International Journal of Engineering Sciences & Emerging Technologies, August 2013.
ISSN: 2231 – 6604 Volume 6, Issue 1, pp: 76-85 ©IJESET

DESIGN OF PHOTOVOLTAIC SYSTEM FOR A BISCUIT PACKING MACHINE

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ABSTRACT

The energy on earth depends on the sun. Solar energy is derived from the sun's nuclear fusion reactions within the continuous energy Earth's orbit. Humans rely on solar energy to survive, including all other forms of renewable energy (except for geothermal resources). The technical feasibility and economical viability of using solar energy depends on the amount of available sunlight (solar radiation). This is sometimes referred to as the available solar resource. This energy (i.e. solar energy) can also be used for industrial purpose to run various machines or to generate steam. Solar energy can be used in industries by converting it in to electrical energy through solar panel. In the present work, a photovoltaic power system (i.e. solar panel) is designed to operate food industry appliances i.e. Biscuit Packing Machine (BPM) using standard methods. The total load is estimated for 23 hours of operation per day. The battery is sized considering different factors that affect battery efficiency to reliably operate the estimated loads during a sequence of below average insulation. The minimum battery size is obtained to be 120 Ah, 12V. The Photovoltaic (PV) array is sized to operate the load on the daily basis based on average weather conditions. The array is sized to proper values in order to operate the system at the estimated load taking into account different types of power losses. Life cycle cost analysis of the proposed system has also been done.

KEYWORDS – *solar energy, BPM connected solar Photovoltaic system (SPV) system, life cycle cost analysis.*

I. INTRODUCTION

From electronic appliances to pharmaceuticals and air conditioning to water heating, energy is a part of people's lives more than ever before. But its benefits extend far beyond what people use individually at home, at wok or on road. A range of essential activities - including agriculture, computing, manufacturing, construction, health and social services- depends on resources of energy. Specially manufacturing industries would not exist without proper resource of energy. A demand of energy is increasing day by day due to the development of industries and modern human life. Due to this conventional resources of Energy (i.e. coal, petroleum and natural gas) are depleting day by day. The frequent supply of energy is affected due to consumption of energy increased, hence in order to fulfil the requirement of energy supply, an alternative source of energy have to be searched & designed. Renewable and non-renewable energy sources can be used to produce secondary energy sources including electricity and hydrogen. Renewable energy sources include solar energy, which comes from the sun and can be turned into electricity and heat. The photovoltaic (PV) effect is the basis of the conversion of light to electricity in photovoltaic, or solar, cells. Described simply, the PV effect is as follows: Light is a form of energy, enters a PV cell and imparts enough energy to some electrons (negatively charged atomic particles) to make them free. A built in-potential barrier in the cell acts on these electrons to produce a voltage (the so-called photo voltage), which can be used to drive a current through the circuit **[1]** individually at home, at work and on the road. Design of a solar panel to operate a "Biscuit packing machine" is observed as one of the best solution to provide energy in order to save conventional resource of energy or to operate a machine where power cut is a major problem. For this purpose we have surveyed different books, journals and papers to get its keen knowledge.

1.1. ENERGY RESOURCE POTENTIAL

Energy is a key input in economic growth. There is a close link between the availability of energy and the future growth of a nation. In spite of the increase in power generation capacity from 2000 MW in 1950 to 91,190 MW by the end of 2000, the peak shortage is expected to touch 30 percent [**1].** Energy is consumed in a variety of forms in India. Fuel wood, animal waste and agricultural residues are traditional sources of energy that continue to meet the bulk of energy requirement in rural India. These non-commercial fuels are gradually getting replaced by commercial fuels such as coal, lignite, petroleum products, natural gas and electricity. Commercial fuel accounts for 60 per cent of the total primary energy supply in India with the balance 40 per cent coming from non-commercial fuels. Of the total commercial energy produced in the form of power or electricity, 69% is from coal or thermal power, 25% is from hydel power, 2% is from nuclear power, 4% is from diesel and gas and less than 1% is from non-conventional sources like solar, wind, bio-gas, and mini hydel etc. [**1].** Petroleum and its derivatives are the other largest sources of energy. The Government of India has formulated an energy policy with the objective of ensuring adequate energy supply at a minimum cost, achieving self-sufficiency in energy supplies and protecting environment from adverse impact of utilizing energy resources in the non-judicial manner. The main features of the policy are accelerated exploitation of domestic conventional energy resources—oil, coal, hydro **[2].**

1.2. CONVENTIONAL RESOURCES

e.g. fossil fuels (coal, petroleum and natural gas), water and nuclear energy.

1.3. NON CONVENTIONAL ENERGY

e.g. solar, bio, wind, ocean, hydrogen, geothermal. India has a vast potential of renewable energy sources and a number of technologies have been developed to harness them. A number of industrial base has been created in the country in the various renewable energy technologies such as solar thermal, solar photovoltaic, wind, small hydro, biomass etc. An aggregate capacity of 900 MW has been installed, based on these technologies **[2].**

1.4. SOLAR PHOTOVOLTAIC SYSTEM

PV cells are made of light-sensitive semiconductor materials that use photons to dislodge electrons to drive an electric current. There are two broad categories of technology used for PV cells, namely, crystalline silicon, as shown in Figure 4 which accounts for the majority of PV cell production; and thin film, which is newer and growing in popularity. [12]

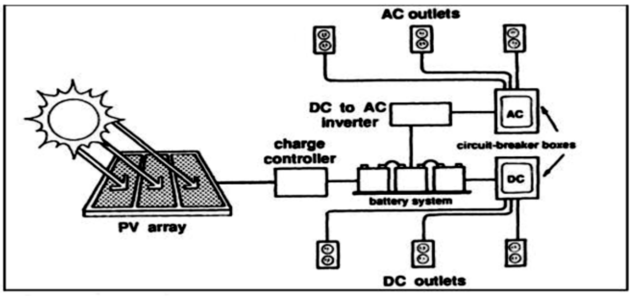

Fig. 1 Schematic diagram of a simple PV system

1.5. CRYSTALLINE SILICON & THIN FILM TECHNOLOGY

Crystalline cells are made from ultra-pure silicon raw material such as those used in semiconductor chips. They use silicon wafers that are typically 150-200 microns (one fifth of a millimetre) thick. Thin film is made by depositing layers of semiconductor material barely 0.3 to 2 micrometers thick onto glass or stainless steel substrates [**3**]. As the semiconductor layers are so thin, the costs of raw material are much lower than the capital equipment and processing costs [**3**]. Module efficiencies for different cell technologies is shown in table 1.

Fig. 2 Mono crystalline silicon PV cell

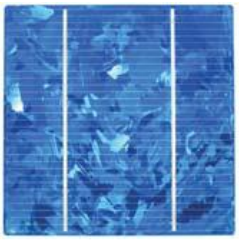

Fig. 3 Poly-Crystalline Silicon PV Cell

Table: 1 conversion efficiencies of various PV module technologies [3]

Technology	Module efficiency
Mono-crystalline Silicon	12.5-15%
Poly-crystalline Silicon	11-14%
Copper Indium Gallium Selenide (CIGS)	10-13%
Cadmium Telluride (CdTe)	9-12%

1.6. GRID CONNECTED PV SYSTEM

These systems are connected to a broader electricity network. The PV system is connected to the utility grid using a high quality inverter, which converts DC power from the solar array into AC power that conforms to the grid's electrical requirements. During the day, the solar electricity generated by the system is either used immediately or sold off to electricity supply companies. In the evening, when the system is unable to supply immediate power, electricity can be bought back from the network.

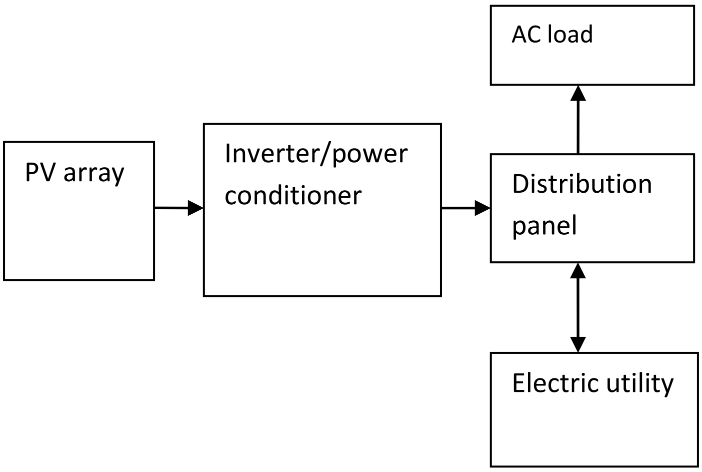

Fig. 4 Diagram of grid-connected photovoltaic system. **[4]**

1.7. OFF GRID SOLAR PV SYSTEM

An off-grid solar PV system needs deep cycle chargeable batteries such as lead-acid, nickel-cadmium or lithium-ion batteries to store electricity for use under required conditions. In this there is little or no output from the solar PV system, such as during the night **[4].**

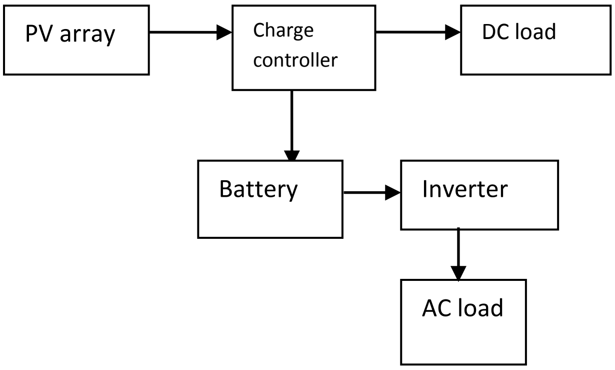

Fig. 5 Diagram of stand-alone PV system with battery storage powering DC and AC loads.

1.8. PHOTOVOLTAIC MODULE

PV cells are the basic building blocks of PV modules. For almost all applications, the one-half volt produced by a single cell is inadequate. Therefore, cells are connected together in series to increase the voltage. Several of these series strings of cells may be connected together in parallel to increase the current as well. These interconnected cells and their electrical connections are then sandwiched between a top layer of glass or clear plastic and a lower level of plastic or plastic and metal. An outer frame is attached to increase mechanical strength, and to provide a way to mount the unit. This package is called a "module" or "panel". Typically, a module is the basic building block of photovoltaic systems. PV modules consist of PV cells connected in series (to increase the voltage) and in parallel (to increase the current), so that the output of a PV system can match the requirements of the load to be powered. The PV cells in a module can be wired to any desired voltage and current **[6].**

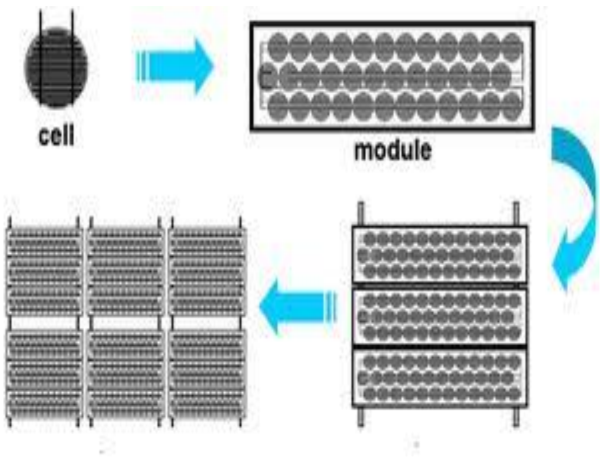

Fig. 6 Photovoltaic cell, module, panel and array

1.9. PHOTOVOLTAIC ARRAY

Desired power, voltage, and current can be obtained by connecting individual PV modules in series and parallel combinations in much the same way as batteries. When modules are fixed together in a single mount they are called a panel and when two or more panels are used together, they are called as array. When circuits are wired in series (positive to negative), the voltage of each panel is added together but the amperage remains the same. When circuits are wired in parallel (positive to positive, negative to negative), the voltage of each panel remains the same and the amperage of each panel is added. This wiring principle is used to build photovoltaic system.[12]

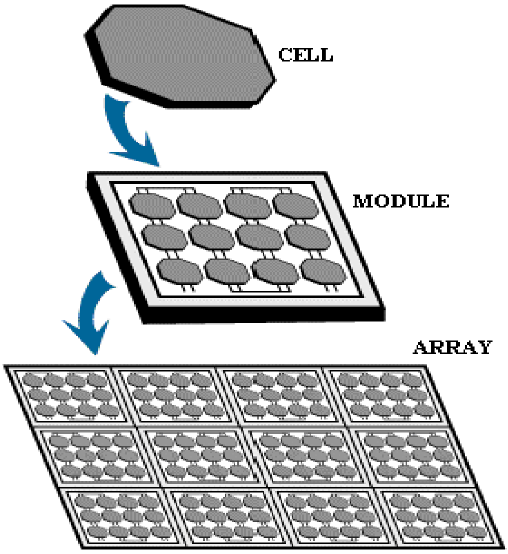

Fig. 7 Diagram of a Photovoltaic Cell, Module & Array.

II. METHODOLOGY

The sizing of standalone PV system consists of following Information [2]

1. The daily load requirement during a year.
2. The mean daily irradiation on the plane of the array for every month of typical year.
3. The maximum numbers of sunless days
4. Mean daily ambient temperature for every month the tilt factor for different tilt and azimuth angles.
5. The required security of supply.
6. The selected DC voltage.
7. Estimated loss in Array due to cable dust etc.
8. Estimated loss in battery.
9. Load estimation
10. Battery sizing
11. Design current and array tilt
12. Array sizing

III. SYSTEM DESCRIPTION

Technical description of biscuit packing machine is shown in table 2

Table: 2 Technical data of Biscuit Packing Machine [10]

Stack width	40mm – 75mm
Stack height	30mm – 70mm
Stack length	60mm – 250mm
Product width + height	<125mm
Wrapper cut-off length	120 – 350mm
Max reel width	280mm
Max reel diameter	340mm
Power	4KW
Input voltage	415/380V, 50/60Hz
Machine size	L 7.3m x W 2.0m x H 1.9m
Weight	2100Kg

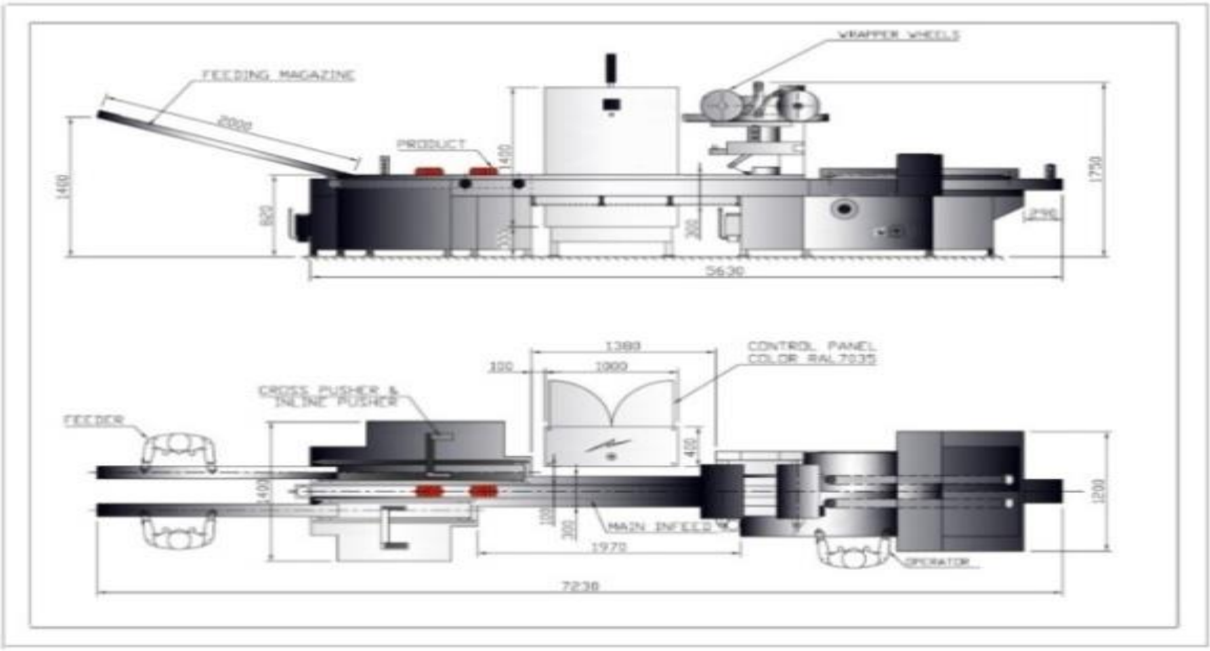

Fig. 8 A horizontal flow wrapping machine

IV. CALCULATION

Table: 3 Total Estimated load of the present system

A	V	PD	ADDC	MDED	MDL
BPM	415	4200	23	96600	233.17

Abbreviations:

A=Appliance

V=Voltage

PD=Power Demand in (Watt)

ADDC= Average Daily duty cycle (Hrs/Day)

MDED=Mean Daily Energy Demand (Wh/Day)

MDL=Mean Daily Load (Ah/Day)

Table : 4 Load Calculation for a typical Month in a year D.C. Bus Voltage = 415V

Mean daily solar radiation vailable	4.7 kWh/ m^2-day
Efficiency of the module	= 15%
Assume mean daily output available from a PVmodule surface area of $1m^2$	4.7× 1000 × 0.15/415= 1.7 Ah/day
Assume Array losses due to module mismatch, blocking diodes, dirt, and degradation	2%
Gross mean daily output available from module area of 1 m^2	1.7 × 0.98 Ah/day 1.66 Ah/day
Corrected mean daily Load	=285.91 Ah / day
Area of PV module required	= 285.91/1.66 = 172.23 m^2
Area of standard PV module	= 1.256 m^2

No. of PV modules	= 172.23/1.256 =137.23--rounded up to 138
For a d.c. bus voltage of 415 V, minimum number of module strings	= 138/35 = 3.94--rounded up to 4.
For a d.c. bus voltage of 415V, No. of modules per string	415+1(allowance for blocking diode) / Working voltage (12V) =34.6 --- rounded up to 35
Arrays will be oriented to latitude angle of the place (Gwalior India)	= 26.14 N

4.1 Battery Sizing

Required Battery Capacity is given by [1]

$$B_{rc} = \frac{E_{c\,(Ah)} \times D_s}{(DOD)_{max} \times \eta_T} \quad (1)$$

Here

D_s =Battery autonomy or storage Day = 2 days

$(DOD)_{Max}$ = Maximum battery depth of discharge = 65%

$\eta_T =$ Temperature correction factor $= 0.9$

Total numbers of Batteries is given by [1]

$$N_b = Bp \times Bs \quad (2)$$

Where,

$$Bp = Brc/B_{SC} , \quad (3)$$

Bp= battery in parallel

Here, Brc = battery required capacity

$$Bs = V_{nsv}/V_{nbv} \quad (4)$$

4.2 Electrical Parameters

Maximum Power Rating P_{max} $(W_p)^*$ = 150
Maximum Power Rating P_{min} $(W_p)^*$ = 180
Rated current I_{mpp} (A) = 4.80
Rated voltage V_{mpp} (V) .34.0
Short Circuit Current I_{SC} (A) = 5.0
Open Circuit Voltage V_{oc} (V) = 42.8
Physical Parameters
Number of Cells = 72
Physical Dimensions (mm) L × W × T
=1580 ×795 × 42 Wt (kg) =14
Environmental NOCT = 45°C±2
Max Permitted module temp ˚C = -80 + 0 + 85
Max. Permissible system voltage = 600
Relative humidity at 85°C = 85%
Temp Coefficient short circuit current + .0004/K
Temp coefficient of Open circuit voltage = .0034/K
Irradiance = 1000 W/m^2
Cell Temp = 25°C

V. COST ANALYSIS

Table: 5 following cost **[8]** for the various items have been considered for calculation of cost analysis of the present system:

INVESTMENT SPECIFICATION	COST
PV module	2520000
PV module installation	60000
Battery bank	3780000
Inverter	10000
Control system	99000
Other components	10000
System installation	20000
Maintenance cost	50000

Assumption:
System degradation per year=4% and no salvage value after 25 years of life
Discount rate=16.6%
Inflation rate-5%

Calculating Life Cycle Cost

While calculating the cost of generating per unit of solar electricity, we use the concept of Lifecycle Cost of Electricity (LCOE). LCOE is the ratio of Total Lifecycle Cost (TLCC) and the Total Lifetime Energy Production (TLEP) [8].

$$LCC\ of\ electricity = \frac{TLCC}{\sum_{n=1}^{N}[Initial\ kWh * (1 - system\ degradation)^n]} \quad (5)$$

Where is N is life of system in years.
TLCC can be calculated as follows:

TLCC = LCC (Initial investments + Recurring Cost + Replacement cost-Salvage value) (6)

Thus in order to find out the TLCC one needs to know (i) initial investments, (ii) recurring cost (the cost of maintenance) and (iii) replacement cost incurred for the operation of system during its lifetime.

(i) Initial investments mean the cost of system is estimated at the time of installation. This is nothing but the sum of all costs of the PV system components.
LCC initial investment= Rs.2709000
(ii) The recurring costs are given as **[8]:**
LCC recurring cost=

$$\text{MC} \times [(\frac{1+inflation}{discount\ rate - inflation}) \times (\frac{1+inflation}{1+discount})^n] \quad (7)$$

(iii) LCC Replacement Costs are given as:
LCC replacement cost =

$$\sum [\text{item cost} \times \{1 + (\frac{1+inflation}{1+discount\ rate})^{Ry}\}] \quad (8)$$

Where R_y = Replacement year

$$LCC\ of\ electricity = \frac{TLCC}{\sum_{n=1}^{N}[Initial\ kWh \times (1 - system\ degradation)^n]}$$

VI. RESULTS

In the present work A Photovoltaic system is design to operate a Biscuit Packing Machine for the estimated load of Machine 233.17 Ah/Day. Battery system is sized for Photovoltaic system and total number of battery (i.e. in Series & Parallel) is determine i.e. in series total number of battery is 35 and in parallel total number of battery is 09 and total number of battery required is 315. The Photovoltaic system is designed for the month of July. Area of Photovoltaic module is determine i.e. 172.23 M^2. Number of Photovoltaic modules is 138 and total number of module / string is 35. The array will be oriented to latitude angle of 26.14 N (slandered for Gwalior). Cost of electricity production from Photovoltaic system is also determine i.e. Rs. 15.095 per unit.

Table : 6 Design parameters of required Photovoltaic System

Estimation	Total Estimated load of the system	233.17Ah/Day
	Corrected Ampere hour load	285.91 Ah/Day
Battery Sizing	Required battery capacity in Ampere hour (Ah) is given by	977.47 Ah
	Capacity of selected battery (Ah)	120 Ah
	Batteries in parallel	09

	Batteries in series	35
	Total batteries	315
Design Month	July	
Monthly average solar radiation of July	4.7 $kWhm^2$	
Mean daily output available from a PV module surface area of $1m^2$	1.7 Ah/Day	
Array Losses due to module mismatch, blocking diode etc	2%	
Gross mean daily output available from module area of $1m^2$	1.66 Ah/Day	
Mean Daily load required	285.91 Ah/Day	
Area of PV module	172.23 m^2	
Area of standard PV module	1.256 m^2	
Number of PV modules	138	
Number of modules/string	35	
Arrays will be oriented to latitude angle of place	26.14 N	
Cost of electricity production from PV system	Rs. 15.095 Per unit	

VII. CONCLUSION

The photovoltaic system is design on the basis of potential measured, system specifications and required load. Each element of this PV system is designed on the basis of design calculation outcomes. The main objective to design this system is to run machines which are producing goods or used in the production of goods i.e. eatables items like biscuits, breads in food manufacturing industry placed in the areas where continuous supply electrical energy is a major problem. The basic work of machine is to pack the freshly made biscuit in order to save them from moisture or from the elements which can contaminate the biscuits and also to make them ready to put in the market to fulfil demand. As it clear from above mentioned points that how proper and timely packing of biscuit or any eatable item plays important role in its production. As power cut or continuous supply of electrical energy to industries is a major problem due to which lot of industries suffering from production loss, so it is very difficult to produce eatables like biscuits etc. by advanced machines under same circumstances as mentioned above that's why in order to solve these problems we have carried out this work for a "Biscuit packing machine". This PV system is designed by taking required load of machine. With help of this system electrical energy can supplied during power cut or during unavailability of conventional sources of electricity generation. The cost of electricity production from PV system is Rs. 15.095 per unit.

VIII. FUTURE SCOPE

In the present work a PV system is designed to operate a single machine used in food industry , in order to save production loss due to unpredicted power cut on a single station of complete production line, the system have limitation to run a single machinery due to some constraints of time limitation to finish design work of this system but still in future within the same methodology of design a PV system may design to run complete production line by supplying electrical energy at all station of production line .

NOMENCLATURE

B_{RC}	BATTERY REQUIRED CAPACITY
$E_{C(Ah)}$	LOAD CORRECTED IN AMPERE HOUR
D_S	DAILY STORAGE (BATTERY)
$(DOD)_{Max}$	BATTERY DEPTH OF DISCHARGE MAXIMUM
η_T	CORRECTION FECTOR TEMPERATURE
Nb	NUMBERS OF BATTERIES
Bp	BATTERY PARALLEL
Bs	BATTERY SERIES

B_{rc}	BATTERY REQUIRED CAPACITY
B_{SC}	SELECTED CAPACITY OF BATTERY
V_{nsv}	NOMINAL SERIES VOLTAGE
V_{nbv}	NOMINAL BATTERY VOLTAGE
P_{max}	POWER MAXIMUM
P_{min}	POWER MINIMUM
W_p	WATT PEAK
I_{mpp}	RATED CURRENT
A	AMPERE
V_{mpp}	RATED VOLTAGE
V	VOLTAGE
I_{SC}	SHORT CIRCUIT CURRENT
V_{oc}	OPEN CIRCUIT VOLTAGE

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BIOGRAPHY

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