

# SMART FARM PV SYSTEM SIMULATOR MANUAL

This application is intended for simulating various microgrid setup involving PV arrays, battery bank, and diesel generator. It gives information about the practical/commercial implication of various setups. The application is written in Python.

Advantage of using this application include:

- Open source. The program can be modified for further research/commercial purposes.
- Lightweight
- The instructions are straightforward. Can be easily used

## I. PROGRAM LOGIC

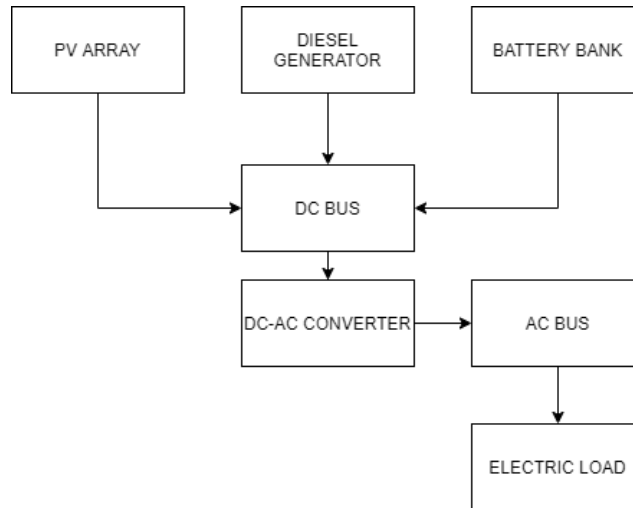
- For every hour of the year,
  - Calculate the user's electric load demand
  - Generate the solar irradiance and the PV array energy production
- After choosing a control mode involving PV array, battery bank and diesel generator,
  - Calculate diesel generator loading and fuel use
  - Compute battery bank's state of charge
  - Calculate excess solar energy (or diesel generator) power
  - Calculate capacity shortage in case of lack of power supply
  - Calculate potential earnings (for PV-Genset setup)

## II. PV ARRAY – BATTERY – DIESEL GEN CONTROL MODES

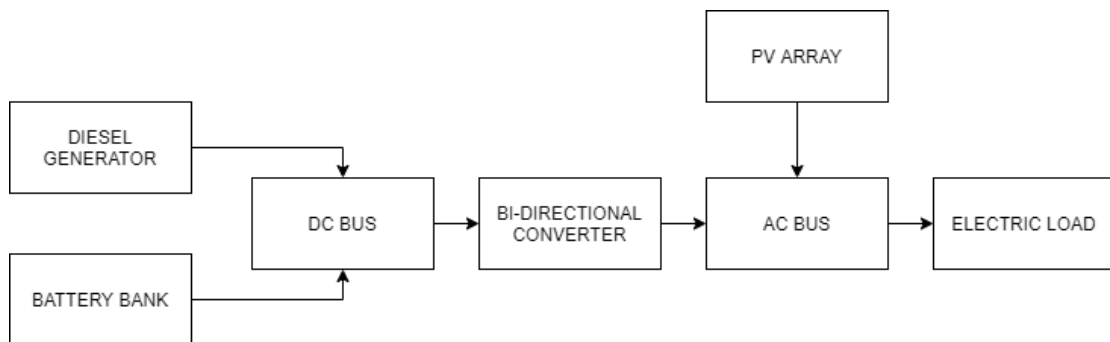
- **Control Mode 1:** Battery Grid Former, Genset Cycle Charging (DC Coupled)
  - The battery bank serves as the power source of the system
  - The PV array charges the battery bank
  - Diesel generator acts as a backup source for the battery bank
  - If the battery bank state of charge is low, the diesel generator charges the battery bank as well as supplies the electric load
  - If the battery bank is at full capacity, the diesel generator is switched off
- **Control Mode 2:** Mixed Master, Genset Cycle Charging (AC Coupled)
  - The battery bank and diesel generator are used interchangeably as the main power source
  - The diesel generator only operates whenever the battery bank state of charge is low or if the power rating of user electric load demand exceeds battery bank rating
- **Control Mode 3:** Mixed Master, Genset Load Following (AC Coupled)
  - The principle is the same as mode 2, however the diesel generator is not used for charging the battery bank

- **Control Mode 4:** Genset Grid Former, Battery Ramp Control
  - The diesel generator and the PV array (grid tied) are used as main power source
  - Battery bank is used for ramp control for compensating scenarios such as variation of PV array output.

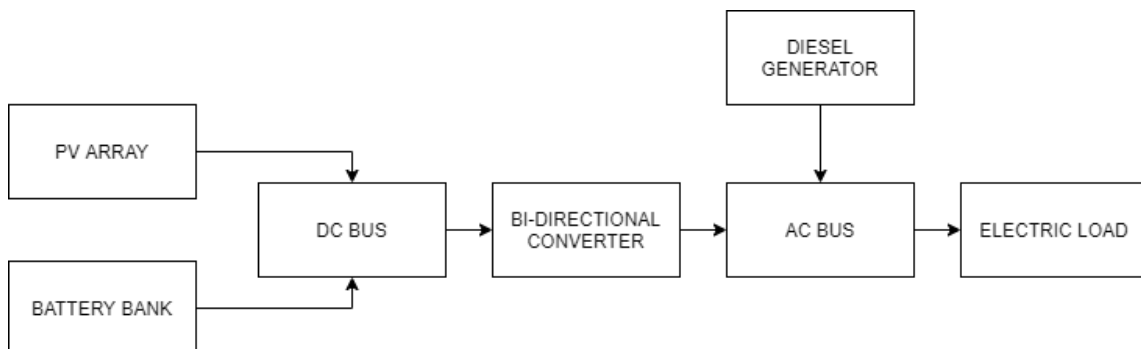
### III. AVAILABLE PV ARRAY- BATTERY – DIESEL GEN SETUP



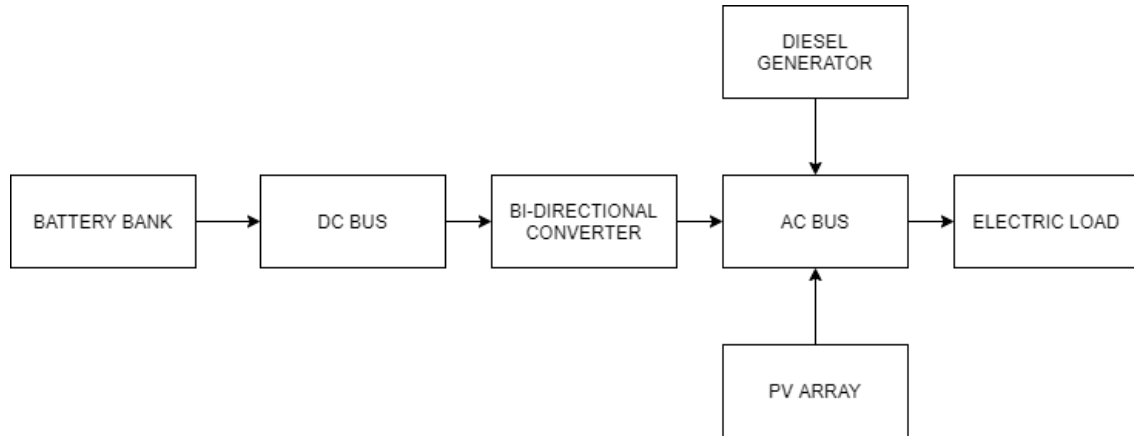
**Type 1:** DC-coupled PV Array and Diesel Generator Set



**Type 2:** AC-coupled PV Array and DC-coupled Diesel Generator Set



**Type 3:** DC-coupled PV Array and AC-coupled Diesel Generator Set



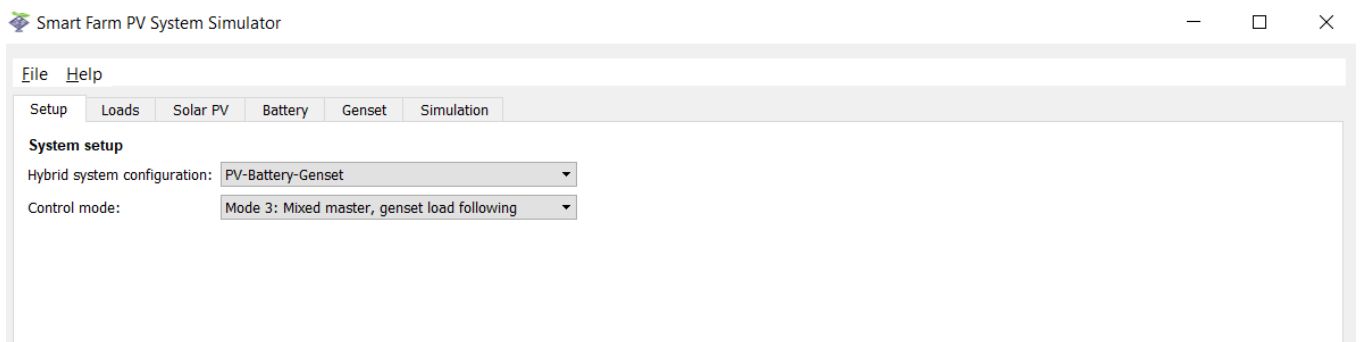
**Type 4: AC-coupled PV Array and AC-coupled Diesel Generator Set**

**Table 1: Control Mode for Solar Power Plant Setup**

Control Mode	Grid Former	Diesel Generator Coupling	Control Strategy
1	Battery Bank	DC (Type 1 and 2)	Battery Dominant, Genset Backup
2	One Main Source	AC (Type 3 and 4)	Battery Dominant, Genset Backup
3	One Main Source	AC (Type 3 and 4)	Battery Dominant, Genset for charging only
4	Diesel Generator	AC (Type 3 and 4)	Genset Dominant Battery for ramp control

## IV. USER INTERFACE

### A. Setup Tab



**Figure 1: User Interface for Setup Tab**

#### ○ Hybrid System Configuration

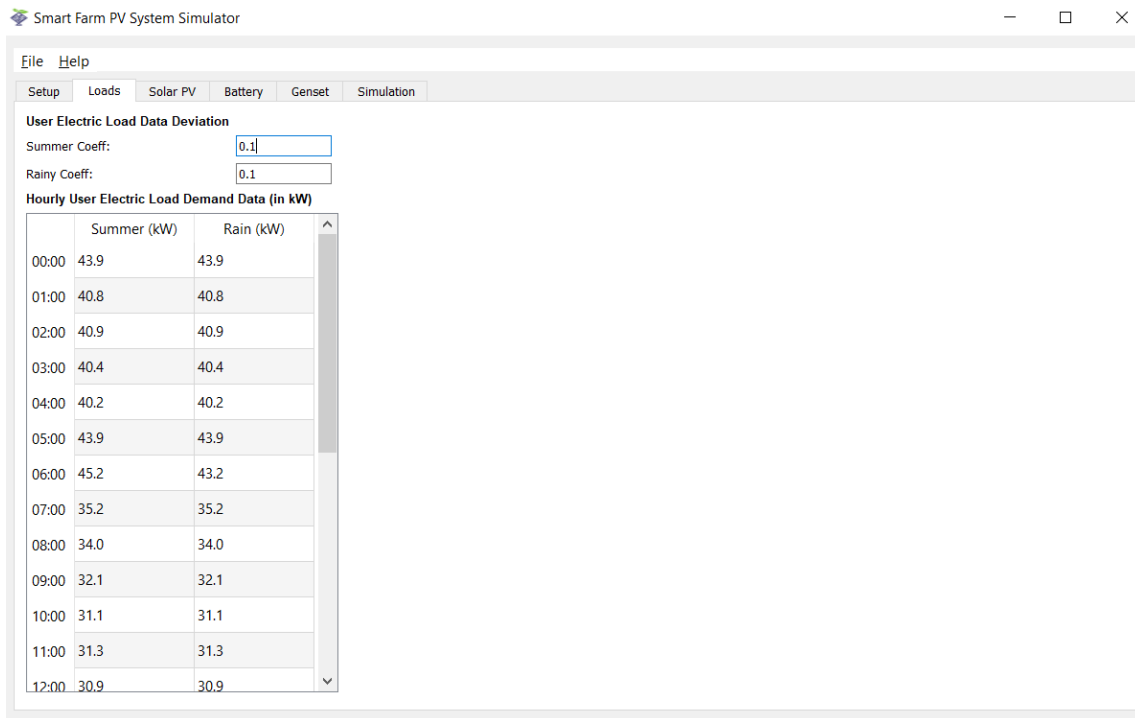
- Allows user to choose the components in power system
  - Genset (Diesel Generator)
  - PV-Genset
  - PV-Battery

- PV-Battery-Genset

- **Control Mode**

- Allows user to choose the strategy for controlling the system configuration (see **PV ARRAY-BATTERY-DIESEL GEN CONTROL MODES**)

## B. Loads Tab



**Figure 2: User Interface for Loads Tab**

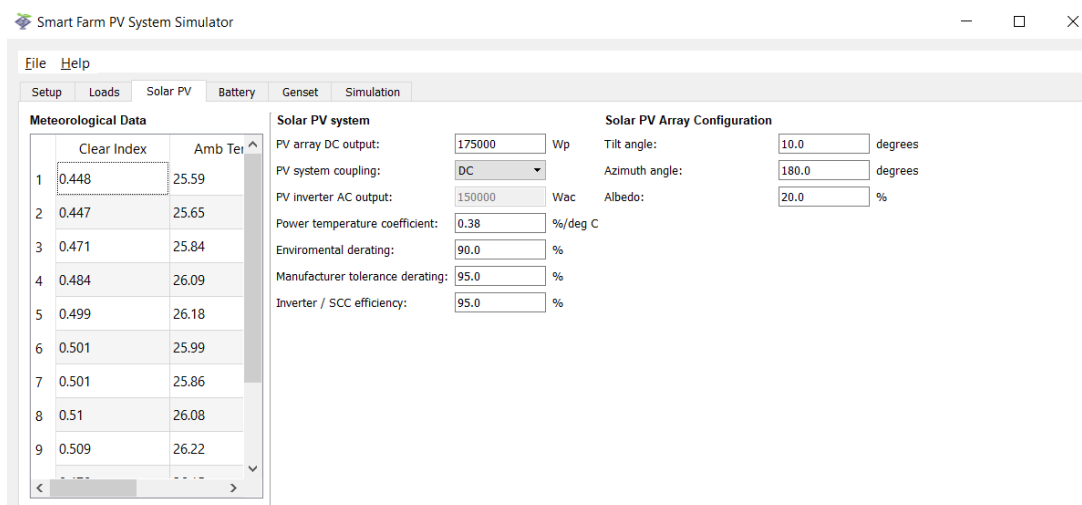
- **User Electric Load Data Deviation**

- Introduce variation of user's electric load consumption

- **Hourly User Electric Load Demand Data**

- **Summer (kW):** Variation of user's electric load in summer months
- **Rainy (kW):** Variation of user's electric load in rainy months

## C. Solar PV Tab



**Figure 3: User Interface for Solar PV Tab**

- **Meteorological Data**
  - Represent the monthly data of meteorological parameters considered
    - Clear Index – monthly clearness indices of the PV site
    - Amb Temp – monthly average ambient temperature of the PV site
- **Solar PV System**
  - PV Array DC Output – Peak power/DC capacity of the PV array (Wp)
  - PV system coupling – coupling of the PV array to the system (AC for grid-tied, DC for offgrid)
  - PV inverter AC output – rated AC capacity of inverter (for AC coupled system)
  - Power Temperature Coefficient- found from PV panel datasheet (module temperature derating factor)
  - Environmental derating factor- constant considering dirt and soiling of PV panels
    - 1.0 – Clean
    - 0.95- Moderate Soiling
    - 0.9 – Heavy soiling
  - Manufacturer Tolerance Factor – assigned constant for tolerances in PV power output (0.95)
  - Inverter/SCC efficiency – conversion efficiency of inverter (AC coupled) or solar charge controller (DC Coupled)
- **Solar PV Configuration**
  - Tilt Angle – tilt angle of PV array measured in degrees
  - Azimuth Angle – Azimuth of the PV array measured in degrees
    - 0 degree – South facing
    - 180 degrees – north facing
    - 90 degrees – west facing
    - -90 degrees – east facing
  - Albedo – another term for ground reflectance. Consider the ground around the PV array
    - 0.04- Fresh Asphalt
    - 0.17 – Bare soil
    - 0.25 – Green grass
    - 0.4- Desert sand
    - 0.8 – 0.9 – Fresh snow

## D. Battery Tab

Smart Farm PV System Simulator

File Help

Setup Loads Solar PV **Battery** Genset Simulation

**Battery Configuration**

Battery Bank # :

Nominal Capacity:  Ah

Nominal Voltage:  Vdc

**Battery Discharge Characteristics**

	Time (hours)	Capacity (A)
1	1.0	600.0
2	3.0	260.0
3	5.0	180.0
4	8.0	120.0

**Battery Charge Parameters**

Battery Converter / Inverter Efficiency:  %

Battery Initial State of Charge (SOC):  %

Battery Minimum State of Charge:  %

Cycle charging SOC setpoint:  %

**Battery Ramp Control Parameters**

PV Output Setpoint For Ramp Control:  W

Ramp Control Start Time:  hour

Ramp Control Stop Time:  hour

**Figure 4: User Interface for Battery Tab**

- **Battery Configuration**
  - Battery Bank # - Number of battery banks connected in parallel
  - Nominal Capacity – Nominal capacity of a battery bank rated in Ah
  - Nominal Voltage- Nominal voltage of a battery bank rated in Vdc
- **Battery Discharge Characteristics**
  - Data points used for estimating battery charge/discharge characteristics. These data points can be found on the battery data sheet
- **Battery Charge Parameters**
  - Battery converter/inverter efficiency
    - Conversion efficiency of battery converter or inverter
  - Battery initial state of charge- initial SOC of the battery at the start of simulation
  - Battery minimum state of charge- Battery SOC at end of discharge
  - Cycle charging SOC setpoint – battery SOC at which point cycle charging is finished
- **Battery Ramp Control Parameters (applicable to mode 4 only)**
  - PV output setpoint for ramp control – Desired PV output
    - If PV output < Setpoint, battery will discharge
    - PV output > setpoint, battery will charge
  - Ramp control start time – hour of the day for ramp-control mode to start
  - Ramp control stop time – hour of the day for ramp-control mode to stop

## E. Genset Tab

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File Help

Setup Loads Solar PV Battery Genset Simulation

**Generator configuration**

Generator #: 1

Nominal Capacity: 60.0 kW

Minimum Generator Loading: 40.0 %

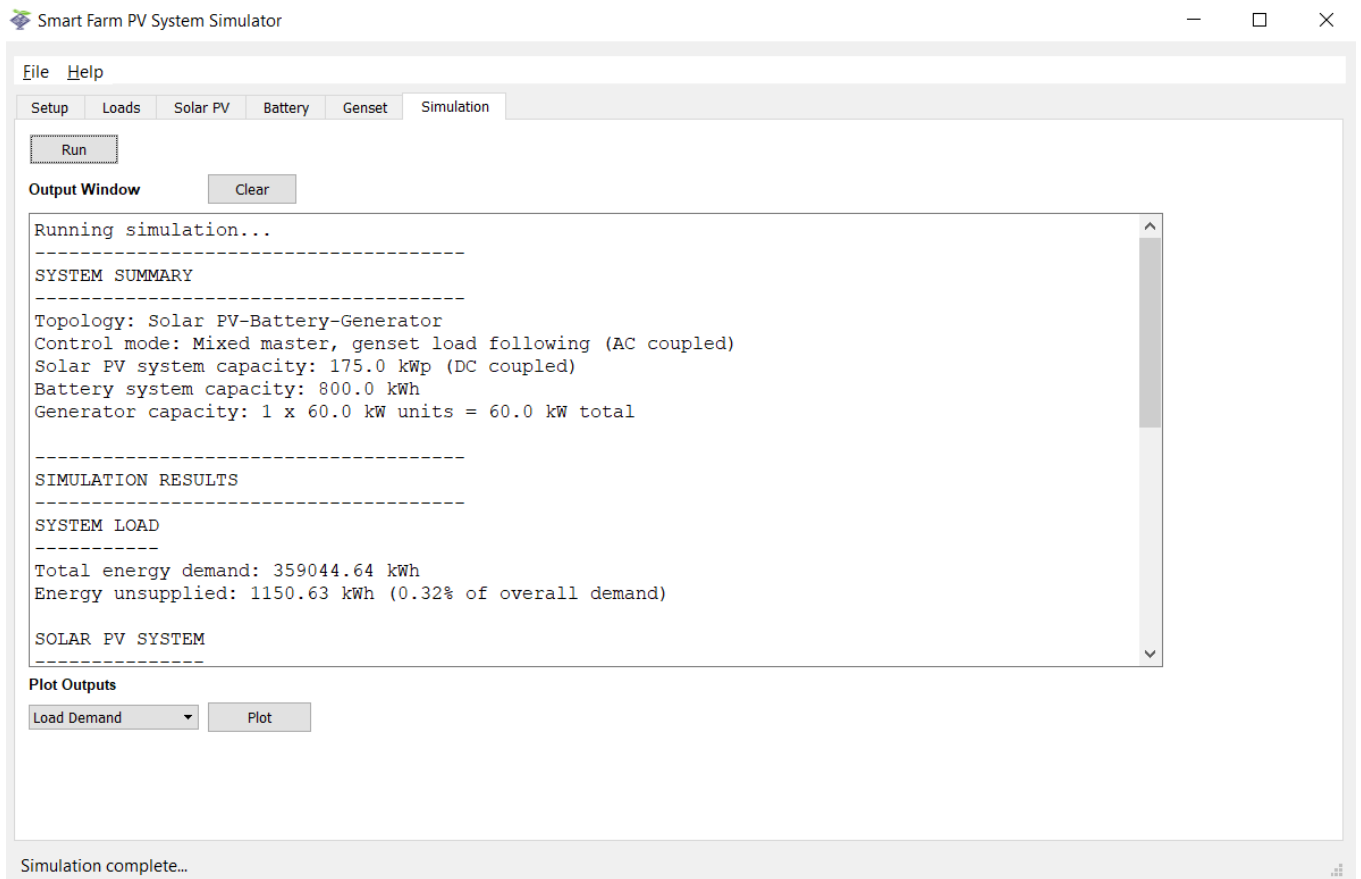
Specific Fuel Consumption: 0.27 litres/kWh

AC/DC Charger Efficiency: 95.0 % (DC Coupled Only)

**Figure 5: User Interface for Genset Tab**

- **Generator #:** Number of diesel generator connected in parallel
- **Nominal Capacity** – nominal capacity of each diesel generator rated in kW
- **Minimum generator loading** – minimum load connected in diesel generator
- **Specific fuel consumption** – measured average fuel consumption (liters/kW)
- **AC/DC charger efficiency** – conversion efficiency of diesel generator battery (for DC coupled systems only)

## F. Simulation Tab



**Figure 6: User Interface for Simulation Tab**

- **Run Button**- runs the simulation
- **Clear Button** – clears the simulation window
- **Plot Button** – provides the plot of simulation result