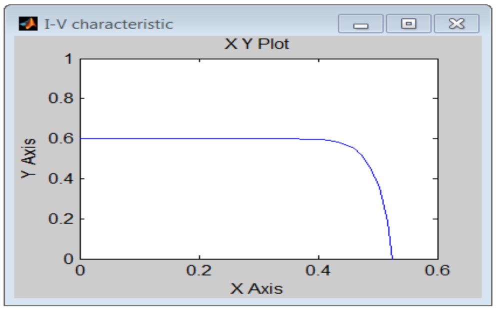
4.3. 800W/m^2

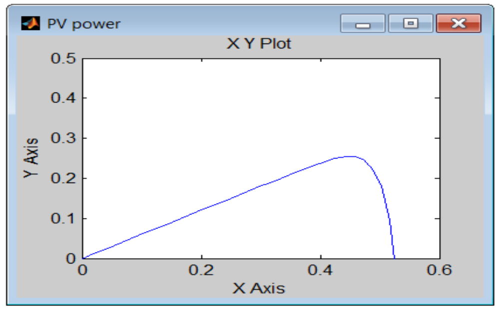




Voltage	Power	current
0.012	0.0096	0.8
0.026	0.0208	0.8
0.04	0.032	0.8
0.054	0.0432	0.8
0.068	0.0544	0.8
0.082	0.0656	0.8
0.18	0.144	0.799999
0.194	0.1552	0.799998
0.208	0.166399	0.799997
0.222	0.177599	0.799995
0.236	0.188798	0.799991
0.46	0.345796	0.751731
0.474	0.339999	0.717297
0.488	0.32125	0.658299
0.502	0.279721	0.557214

4.4. 600W/m^2

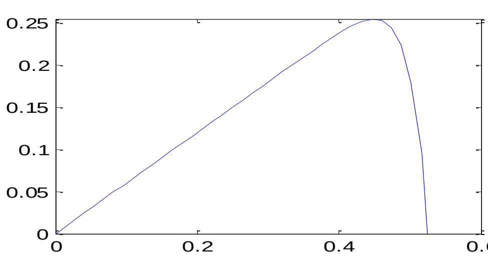


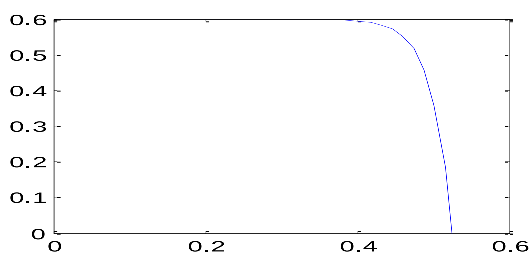


Voltage	power	Current
0.012	0.0072	0.6
0.026	0.0156	0.6
0.04	0.024	0.6
0.054	0.0324	0.6
0.068	0.0408	0.6
0.082	0.0492	0.6
0.18	0.108	0.599999
0.194	0.1164	0.599998
0.208	0.124799	0.599997
0.222	0.133199	0.599995
0.236	0.141598	0.599991
0.46	0.253796	0.551731
0.474	0.245199	0.517297
0.488	0.22365	0.458299
0.502	0.179321	0.357214

4.5. Curve for maximum values

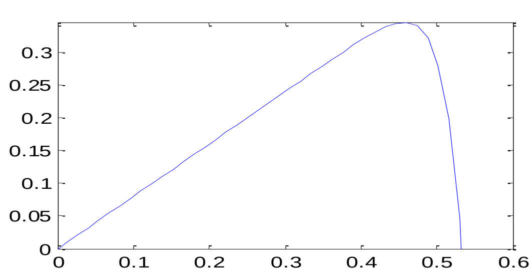
4.5.1. 1000W/m^2

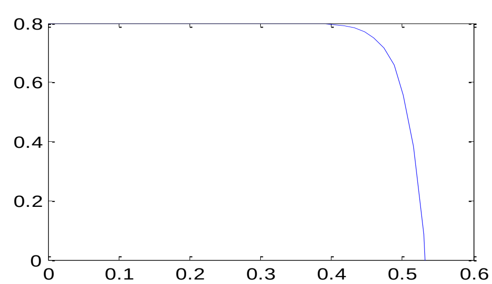




MPP power	MPP voltage	MPP current
0.255	0.446	0.5718

4.5.2. 800W/m^2





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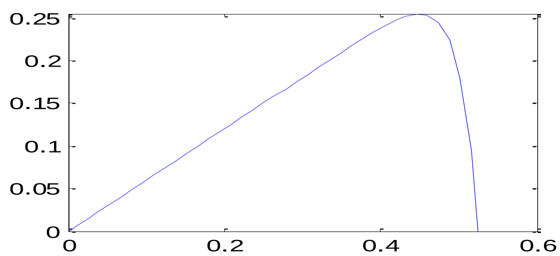
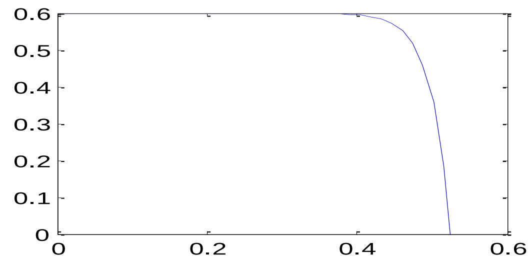
MPP power	MPP voltage	MPP current
0.3458	0.4600	0.7517

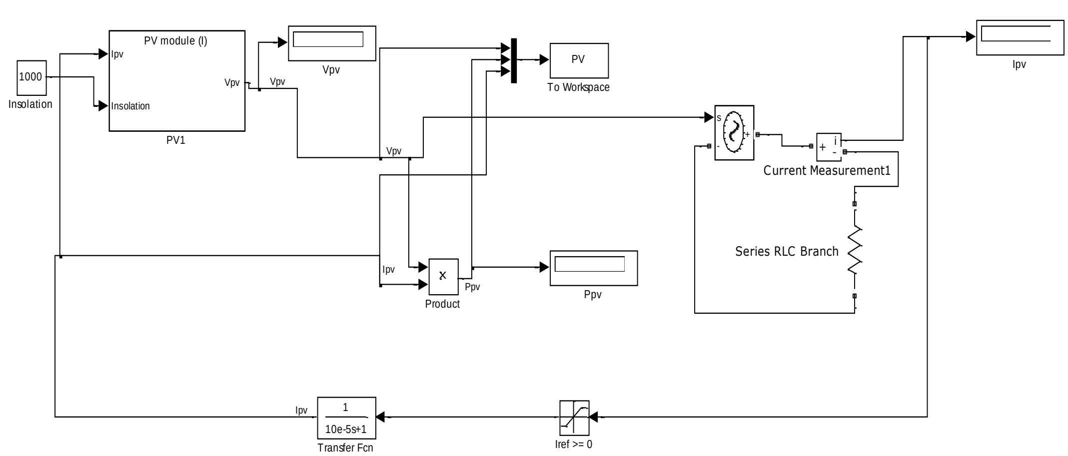
4.5.3. 600W/m^2





MPP power	MPP voltage	MPP current
0.2550	0.4460	0.5718

4.6. PV Array Single (36 CELL CONNECTED IN SERIES)



Isc = 5.45, Voc = 22.2, I pm = 4.95, V pm = 17.6, V= I*R, 22.2 = 5.45 R, R = 4.07Ω1000W/m^2

pv array 36 cell in series (1000W/m^2)			
Resistant	**voltage**	**power**	**current**
10	20.92	43.93	2.092
8	20.58	53.07	2.573
6	19.98	66.67	3.33
4	18.46	85.02	4.616
3	15.55	81.19	5.184
2	10.46	55.58	5.231
1	5.203	27.94	5.203

pv array 36 cell in series (800W/m^2)			
Resistant	**voltage**	**power**	**current**
10	20.56	42.23	2.056
8	20.15	50.59	2.519
6	19.34	62.37	3.224
4	16.36	67.22	4.091
3	12.26	51.56	4.086
2	9.105	38.62	4.552
1	5.136	22.01	5.136

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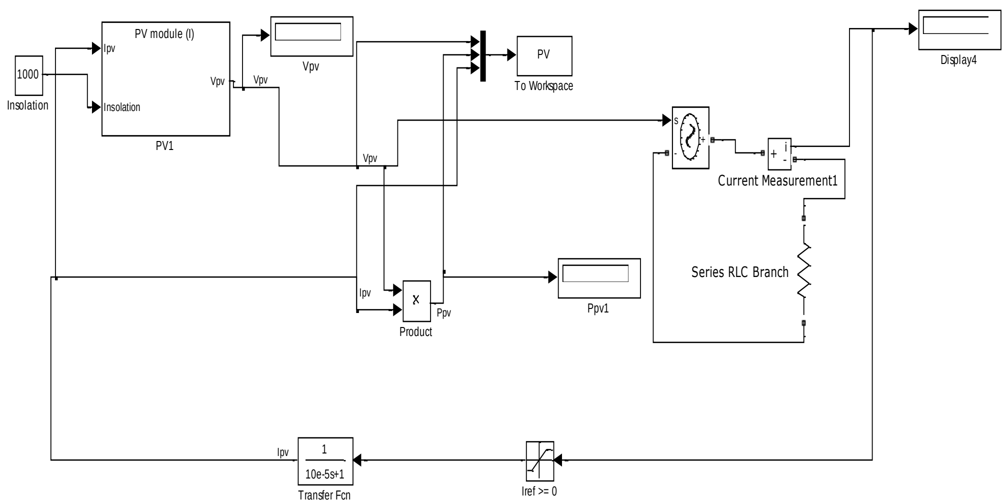
pv array 36 cell in series (600W/m²)			
Resistant	**voltage**	**power**	**current**
10	19.95	39.71	1.995
8	19.31	46.6	2.414
6	17.58	51.68	2.929
4	12.57	39.19	3.143
3	9.637	30.36	3.212
2	6.27	19.98	3.135
1	3.572	11.49	3.572

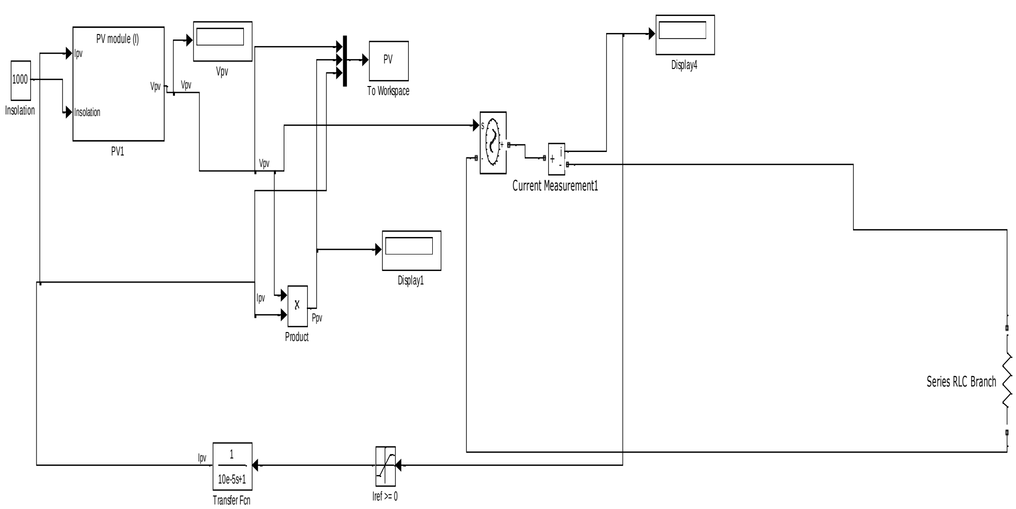
4.7. PV Array 15 KW Output



Isc = 54.5, Voc = 444, I pm = 49.5, V pm = 352, V= I*R, 444 = 54.5 R,R = 8.161 Ω
pv array 15 kw

Rating	Resistant	Voltage	power	Current
1000W/m²	10	389	15.13	38.9
800W/m²	10	369.8	13.66	36.98
600W/m²	10	306.3	9427 w	30.63
200W/m²	10	102.7	1057	10.27

4.8. PV Array 50 KW Output



Isc = 87.2, Voc = 888, I pm = 79.2, V pm = 704, V= I*R, 888 = 87.2 R, R = 10.18 Ω

Rating	RESISTANT	voltage	power	current
1000W/m²	10	737.7	54.49	73.77
800W/m2	10	655.7	43.08	65.57
600W/m2	10	500.6	24.99	50.06
200W/m2	10	166.1	2765 w	16.61

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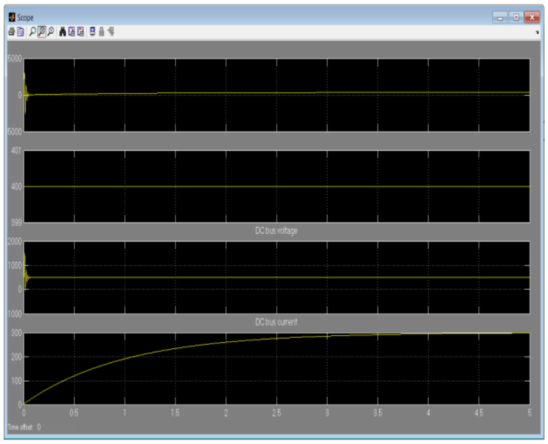
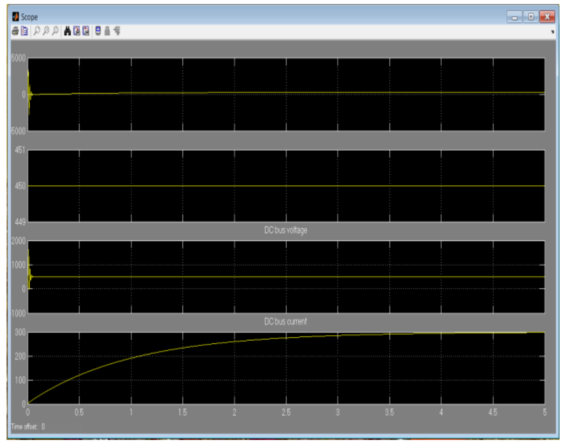
5. CONCLUSION

Solar energy offers many advantageous features over other alternative sources of energy and as shown in the paper the simple principle of heat energy can be applied in a variety of applications. Here result of pv array 36 cell in series and 15 & 50 KW output is attached.

INPUT	OUTPUT	CHANGE INPUT VOLTAGE	
Vdc = 400	Vdc = 500	Vdc = 450	Vdc = 500
Idc = 372.5	Idc = 298	Idc = 298	Idc = 331.1





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