# Design and Analysis of Mini Grid in ETAP Software

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***Abstract:*** Demand of power supply is increasing now a days. Consumer requires a reliable and continued supply. Mini grid is very useful option for meeting an increased demand of supply. Small and remote villages are more electrified by mini grid. Pollution in environment and cost of conventional sources increase day by day, so we are moving to the non-conventional sources like wind, sun, geothermal, biomass, etc. These sources are more economical and easily available at remote areas. Here, PV cells are used for source of energy. In this paper, mini grid is compared with other electrifications systems, basic elements, challenges and opportunities. This paper discusses design methodology and analysed case study of PV based mini grid in ETAP software.

***IndexTerms*** **- Mini-Grid, Rural Area, PV Cell, Renewable Energy (RE), Battery, ETAP, AC and DC load flow**

## I. INTRODUCTION

Mini gird is a system which has a renewable energy based generator whose capacity is of 10KW or above and giving supply to a set of customers mainly residential, productive, commercial and industrial [1]. Mini grids give a better opportunity for rural electrification. Mini grid provides a low cost, better reliability of power, good environment [2]. Mini grid can be classified as follows: (1) Category A - < 10 KW, (2) Category B – 10 to 100 KW, (3) Category C – 100 to 250 KW, (4) Category D - > 250 KW [2]. Mini grid helps to improve environment condition and carbon emission [2]. Small size and local physical infrastructure system reduces problems of power theft. Mini grid is more attractive because of low cost of renewable power source as compared to fuel cost [2]. Mini grid is mainly used in remote area to supply load [5].

## II. MINI-GRID CONFIGURATION

### 2.1. Configuration

Mini grid system includes following configuration such as system can be supplied DC load, AC load or AC/ DC load both together which depends on which type of load have to supply. Mini grid can be a hybrid system to increase reliability of supply but it will increase the complications in design. Fig 1, 2 and 3 shows a hybrid mini grid system which convert its supply to same voltage rating.

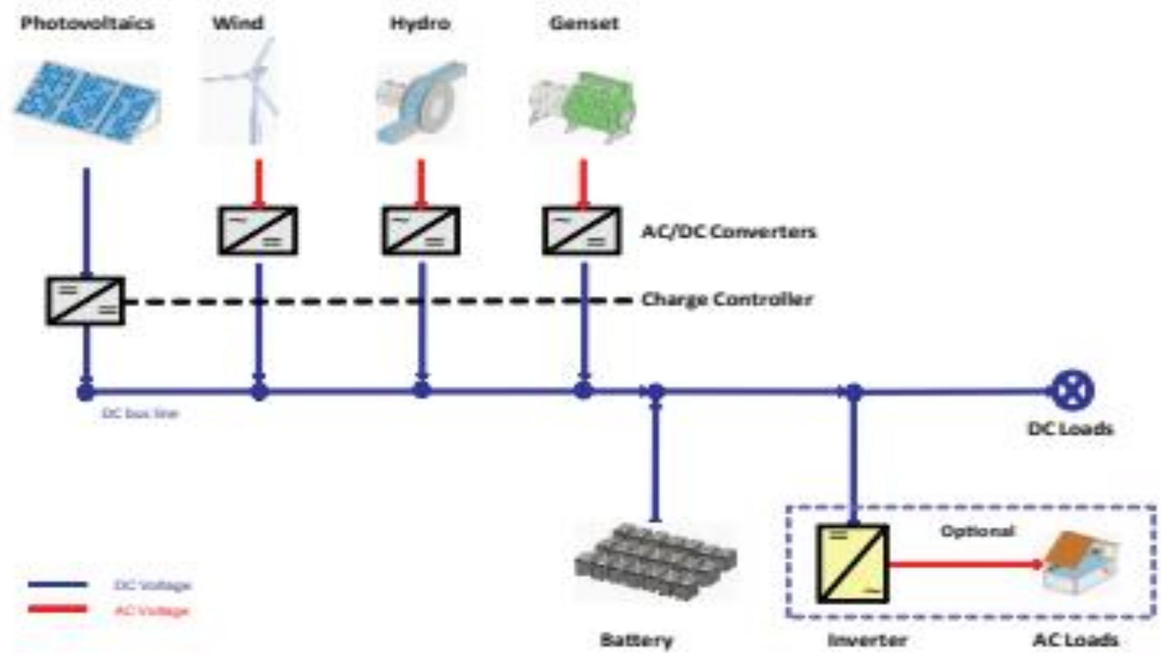



Figure 1. Electricity generation coupled at DC bus bars

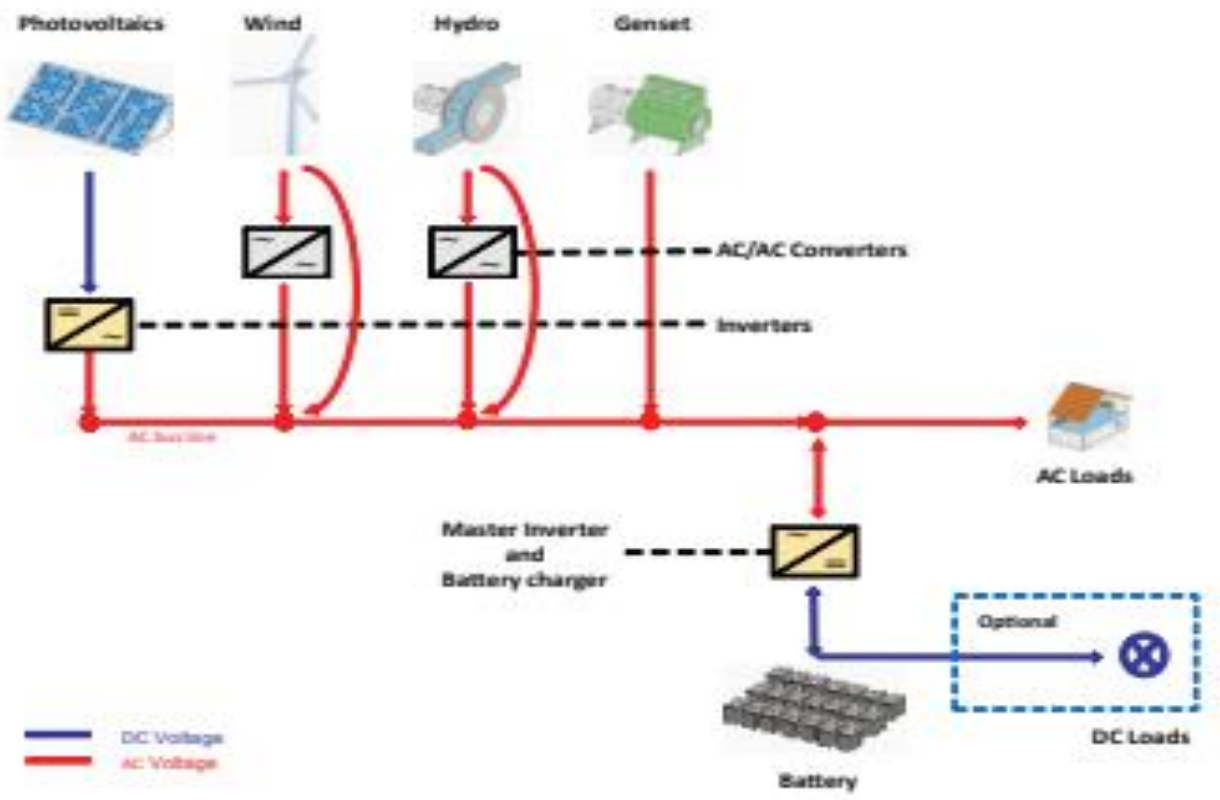



Figure 2. Electricity generation coupled at AC bus bars

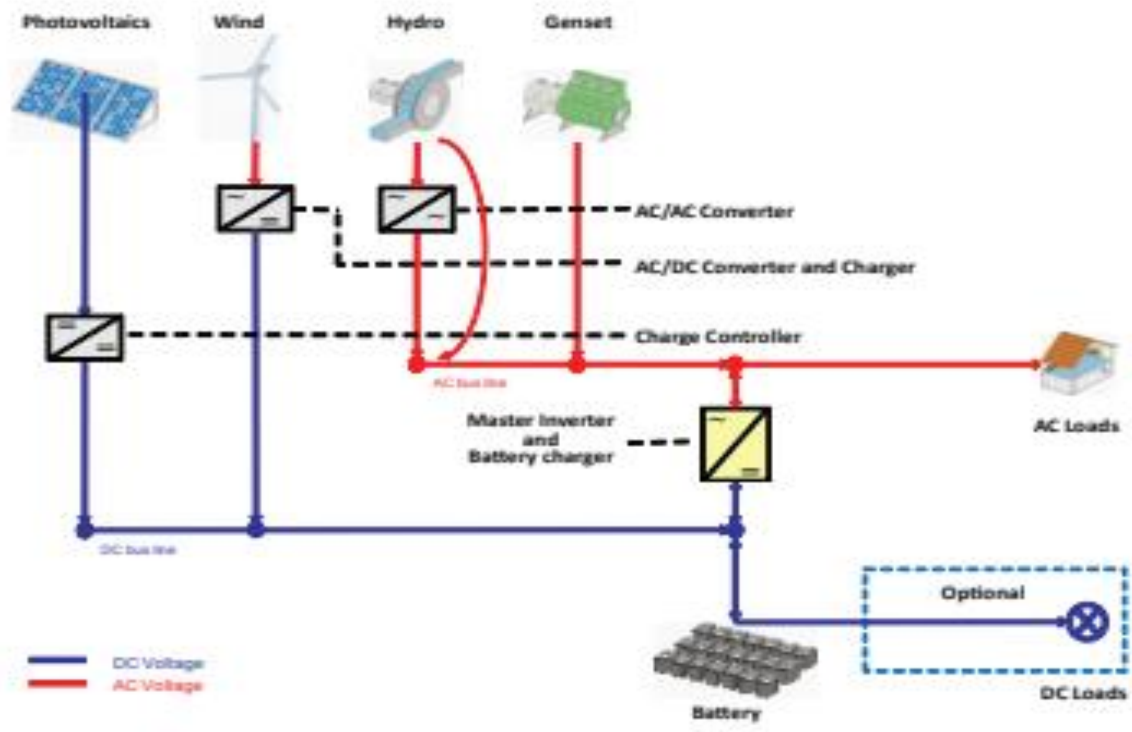



Figure 3. Electricity generation coupled at AC/DC bus bars

## III. DESIGN OF SOLAR PV (STANDALONE) SYSTEM AS MINI GRID

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [2], [5]. The discussion can be made in several sub-chapters.

### 3.1. System Description

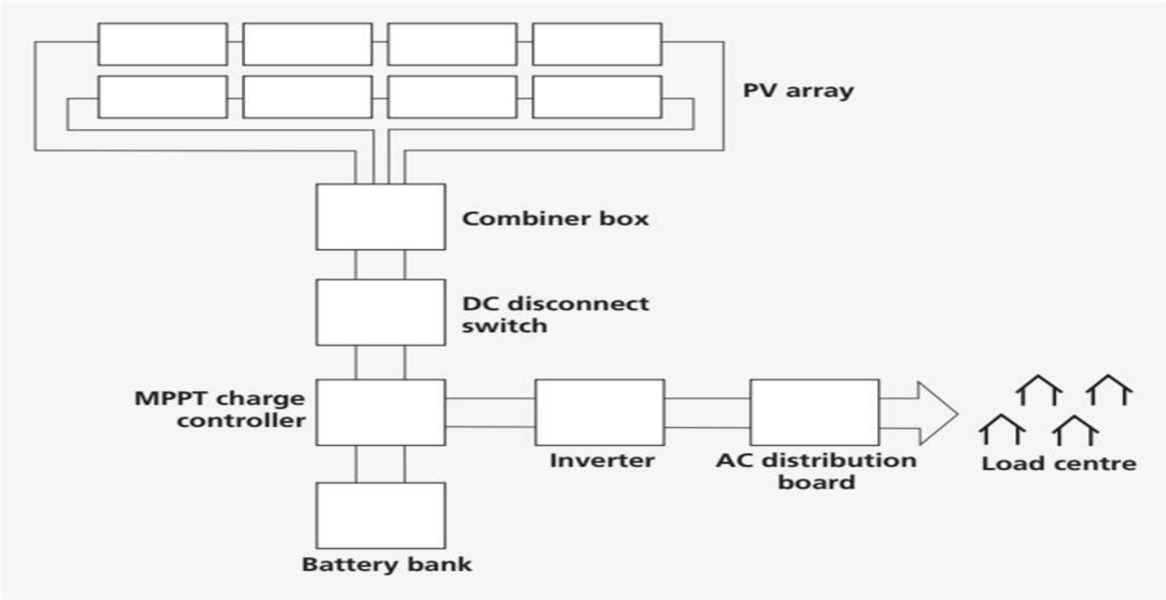



Figure 4. Standalone Mini Grid

PV array which containing the series and parallel combination of PV cells for meeting an increased demand of supply. A single module can produce the power in range of few watts. So PV array gives a large range of power supply. Combiner box connects the each PV module through a cable and also it's provide protection from surge. DC disconnect switch which mainly provided inside the combiner box, is used to separate out the PV for the protection purpose. MPPT charge controller has two functions: it provide a maximum power point means it gives a maximum power from PV array and charges the battery according to its requirement. Battery does the main function when sunlight is not available. It gives a power to the consumers. Inverter provides the AC power supply to the load by converting DC supply into the AC supply. Load which contains total number of houses of village. AC distribution box from which AC power supply is given to load.

### 3.2. Design of System

PV system can be designed by following steps which are: Estimation of Load, Selection of Electronics Components, Size of Battery, size of PV module and other component. System design starts from load side to PV array. So direction of power flow is PV array to Load side and system design is load to PV array. Flow of energy in PV Mini grid is shown in fig 5.

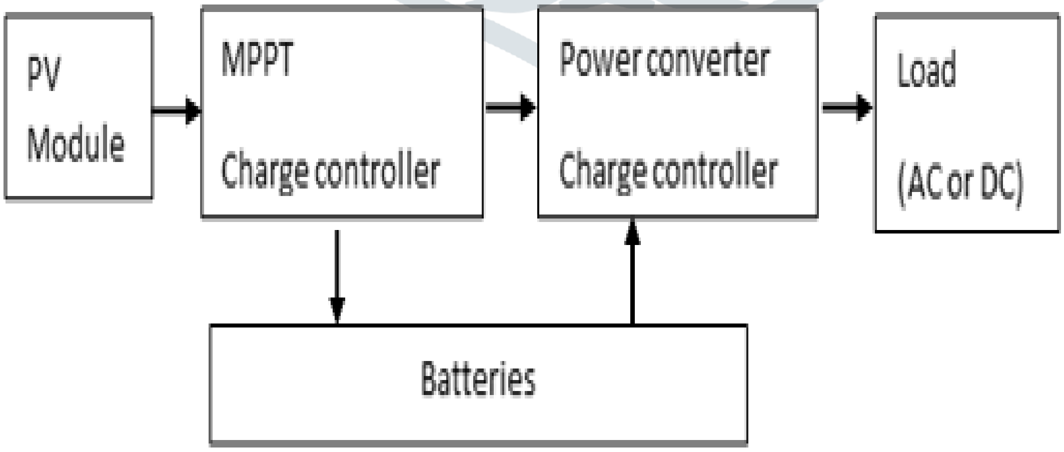



Figure 5. Flow of Energy

#### 3.2.1. Load estimation

First and very important step for system design is determination of total supply required for load which contains 40 houses. Number of houses, appliances and their consumption is shown in Table 1. So, the total power and energy are 3,648 W and 25,920 Wh respectively.

Table 1. Demand of electricity

| Appliances | Nos. | Power (W) | Power consumption (hours) | Households | Power require (W) | Energy require/ day (Wh) |
|---|---|---|---|---|---|---|
| Lights (LED) | 2 | 4 | 6 | 40 | 320 | 1,920 |
| Lights (LED) | 2 | 2 | 6 | 40 | 160 | 960 |
| Television | 1 | 12 | 5 | 40 | 480 | 2400 |
| Ceiling/table fan | 1 | 25 | 12 | 40 | 1000 | 12000 |
| Mobile charging | 1 | 8 | 3 | 40 | 320 | 960 |
| VCD/set-top box | 1 | 30 | 5 | 40 | 1200 | 6000 |
| Street light | 14 | 12 | 10 | - | 168 | 1680 |
| Total | | | | | 3648 | 25920 |

**3.1.2. Selection of Electronics Components**

Proper selection of electronics component is the next step in design process in which MPPT charger controller and inverter is included. Inverter rating is decided from rating power of load which is product of voltage and current at load. Here the capacity of inverter is not total load power (means 3648 W), but also consider power loss in transmission lines and distribution lines (21% in India). Here, efficiency of inverter is assumed as 90% and system voltage 250 V. Input and output parameters of Inverter is shown in Fig. 6.

$$Output\ power\ from\ inverter = \frac{Total\ load\ power}{(1-0.21)} = \frac{3648}{0.79} = 4{,}618\ W \quad (3.1)$$

$$Input\ power\ from\ inverter = \frac{Output\ Power}{efficiency} = \frac{4618}{0.9} = 5{,}131\ W \quad (3.2)$$

$$Current = \frac{Battery\ output\ power}{System\ voltage} = \frac{5{,}131}{250} = 20.52 = 21\ A \quad (3.3)$$

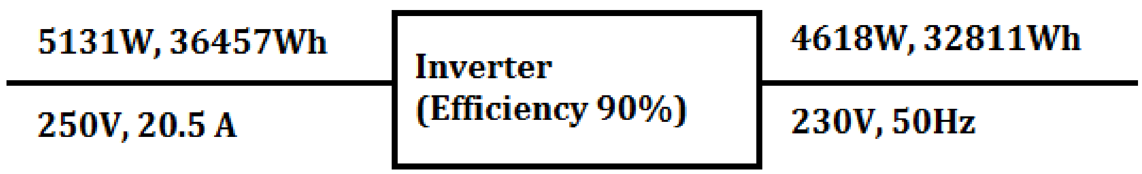



Figure 6. Input and output of Inverter

**3.1.3. Size of Battery**

The output of Battery is given to inverter as input. Capacity of battery is found by following formula.

$$Battery\ capacity(Ah) = \frac{Input\ energy\ of\ inverter * Days\ of\ Autonomy}{Sys.voltage(V) * DoD(\%)} \quad (3.4)$$

$$Battery\ bank\ capacity(Ah) = \frac{36457\ Wh*1}{250\ V*50\%} = 292\ Ah \quad (3.5)$$

Battery is not totally discharged to give supply to the load. How many percentage of charge is discharged is called Depth of discharge (DoD).

$$Number\ of\ batteries\ connected\ in\ series = \frac{System\ voltage}{Battery\ voltage} = \frac{250}{12} = 21 \quad (3.6)$$

$$Number\ of\ batteries\ connected\ in\ parallel = \frac{292}{150} = 2 \quad (3.7)$$

**3.1.4. Size of PV Module**

Efficiency of battery is taken as 90%. Tata Power Solar – TP 260 is taken for given system.

$$PV\ modules\ output\ energy = \frac{Output\ of\ battery}{Effeciency\ of\ Battery} = \frac{36{,}457\ Wh}{0.9} = 40{,}507\ Wh \quad (3.8)$$

The average radiation is up to 7 KWh/m$^2$ per day. Rated solar radiation is given as 1 KWh/m$^2$ by manufacturer. Solar radiation for village is assumed as 6 KWh/m$^2$.

$$Daily\ hours\ of\ sunlight = \frac{Daily\ solar\ radiation}{Power\ density\ in\ STC} = \frac{6\ KWh\ per\ sq.m}{1\ KW\ per\ sq.m} = 6\ hours \quad (3.9)$$

Module's power rating is 260 W and the voltage and the current at maximum power point are 30.6 and 8.49 respectively.

$$Total\ PV\ wattage(W) = \frac{Energy\ demand(Wh)}{Average\ sun\ hours\ (h)} = \frac{40507.8}{6} = 6751\ W \quad (3.10)$$

$$Total\ modules\ required = \frac{Total\ PV\ wattage(W)}{Module\ power\ (W)} = \frac{6751.2}{260} = 25.9 = 26\ modules \quad (3.11)$$

So we require a 26 modules in our system.

$$Number\ of\ modules\ in\ series = \frac{System\ voltage}{Module\ power} = \frac{250}{30.6} = 8.2 = 9\ modules \quad (3.12)$$

$$Number\ of\ modules\ in\ parallel = \frac{System\ current}{Module\ current} = \frac{20.52}{8.49} = 2.4 = 3\ modues \quad (3.13)$$

So, we have to connect 9 modules in series and 3 modules in parallel.

**3.1.5. Size of Wire**

For DC side,

Operating voltage is system voltage 250 V

$$Maximum\ current\ (A) = \frac{Max\ power}{System\ voltage} = \frac{6751.2}{250} = 28\ A \quad (3.14)$$

Similarly for AC side,

Operating voltage is 230 V

$$Maximum\ current\ (A) = \frac{Max\ power}{System\ voltage} = \frac{4618}{230} = 21\ A \quad (3.15)$$

## IV. SIMULATION IN ETAP 12.6 FOR DESIGN AND ANALYSIS OF THE SYSTEM

### 4. 1. System model

Given system is implemented in ETAP as shown in Fig. 7. Here PVA1, PVA2, and PVA3 are particularly 3 array strings each constitutes 9 solar module in series. DC cable are used which connect string array and array combiner box to get single output. AC cables are used and load demand is of 4 KW for distribution.

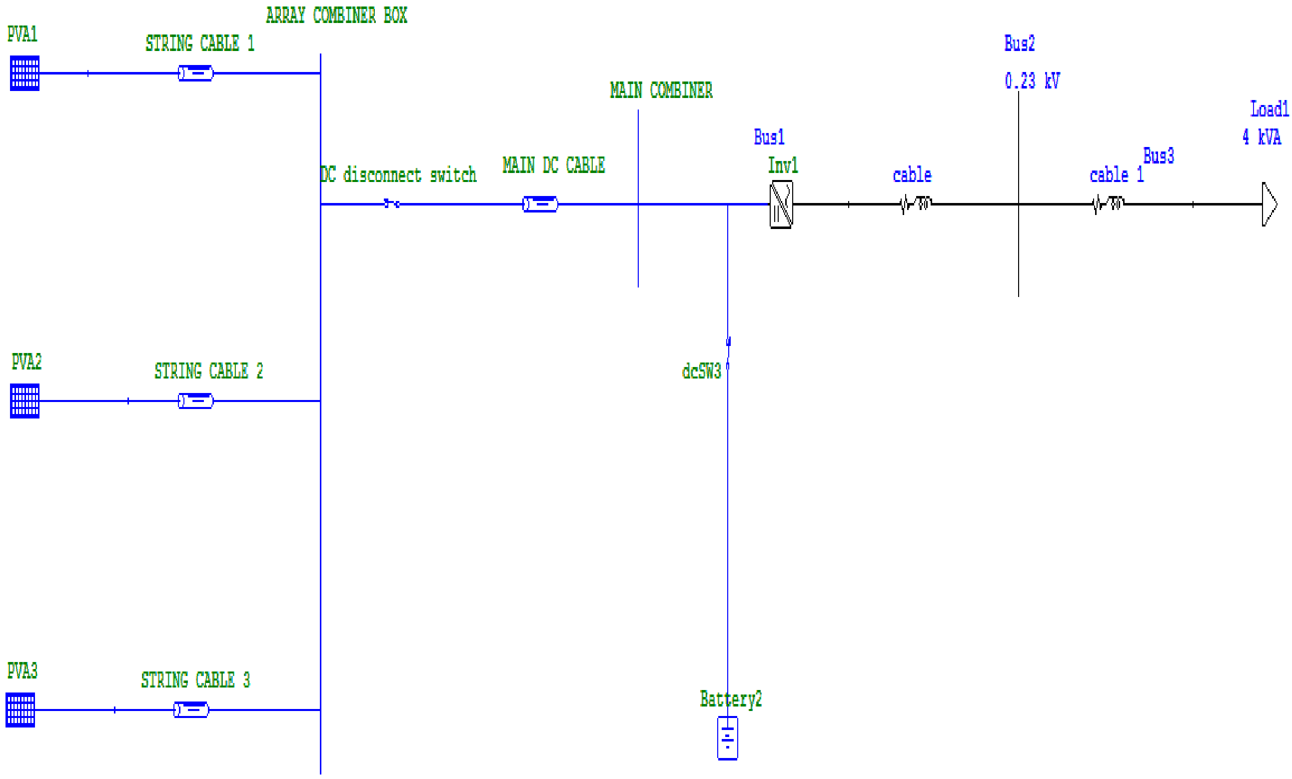



Figure 7. Simulation model in ETAP 12.6

**4. 2. Parameters of PV System Elements**

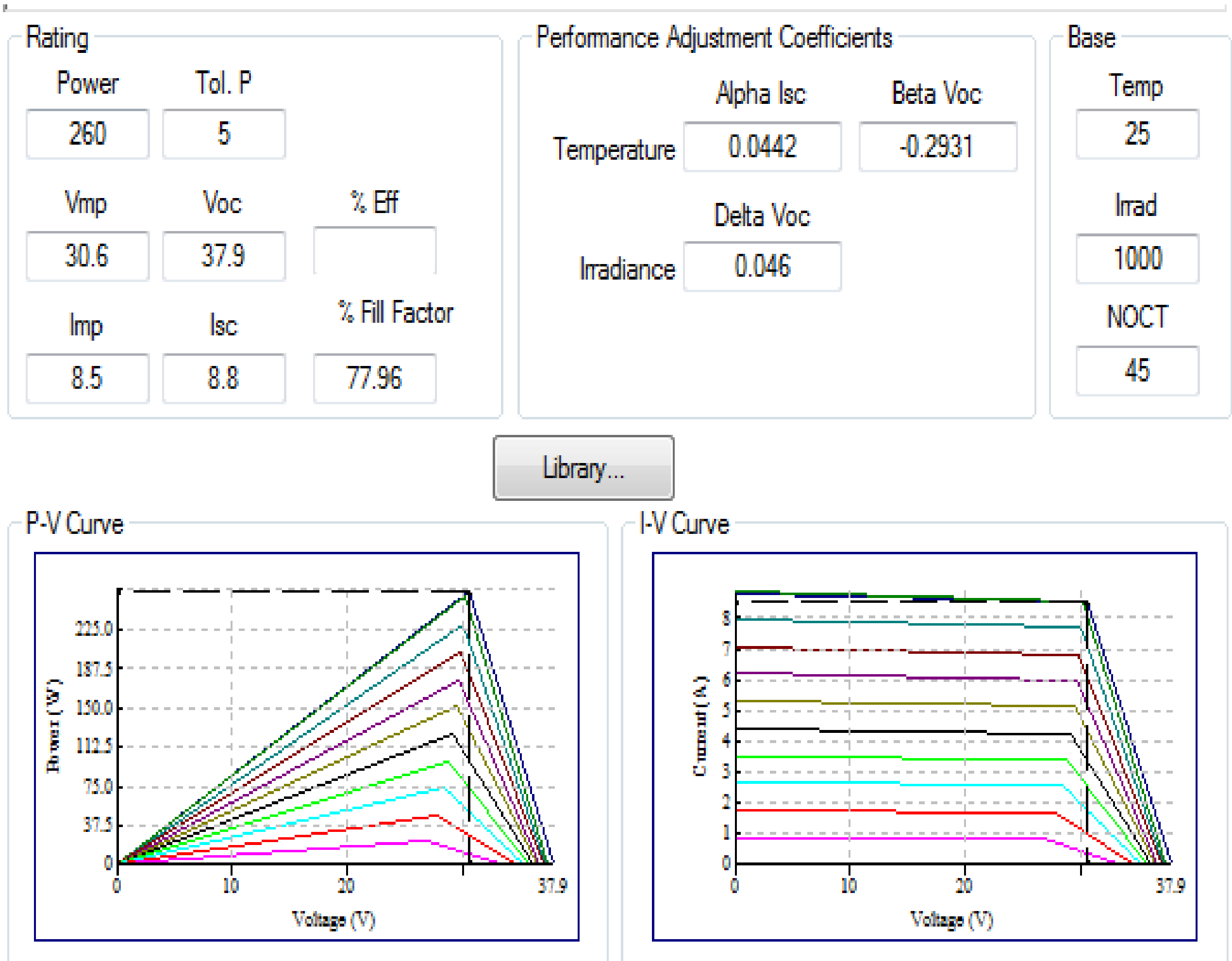
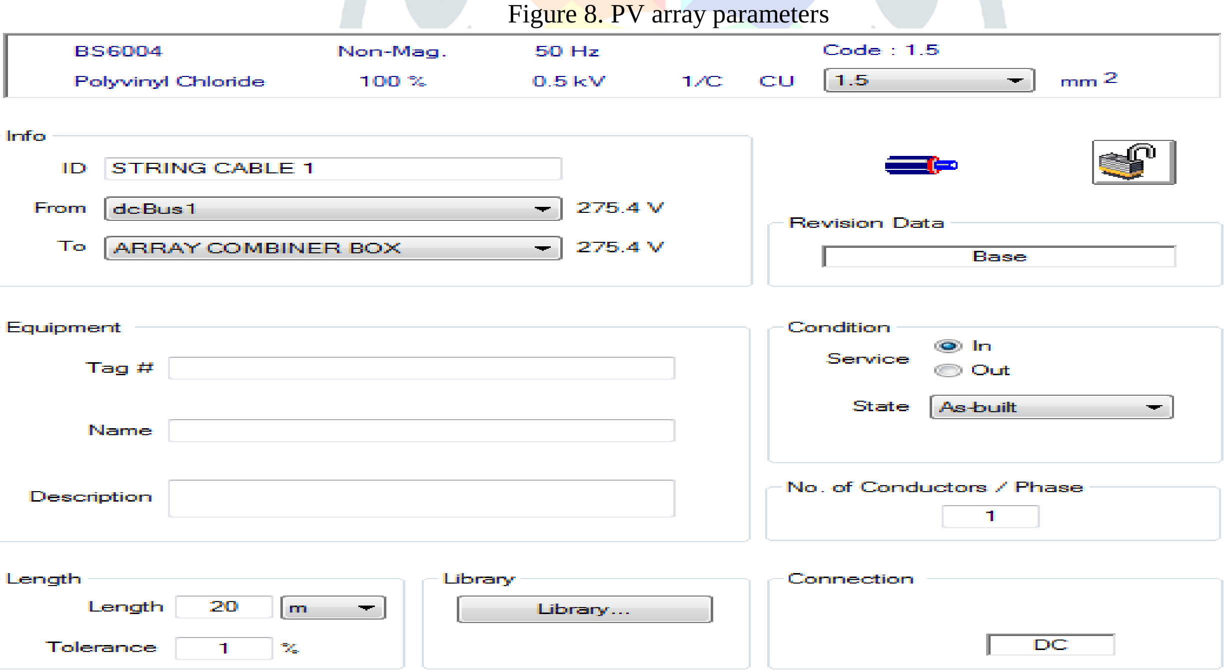



Figure 8. PV array parameters



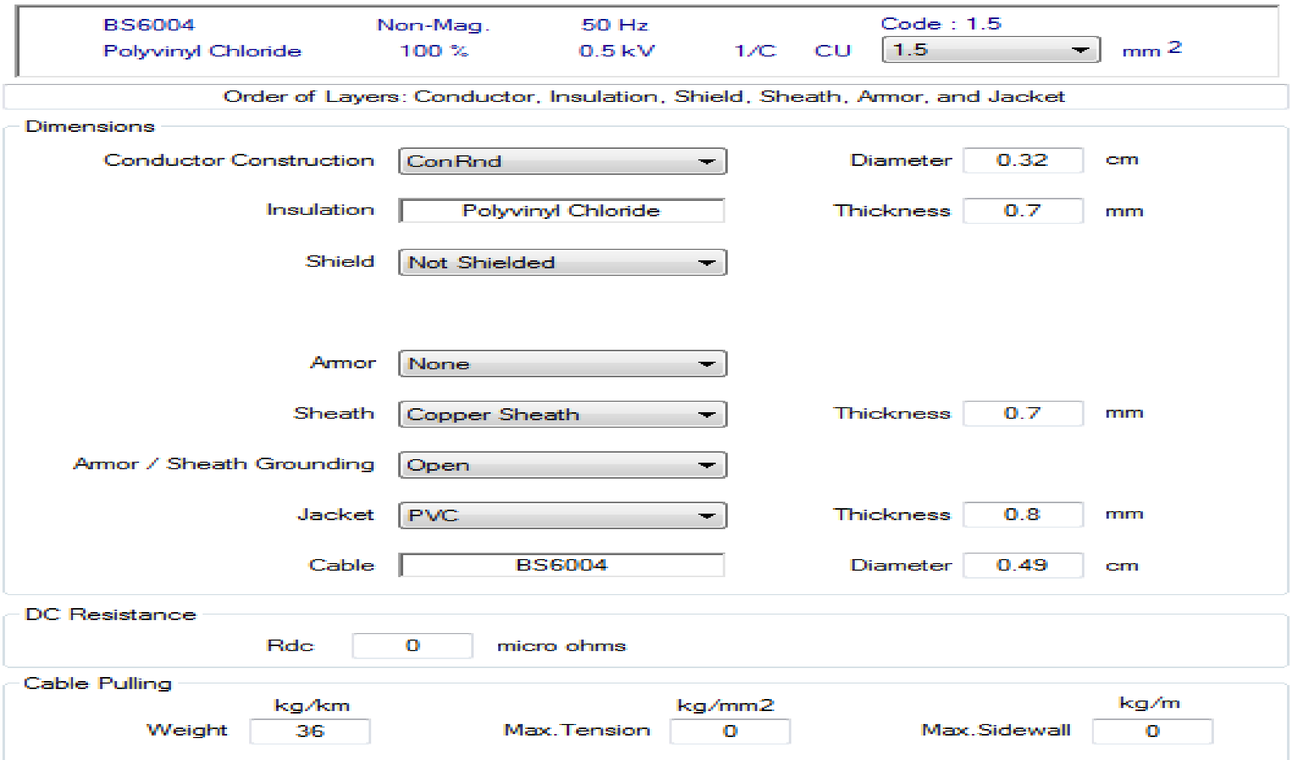



Figure 9. String DC cable parameters

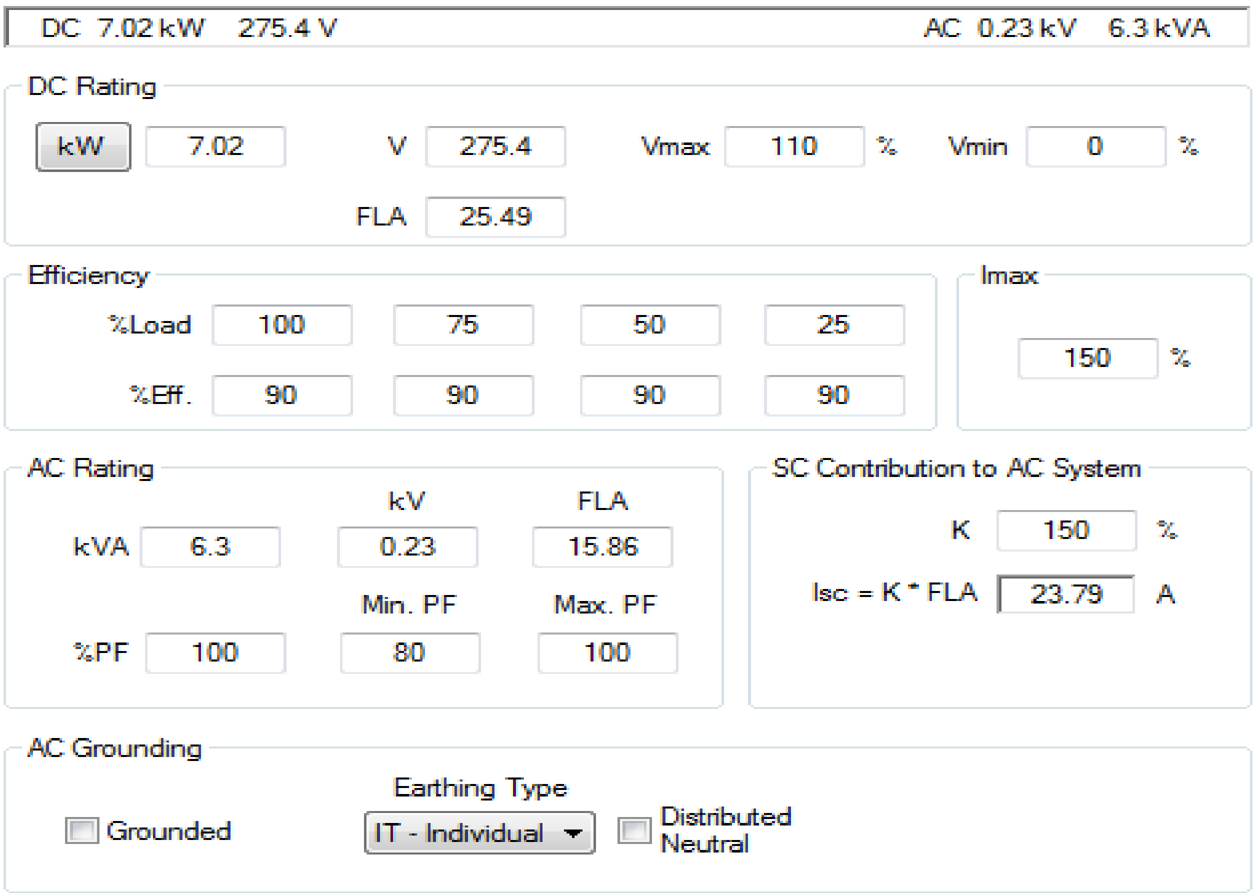



Figure 10. Inverter Parameters

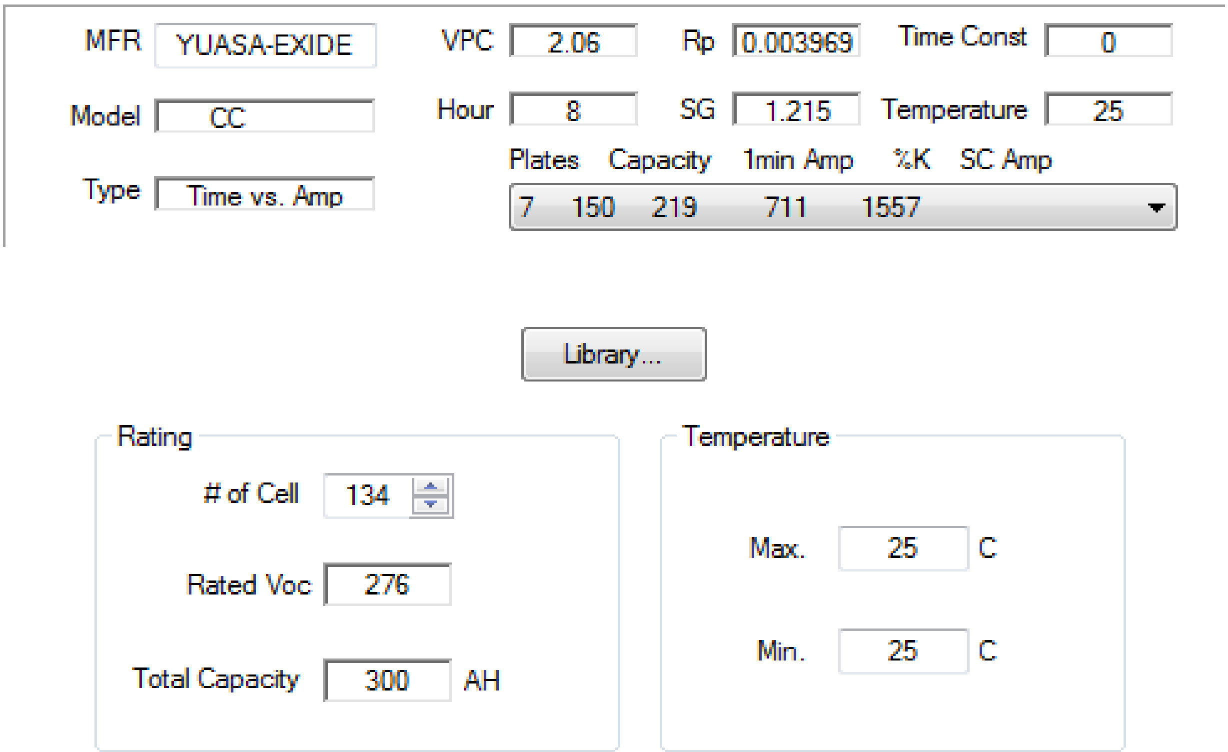



Figure 11. Battery Parameters

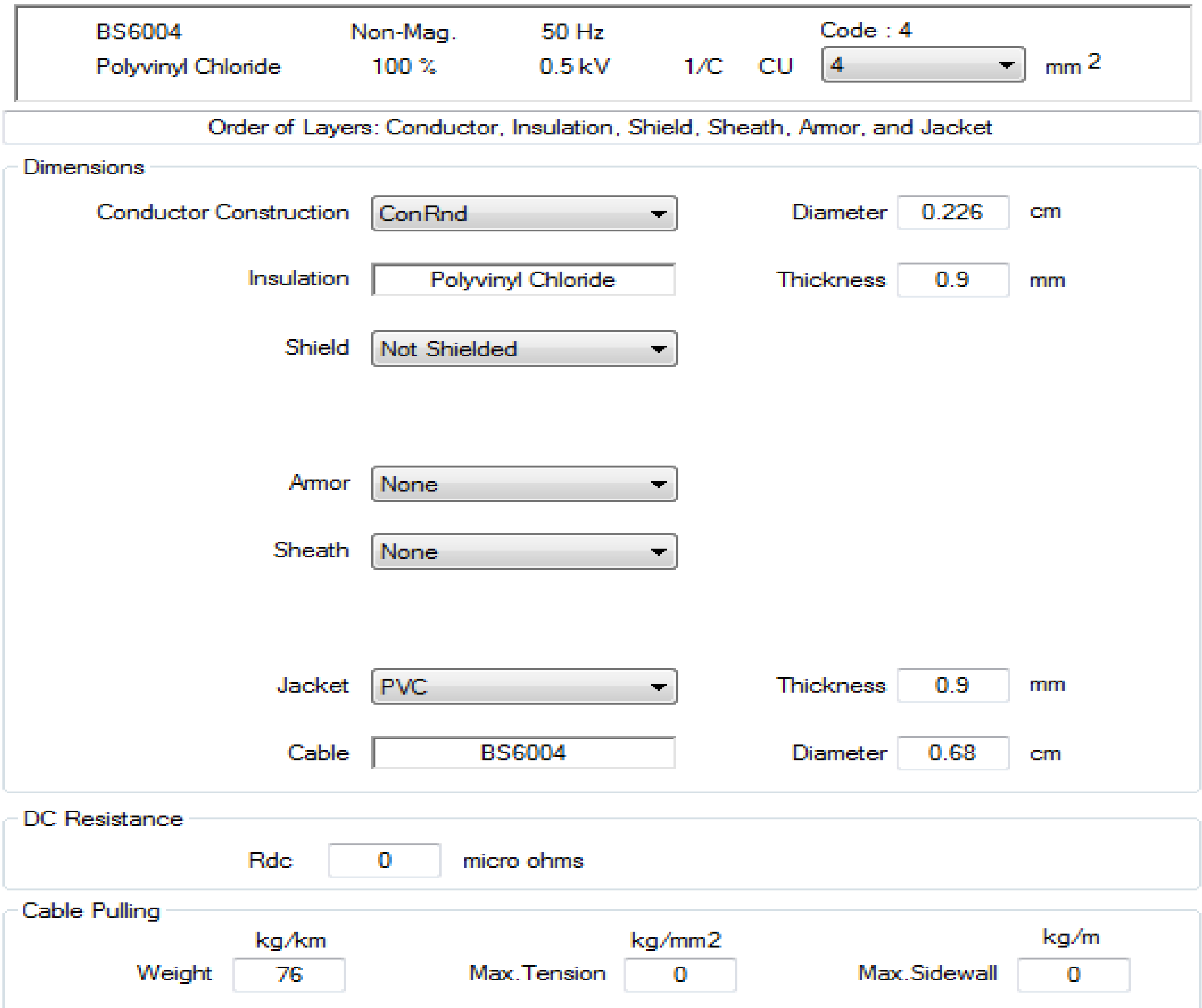



Figure 12. Main Distribution AC Cable Parameters

## V. RESULTS OF SIMULATION

(Note: ETAP shows either a DC load flow or AC load flow at a time). As shown in Fig. 13, PV gives supply to the battery for charging it and also gives a supply to the load. DC load flow is shown in Fig. 13. AC load flow is shown in Fig. 14 where battery is not giving a power to the load, only PV gives power supply to the load. Table 2 shows a power flow when PV is as source.

Table 2. Power flow when PV as source

| Power Flow Direction | Kw | V |
|---|---|---|
| PVA1 to Array Combiner Box | 2.193 (DC) | 275.4 (DC) |
| PVA2 to Array Combiner Box | 2.193 (DC) | 275.4 (DC) |
| PVA3 to Array Combiner Box | 2.193 (DC) | 275.4 (DC) |
| Array Combiner Box to Main Combiner | 6.581 (DC) | 257.27 (DC) |
| Main Combiner to Inv1 | 4 (DC) | 257.27 (DC) |
| Inv1 to Bus 2 | 4 (AC) | 230 (AC) |
| Bus 2 to Load | 4 (AC) | 227 (AC) |

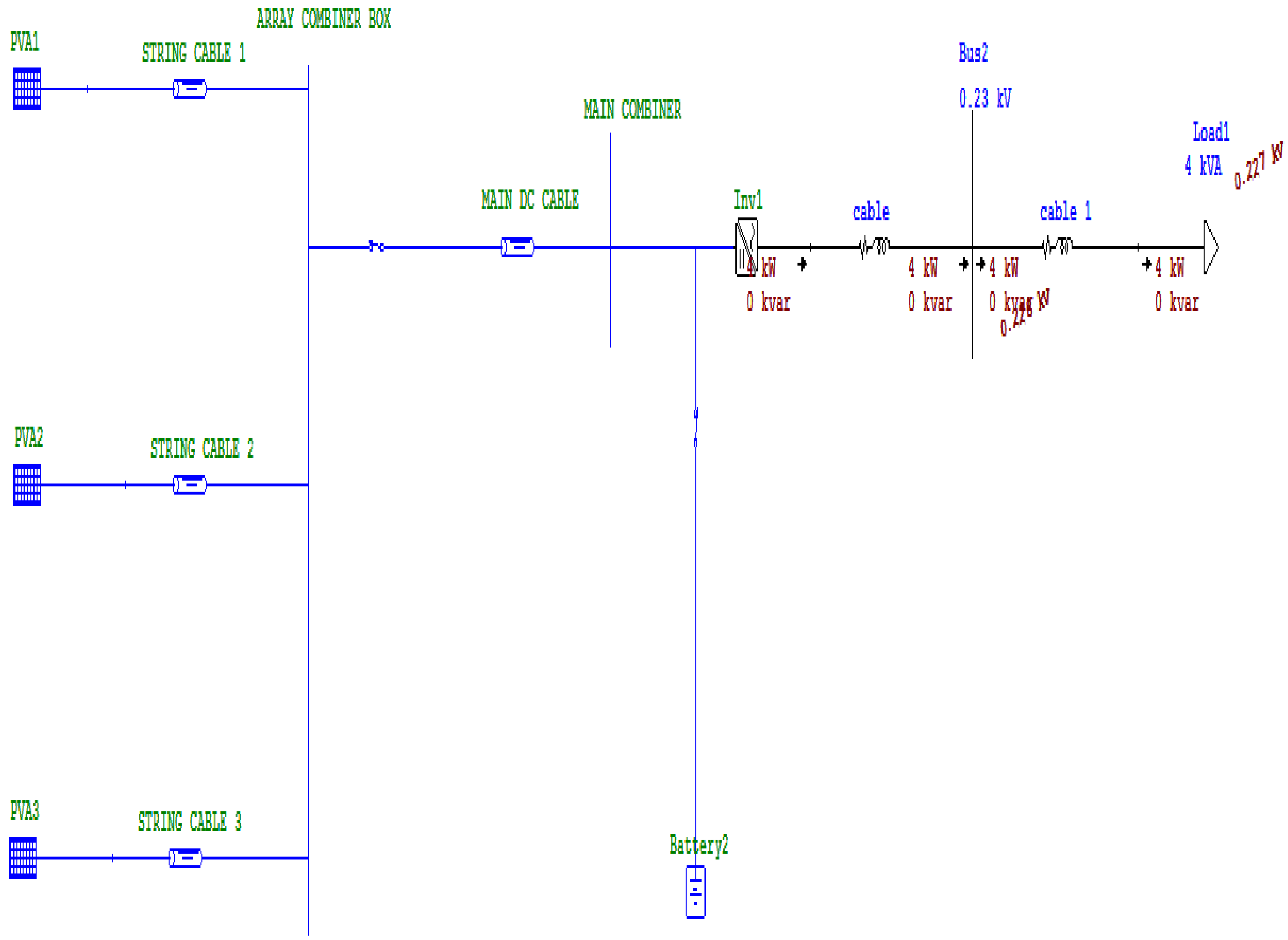



Figure 13. AC Load Flow

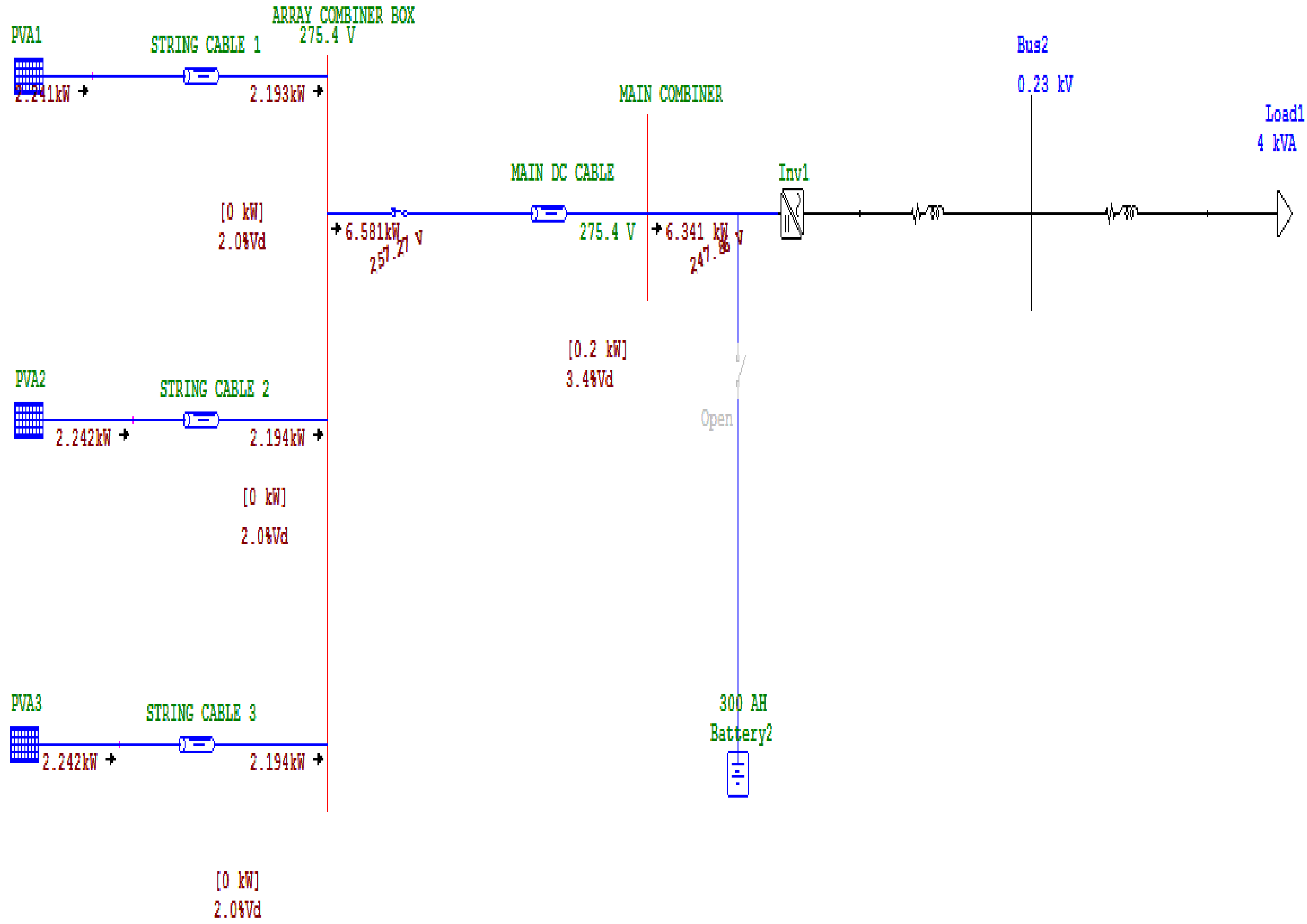



Figure 14. DC Load Flow

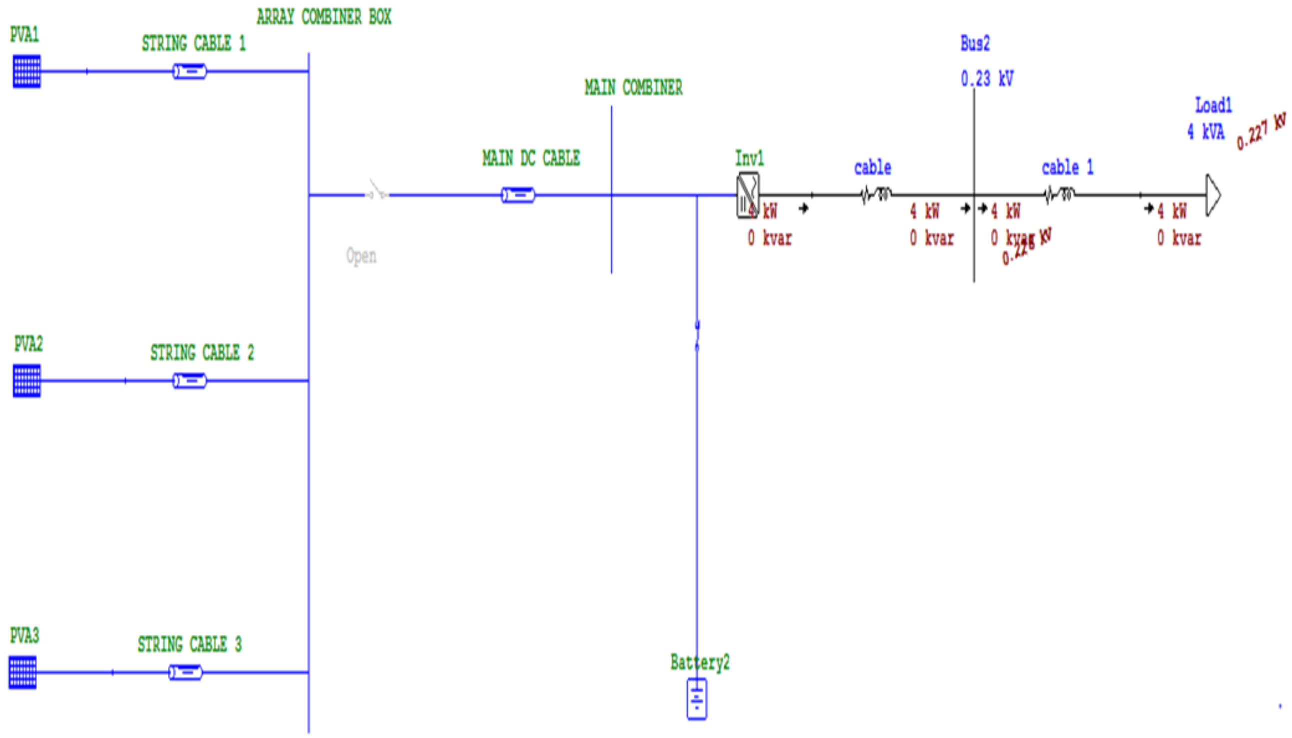


Figure 15. Power flow for battery operated system

Solar radiation is not available at night so battery gives a supply at that time. Fig. 15 shows power flow from battery to load. Here, battery produces a DC supply, then through the inverter DC converts into the AC supply. Flow of power is shown in Table 3. (Note: ETAP shows either a DC load flow or AC load flow at a time). Thus, AC power flow is only displayed in Fig. 15. So, DC supply from battery is not displayed through ETAP.

Table 3. Power flow when battery as source

| Power Flow Direction | kW (DC) | kV (DC) |
|---|---|---|
| Battery to Inverter | 4 | 0.227 |
| Inverter to Bus NO. 2 | 4 | 0.227 |
| Bus 2 to Load | 4 | 0.227 |

## VI. CONCLUSION

Mini grid is studied deeply from all aspects in this paper. In India, most available energy is sun lights, so villagers used solar energy for supporting their loads economically and pollution free. This is the best solution for fulfilling the increased demand of power. Here, small village's system data is taken and designed all parameters required in given system. After calculating parameters, implement the system in ETAP 12.6 software. Each elements are designed AC and DC load flow is done and verified system behaviour when it will be implemented actually. Mini grid can be used for domestic purpose as well as local business by providing proper design to supply required power. It is an effective and economical solution for rural electrification.

## VII. ACKNOWLEDGEMENT

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