

Figure 1: Future Work - Real-Time Forecasting System

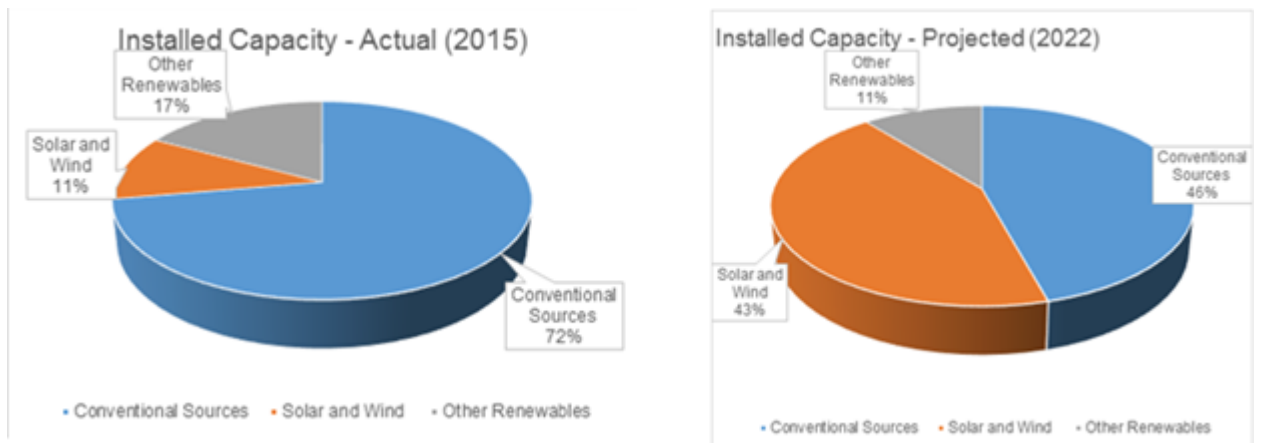


Figure 2: Actual and Projected Installed Electricity Generation Capacity Distribution

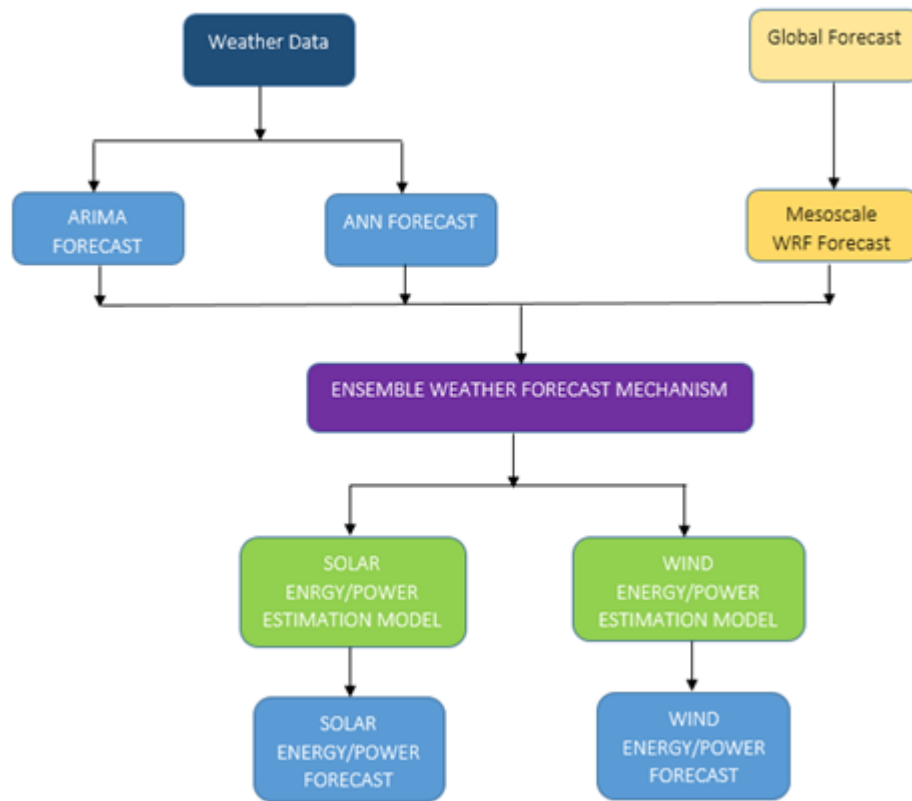


Figure 3: Block Diagram Ensemble Solar/Wind Power Forecasting

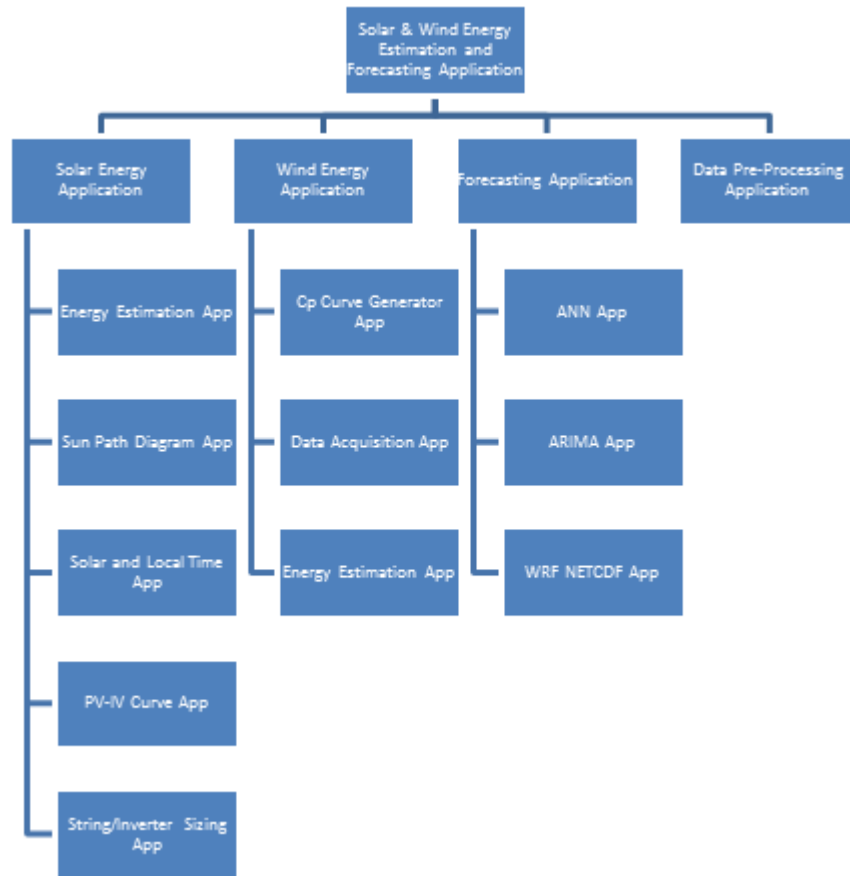


Figure 4: Organization of Application

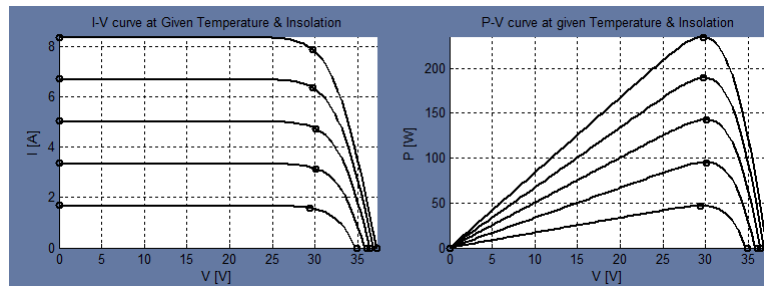


Figure 5: Polycrystalline Solar PV module I-V and P-V Curves at different Irradiances

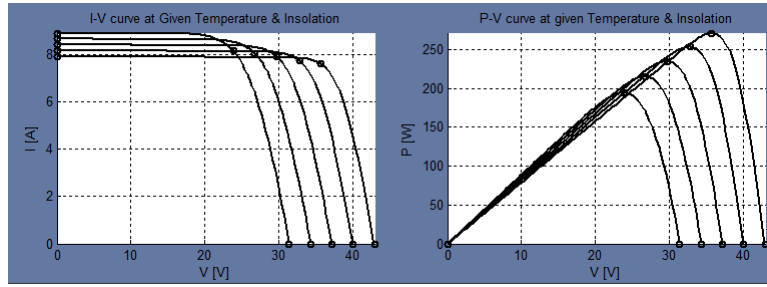


Figure 6: Polycrystalline Solar PV module I-V and P-V Curves at different Temperatures

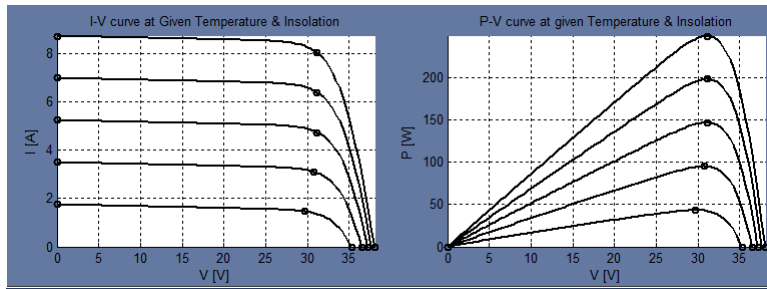


Figure 7: Monocrystalline Solar PV module I-V and P-V Curves at different Irradiances

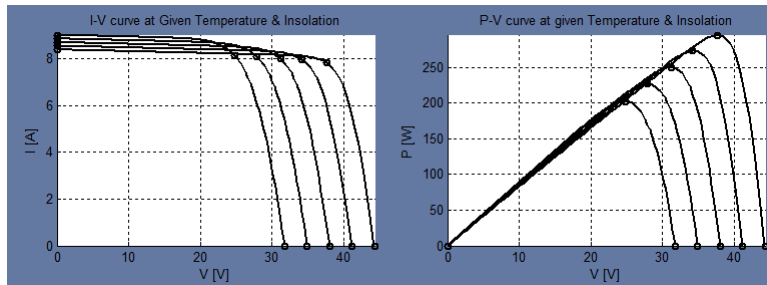


Figure 8: Monocrystalline Solar PV module I-V and P-V Curves at different Temperatures

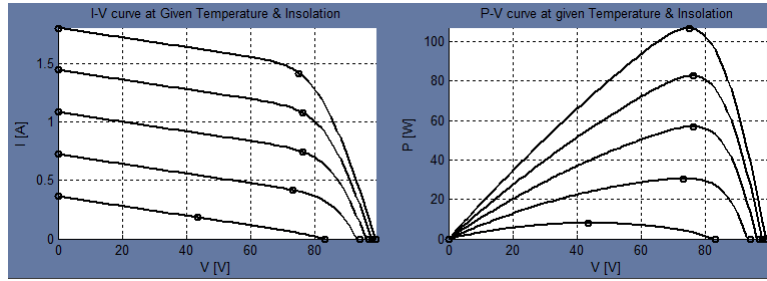


Figure 9: A-Si Thin Film Solar PV module I-V and P-V Curves at different Irradiances

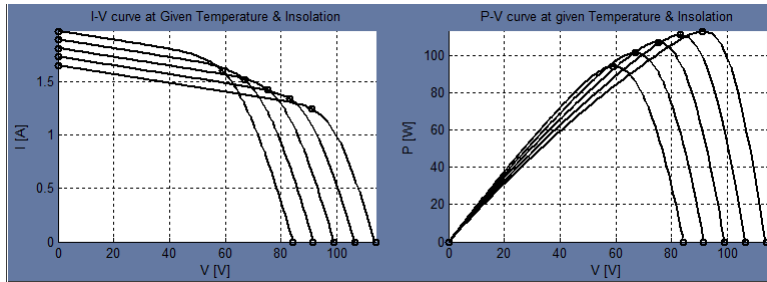


Figure 10: A-Si Thin Film Solar PV module I-V and P-V Curves at different Temperatures

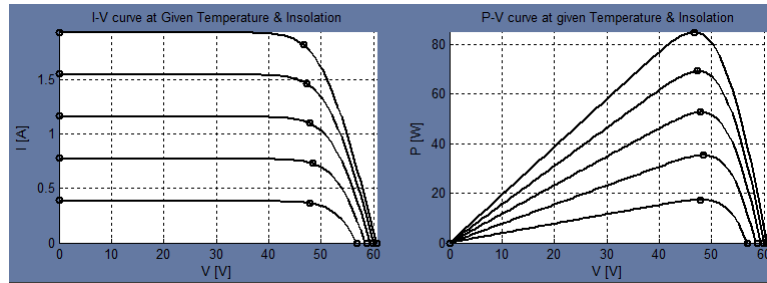


Figure 11: CdTe Thin Film Solar PV module I-V and P-V Curves at different Irradiances

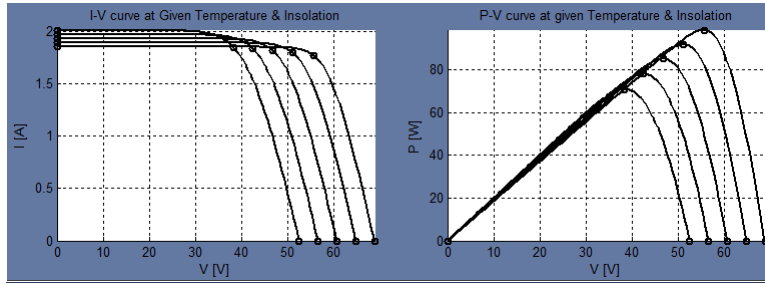


Figure 12: CDTE Thin Film Solar PV module I-V and P-V Curves at different Temperatures

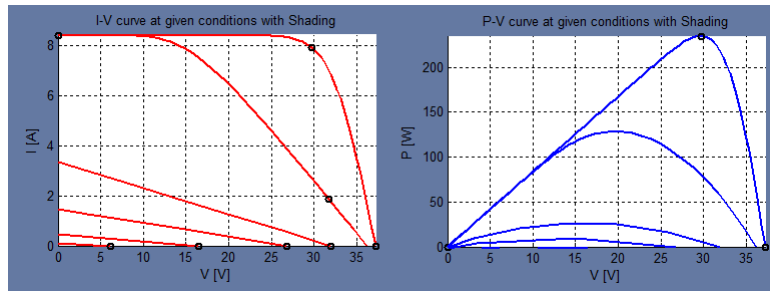


Figure 13: Polycrystalline Solar PV module P-V and I-V curves for Shading without Bypass Diode and at different number of shaded cells

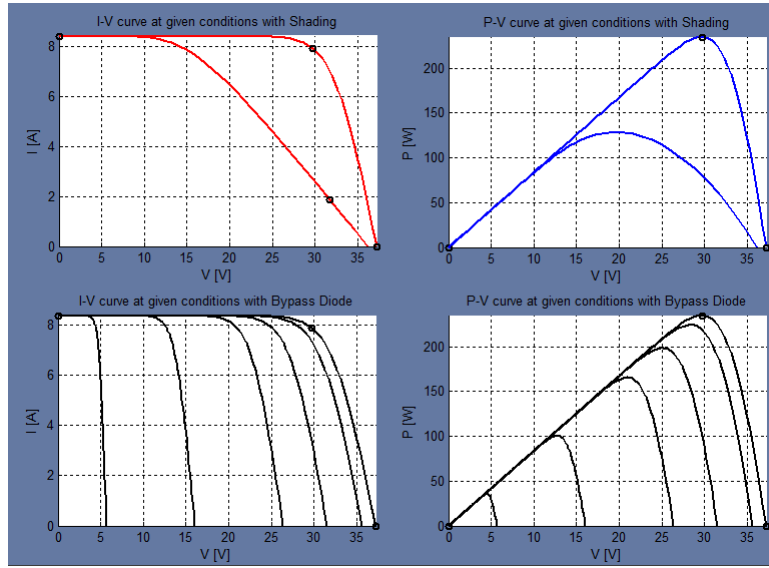


Figure 14: Polycrystalline Solar PV module P-V and I-V curves for Shading with Bypass Diode and at different number of shaded cells

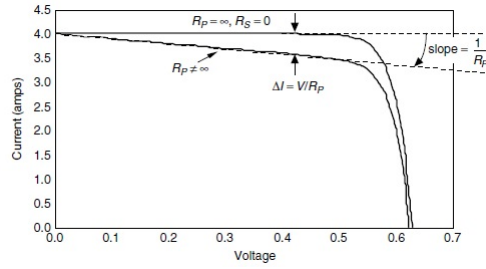


Figure 15: Effect of Parallel Resistance on I-V Curve

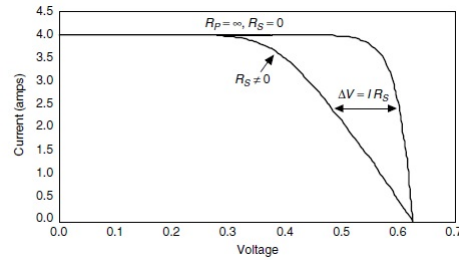


Figure 16: Effect of Series Resistance on I-V Curve

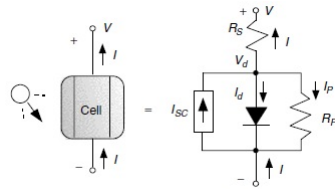


Figure 17: Complete Model of PV Cell

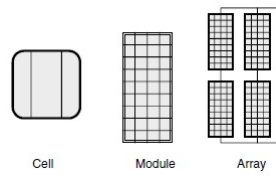


Figure 18: PV - Cell, Module and Array

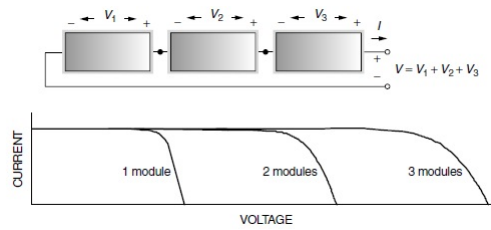


Figure 19: Effect of Series connected modules on I-V Curve

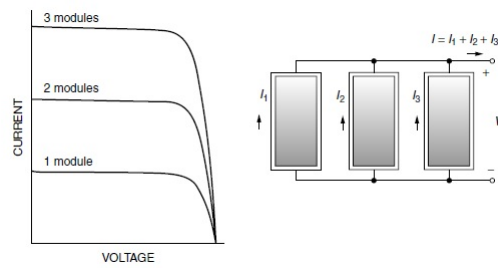


Figure 20: Effect of Parallel connected modules on I-V Curve



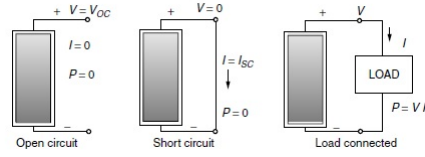


Figure 21: PV module - Open Circuit, Short Circuit and Load Connected

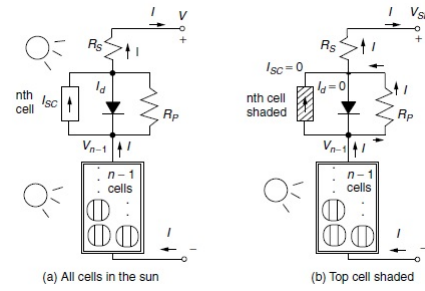


Figure 22: PV module with  $n$  Cells - top cell in sun, or in shade

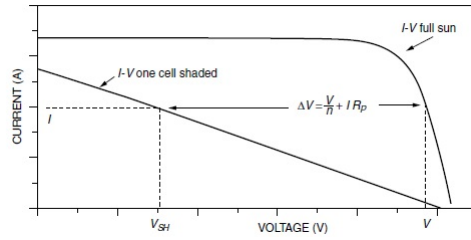


Figure 23: Effect of shading one cell in  $n$  cell module

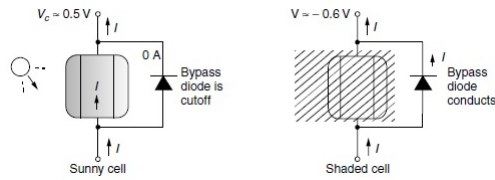


Figure 24: Mitigation of shading problem with Bypass Diode - In sunny cell bypass diode is cut-off, in shaded cell it conducts

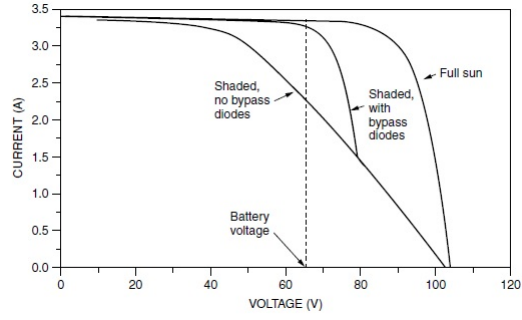


Figure 25: Effect of Bypass Diode on I-V Curve

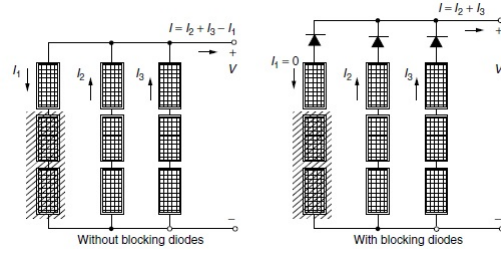


Figure 26: Blocking Diode prevents reverse flow of current through PV modules

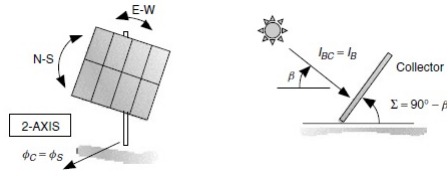


Figure 27: Charanka Solar Park PV Technology-Wise CUF Comparison

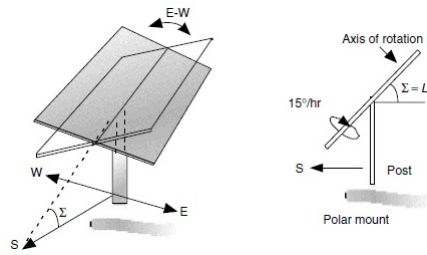


Figure 28: Charanka Solar Park PV Technology-Wise CUF Comparison

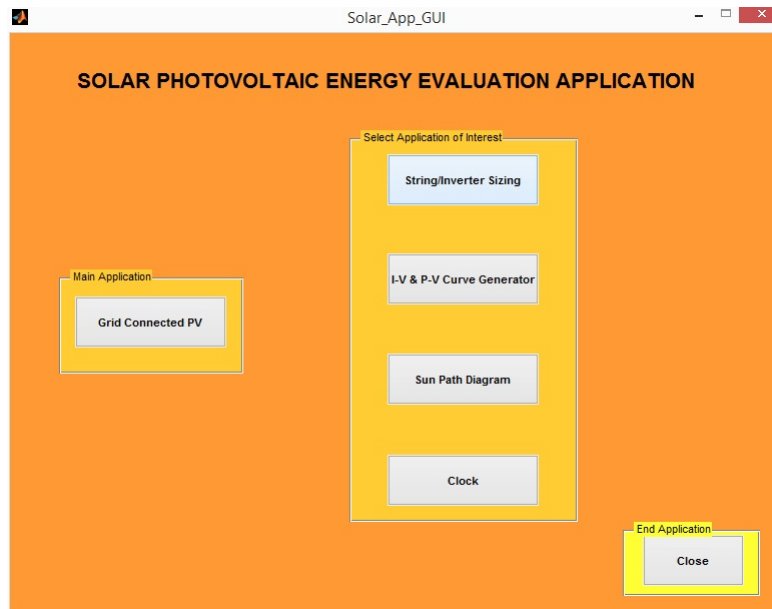


Figure 29: Starting Screen of Solar Application

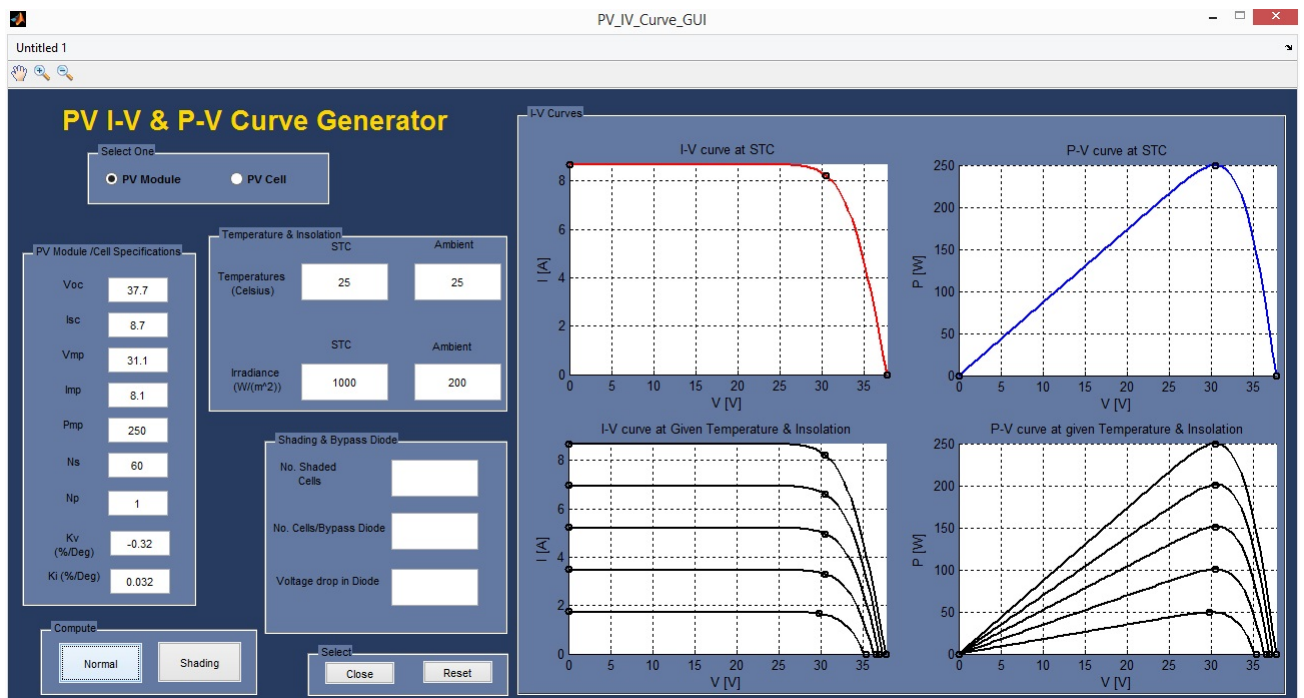


Figure 30: PV I-V and P-V Curve Generator Module

**String/Inverter Sizing**

**Plant Capacity**  
Plant Capacity (kW) 5000

**PV Module Specifications**  
 Voc (V) 85.5  
 Isc (A) 2.54  
 Vmp (V) 64.7  
 Imp (A) 2.32  
 Pmp (W) 145  
 Module Efficiency (%) 98  
 Module Length (mm) 1412  
 Module Breadth (mm) 1112

**Inverter Specifications**  
 Vmax (V) dc 820  
 Imax (A) dc 1104  
 Pmax (kW) dc 630  
 Inverter Efficiency (%) 98

**String/Inverter Sizing Results**  
 Total No. of Modules (Type 1) 33993  
 Total Area of Modules (m<sup>2</sup>) 53373.905  
 No. of Modules in one String 9  
 Total No. of Strings 3777  
 Nominal Power Output 5102.4853  
 Total No. of Inverters 10  
 No. of Strings per Inverter 348

Select  
 Compute Reset Close

Figure 31: String and Inverter Sizing Module

**SOLAR & LOCAL CLOCK**

**Site Information**  
 Year Day Number 100  
 Latitude 23.22  
 Time Meridian 82.58  
 Local Meridian 72.68  
 E/W Hemisphere 1

**Local Time To Solar Time**  
 Clock Time 6.4061  
 Solar Time 5.7196  
 Calculate

**HMS To Decimal**  
 Hours 6  
 Minutes 24  
 Seconds 21  
 Decimal Time 6.4058  
 Convert

**Sunset/Sunrise Time**  
 Sunrise Time 5.7196  
 Sunset Time 18.2804  
 Calculate

**Local Time To Solar Time**  
 Solar Time 5.7196  
 Clock Time 6.4061  
 Calculate

**Decimal To HMS**  
 Decimal Time 6.4061  
 Hours 6  
 Minutes 24  
 Seconds 21  
 Convert

Select  
 Close Reset

\*All Times used as inputs are in Decimal/Use 24Hour Clock\*

Figure 32: Solar and Regional Clock Module

Solar\_APP\_Main\_GUI

### Grid Connected PV Energy Evaluation

**Site Data (Step 1)**

Project Name: ack Bone SMW

Plant Capacity (kW): 5000

Latitude: 23.365

Longitude: 70.623

**Orientation Data (Step 3)**

Select:

☒ Fixed Tilt

☐ Seasonal Tilt

☐ Single-Axis EW

☐ Single-Axis NS

☐ Double Axis

Press for Entering Data:

Fixed Tilt

Seasonal Tilt

Single Axis EW

Single Axis NS

Double Axis

**Computation Options & Weather Data (Step 5)**

Simulation Resolution (minutes): 15

Select Mode:

☐ Use Irradiance Calculator

☐ User has Irradiance File

☒ User has Daily Insolation File

Load Weather Files:

Temperature

Wind Speed

Select Insolation Distribution:

☒ Gaussian

☐ Sinusoidal

☐ Average

**PV Module Data (Step 2)**

Use following Values:

Crystalline-1 Thin Film-2

Module Power (W): 145

Total Number of Modules: 34485

PV Technology: 2

Module Temperature Co-efficient (%/Deg): -0.28

STC Temperature (Deg Celsius): 25

STC Insolation (W/m<sup>2</sup>): 1000

**Number of Days for Simulation (Step 4)**

Select:

☐ Leap Year

☒ Non-Leap Year

Select Simulation Period:

Start Month: January

Start Day: 1

End Month: December

End Day: 31

**Loss Parameters (Step 6)**

Loss Parameters

**Select (Final Step)**

Start Simulation

Close

Reset

Figure 33: Grid Connected PV Energy Evaluation Module

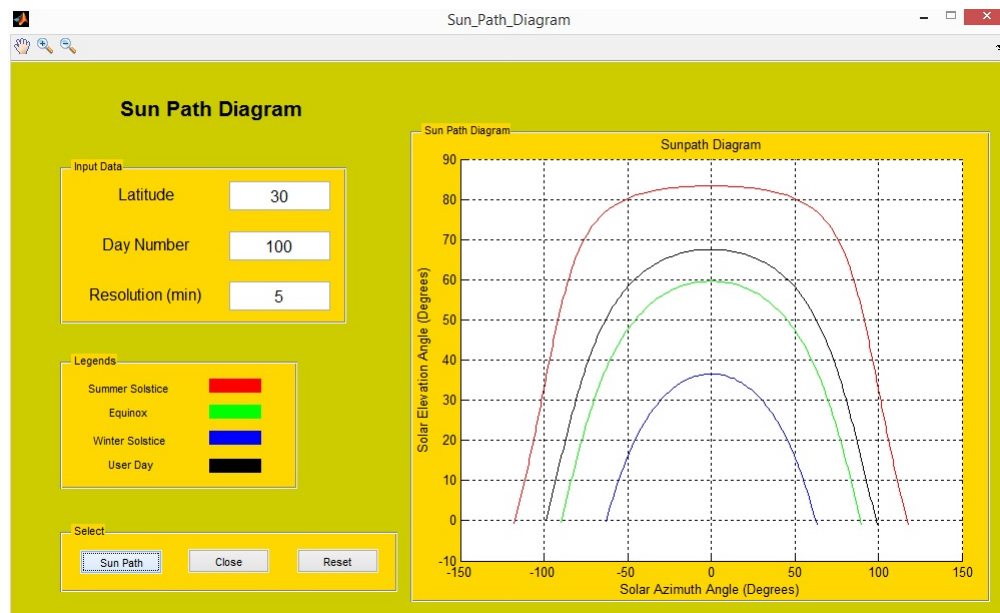


Figure 34: Sun Path Diagram Module

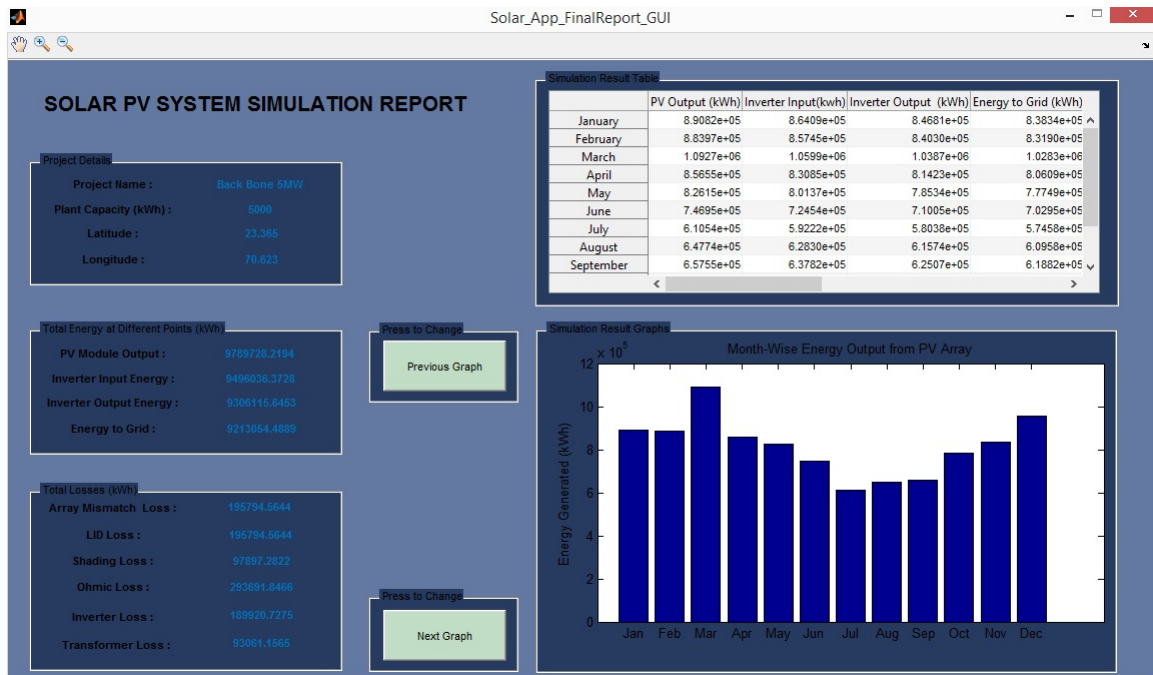


Figure 35: Grid Connected PV Energy Result Screen

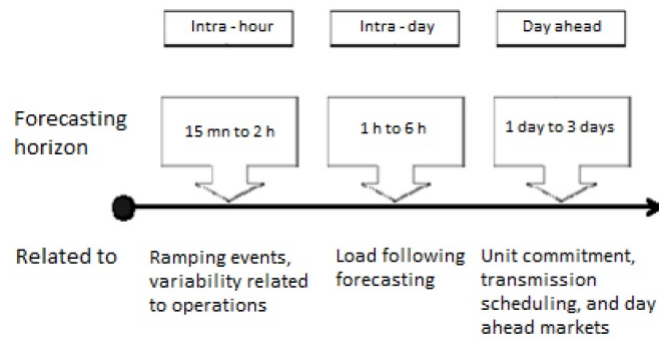


Figure 36: Time Horizons for Solar Forecasting

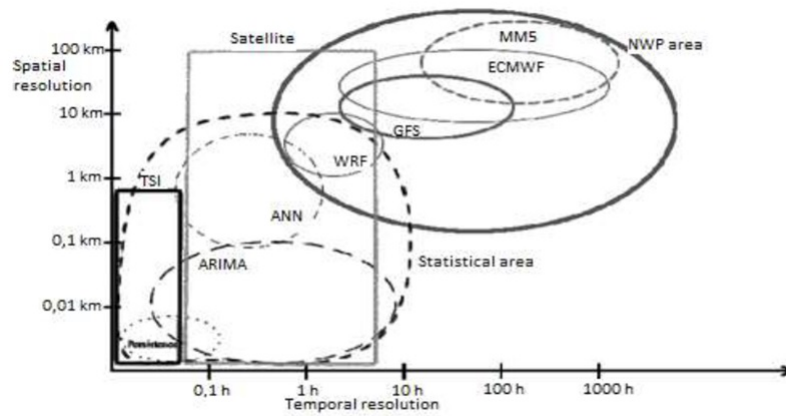


Figure 37: Time Horizons for Solar Forecasting

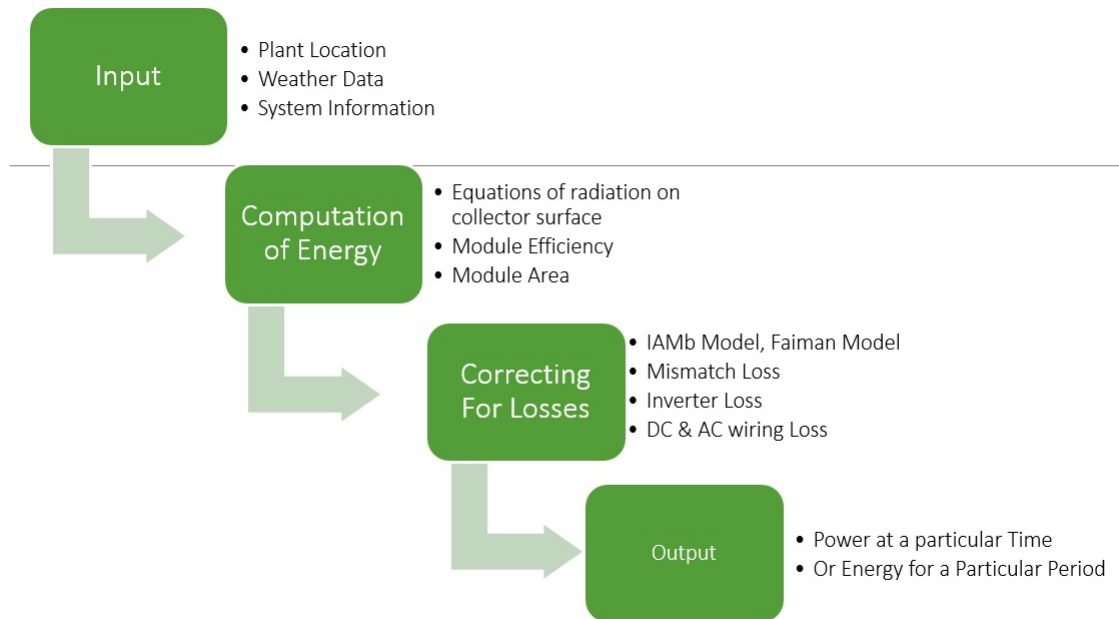


Figure 38: Time Horizons for Solar Forecasting



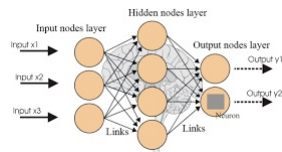


Figure 39: Feed-Forward Neural Network Schematic

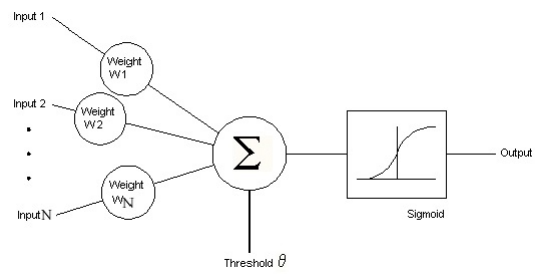


Figure 40: Artificial Neuron Model

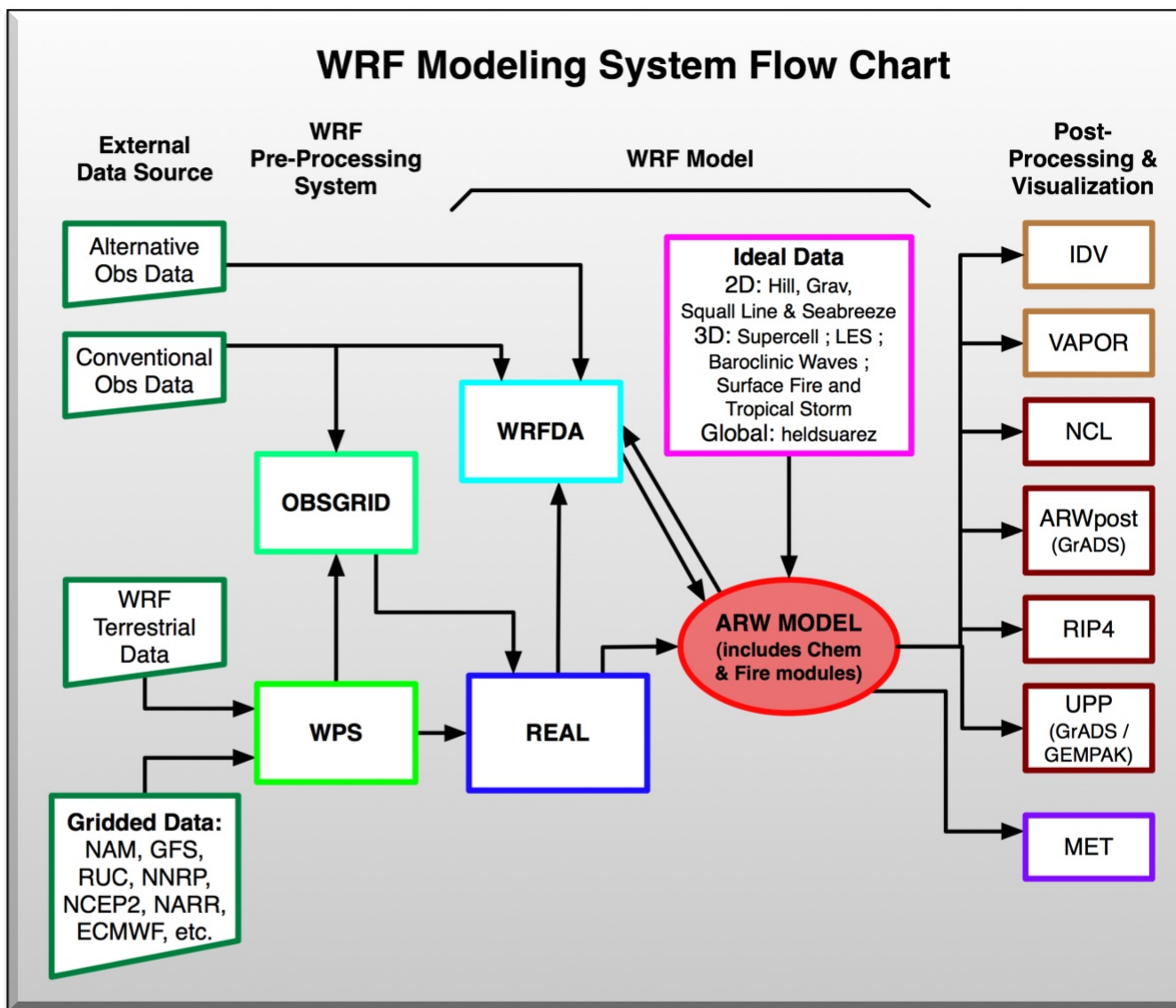


Figure 41: WRF Software Schematic

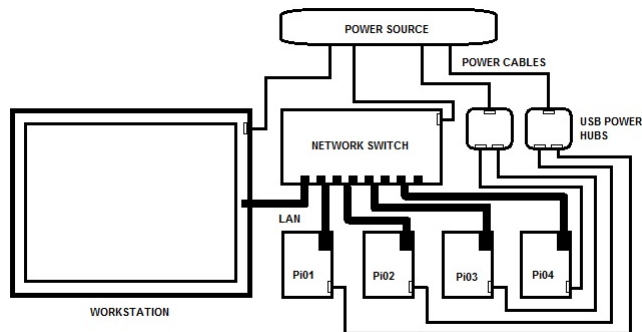


Figure 42: Raspberry-Pi Cluster Schematic

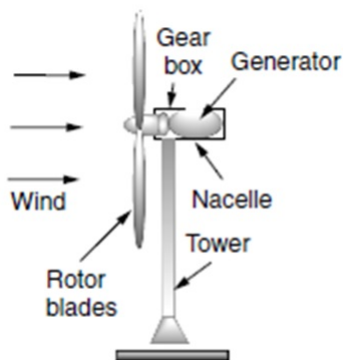


Figure 43: Wind Turbine

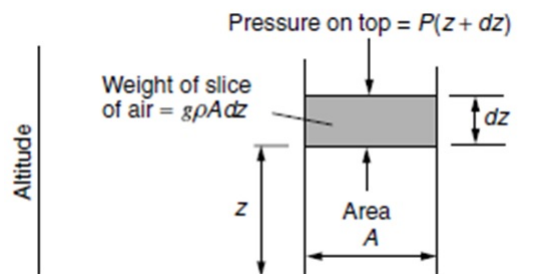


Figure 44: Effect of Altitude on Pressure

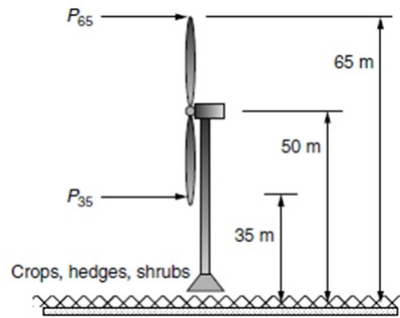


Figure 45: Effect of Hub-Height and Terrain on Wind Velocity

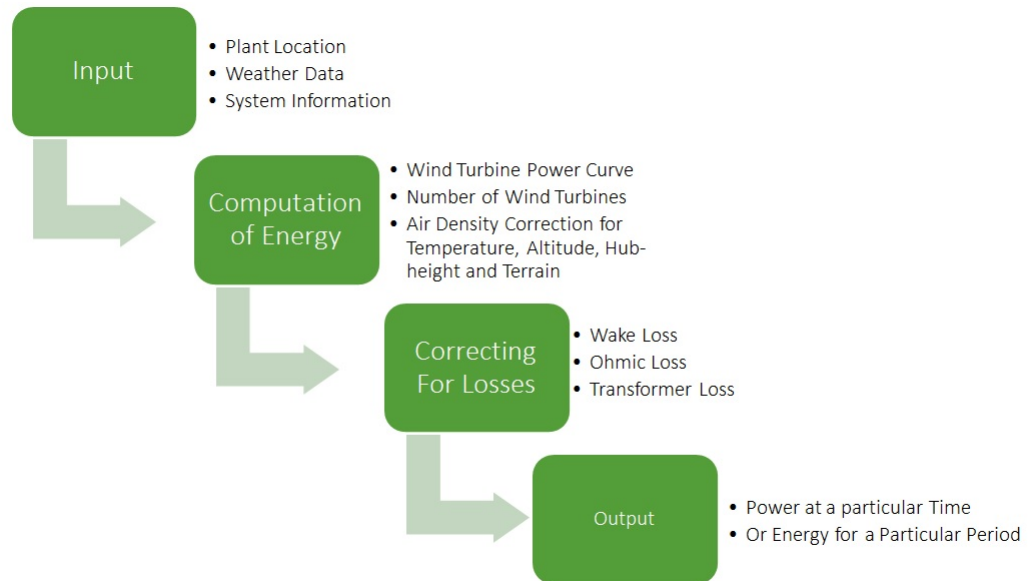


Figure 46: Wind Turbine Energy Estimation Schematic