Impact of PV Systems and Battery Storage in Hybrid Power Systems with Grid Connection

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INTRODUCTION

Conventional power system

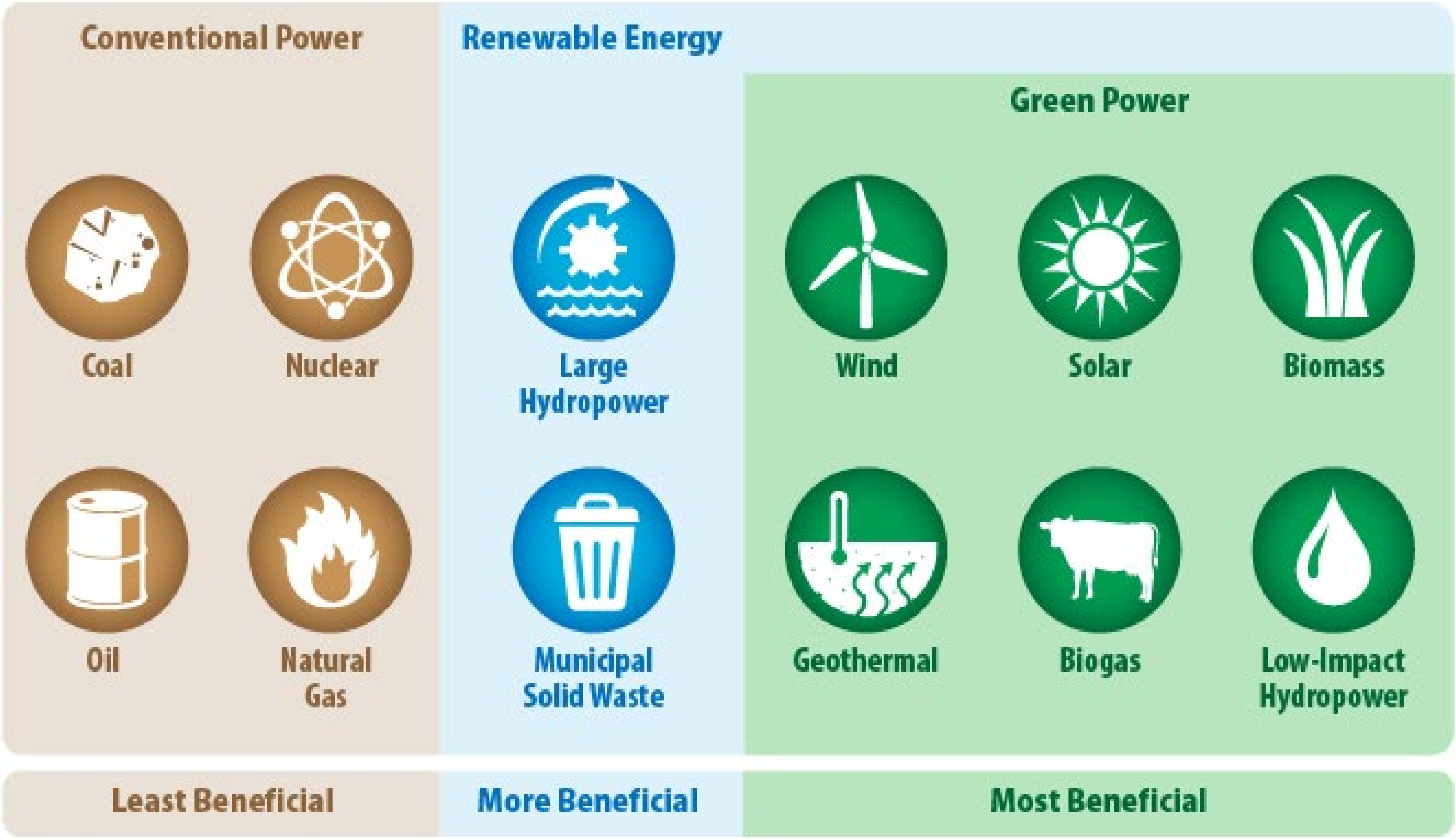
- Electric power system are centrally coordinated.
- Internally connected to the transmission and distribution lines based on the voltage levels.
- Conventional system is under transformation stage to involve RESs for making smart and strong grid.

Distributed generation (DG)

- DGs: A set of electrical power sources such as renewable and non-renewable resources connected to the distribution system or the customer side.
- Very much suitable for Smart grid application
- Significant role in deregulation markets

Renewable energy source

Renewable energy sources penetration to grid is continuously rising:



Factors that leads to the rural electrification using RESs :

- Location constraint
- Cost implication.
- Terrain constraints.
- Diversification of primary energy supplies.
- Reduction of global GHG emissions and cost of energy.
- The cost of fossil fuel transportation.
- The choice of a hybrid system to provide a sustainable power at a low cost.
- It is cost effective owing to its relative low maintenance and operation cost.

Photovoltaic System Configuration

The hybrid system is configured in two ways, centralized or distributed.

Centralized Configuration

- The objective is to ensure a continuous operation of the power system, instead of supplying certain critical loads.
- Advantages: Lower cost, little and easy maintenance.
- Disadvantage: The whole power system would fail if the central converter fails.

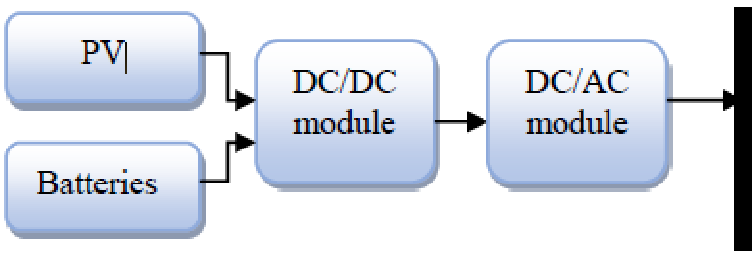


Fig. 1 Centralized configuration

Distributed configuration

- This system has separate conditioning units for every renewable input.
- The system operates in parallel to increase the availability of uninterrupted power supply.
- Advantage: permits easy upgrading of the system when higher capacity is needed.
- Disadvantage: costlier than centralized configuration.

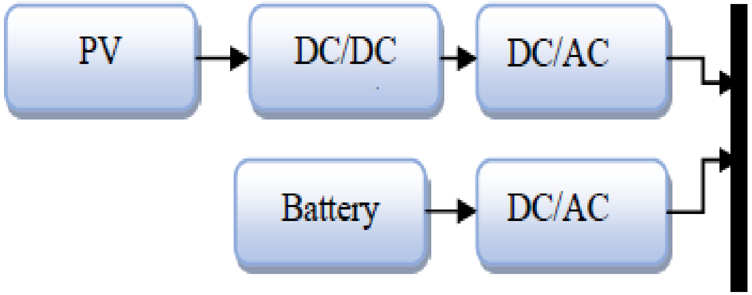


Fig. 2 Distributed configuration

Issues with PV systems

- Photovoltaic systems play a promising role in the generation of clean energy.

- Nevertheless, the push for the adoption of renewable energy sources, such as PV, results in an increased penetration of an **unstable energy** source.

- The intermittent nature of the source is of concern with regards to the **stability and reliability** of the electric network.

Modeling of PV system

- PV cell model: single cell produces around 0.5 Volts.
- PV cells are cascaded in series to boost the voltage level and connected in parallel to increase the current output

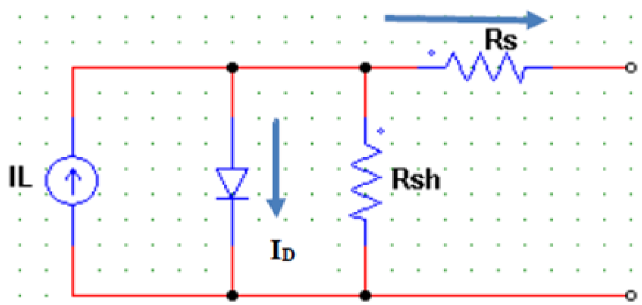
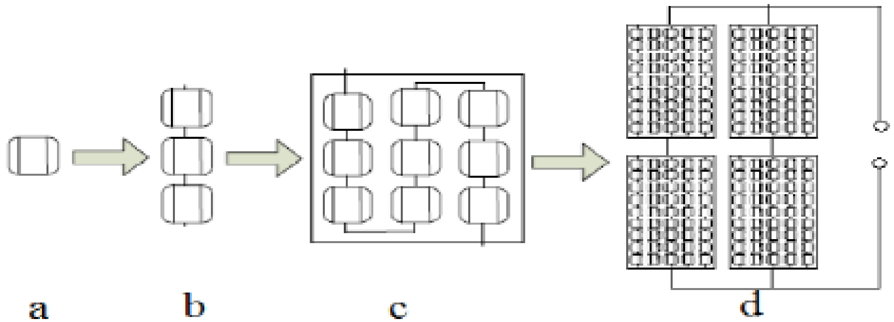


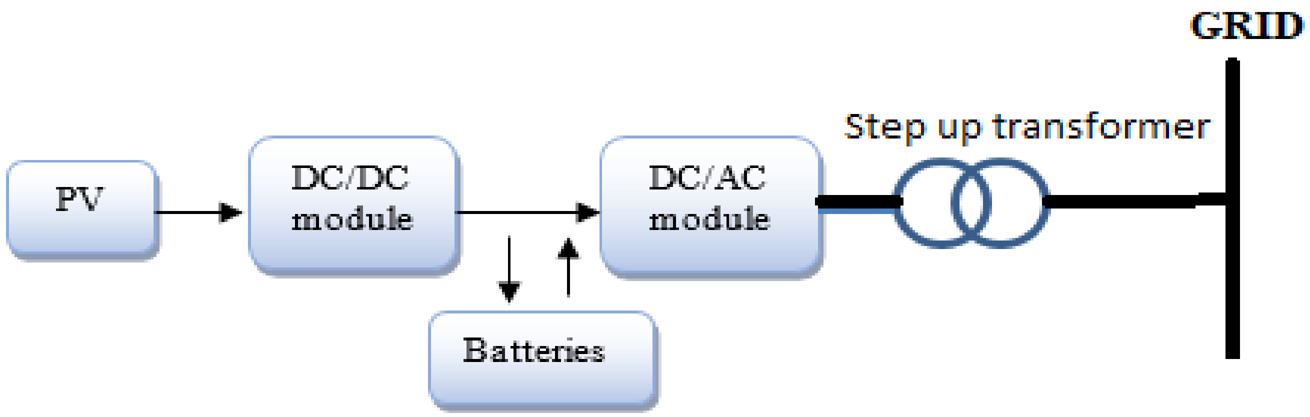
Fig. PV cell

- (a) PV cell
- (b) cell series (string)
- (c) cell module
- (d) PV array



- A PV array: consists of n-number of PV modules
- For grid-connected modules, many solar arrays are connected to meet the required voltage.

GRID CONNECTED PV SYSTEMS



Sizing of PV array:

- H is the *sunshine hours of radiation* (h)
- T is the *daily avarage work of load* (h)
- P_L is the *avarage load power* (W) and
- μ is the conversion coefficient

$$P = \frac{\mu T P_L}{H} \qquad (1)$$

Objectives of the study

The aim of this work is to investigate the impact of PV systems with battery storage on the grid.

- To use PV systems and battery storage systems for improving the voltage levels of constrained feeders and achieve peak shaving during peak hours.

- To model the system and its size accordingly for optimal operation.

Methodology

- To analyze the behavior of PV system a circuit model is implemented on PSIM software.
- For grid connection, the model was also connected to an 11kV feeder model using **Digsilent** (Power factory) software
- The analysis of the impact of PV on the feeder has been done.

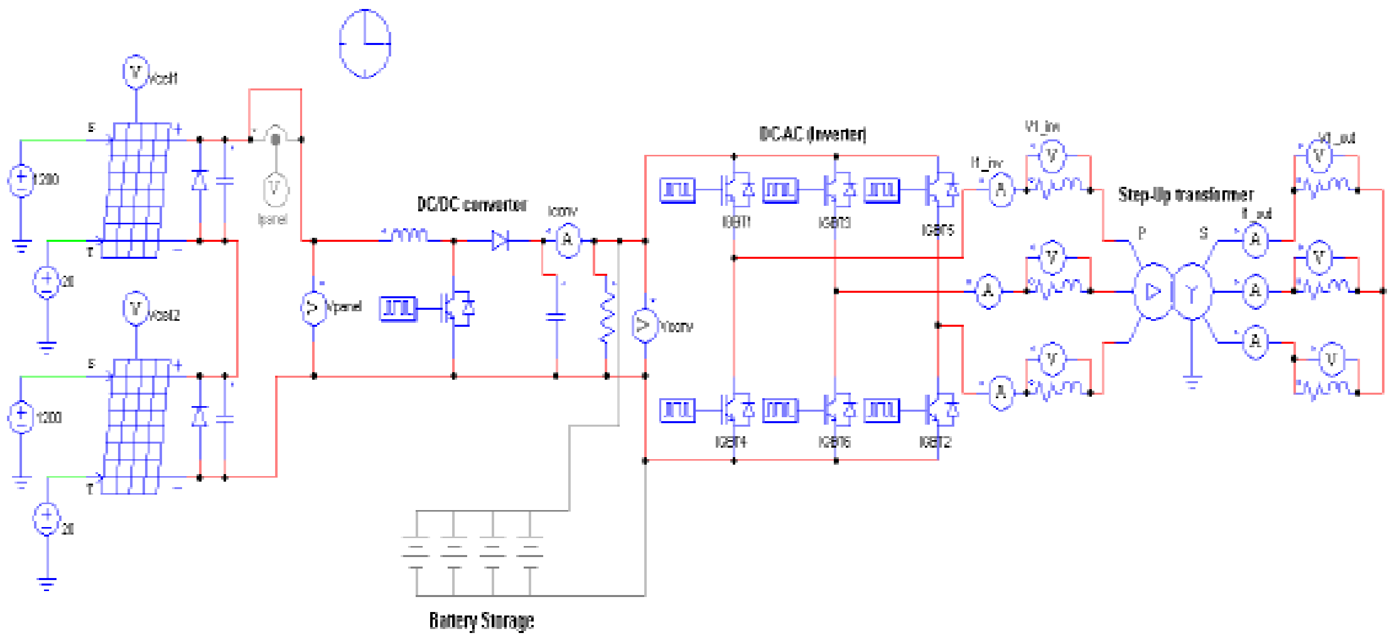


Fig. 5. Grid connected PV system with battery storage modeled on PSIM software

Table 1. effect of temperature on output voltage

Temperature	Vpanel	Vout (Converter)
20	80.03	419.81
22	79.39	416.62
24	78.75	413.44
26	78.12	410.24
28	77.84	407.04
30	76.84	403.83

Table 2. effect of irradiance on output power

Irradiance	Pin (panel)	Pout (Converter)
400	94.91	60.51
600	150.23	123.67
800	198.63	165.95
1000	247.58	206.48
1200	296.88	258.30

DC-DC converter module

- The step-up DC-DC converter module was modeled in such a way that for varying dc input from the solar panels, the output voltage should remain constant at 400Vdc.
- Fig. 6 shows the operation of step-up DC-DC converter from 80Vdc to 400Vdc.

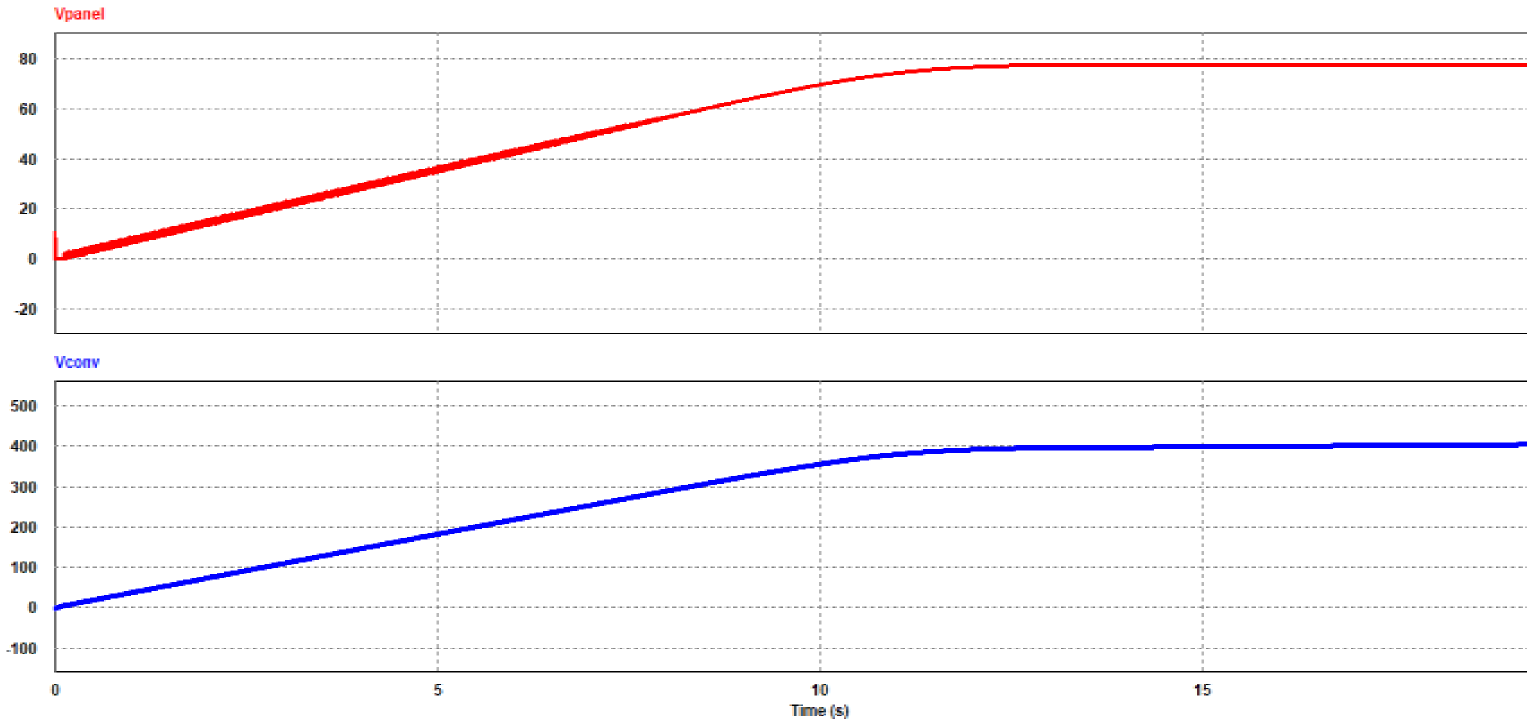


Fig. 6 Voltage from PV panel and converter output

Inverter module

- The output of the inverter will not vary (with the fluctuating weather conditions (temperature and irradiance).) because the output of the DC-DC converter is maintained at a constant level.
- Fig. 7 shows inverter output with amplitude of 400V from the simulated inverter model.

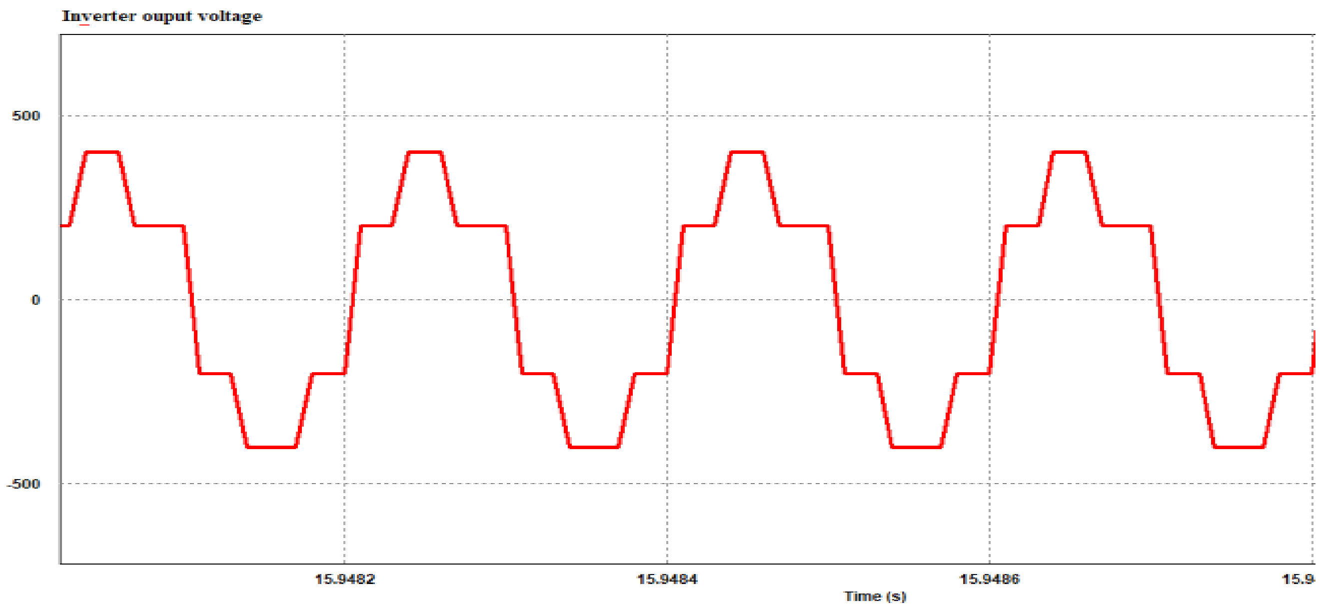


Fig. 7. AC voltage from the inverter

Step up Transformer (400/11kV)

The ac voltage waveform after the step up transformer is presented in Fig. 8.

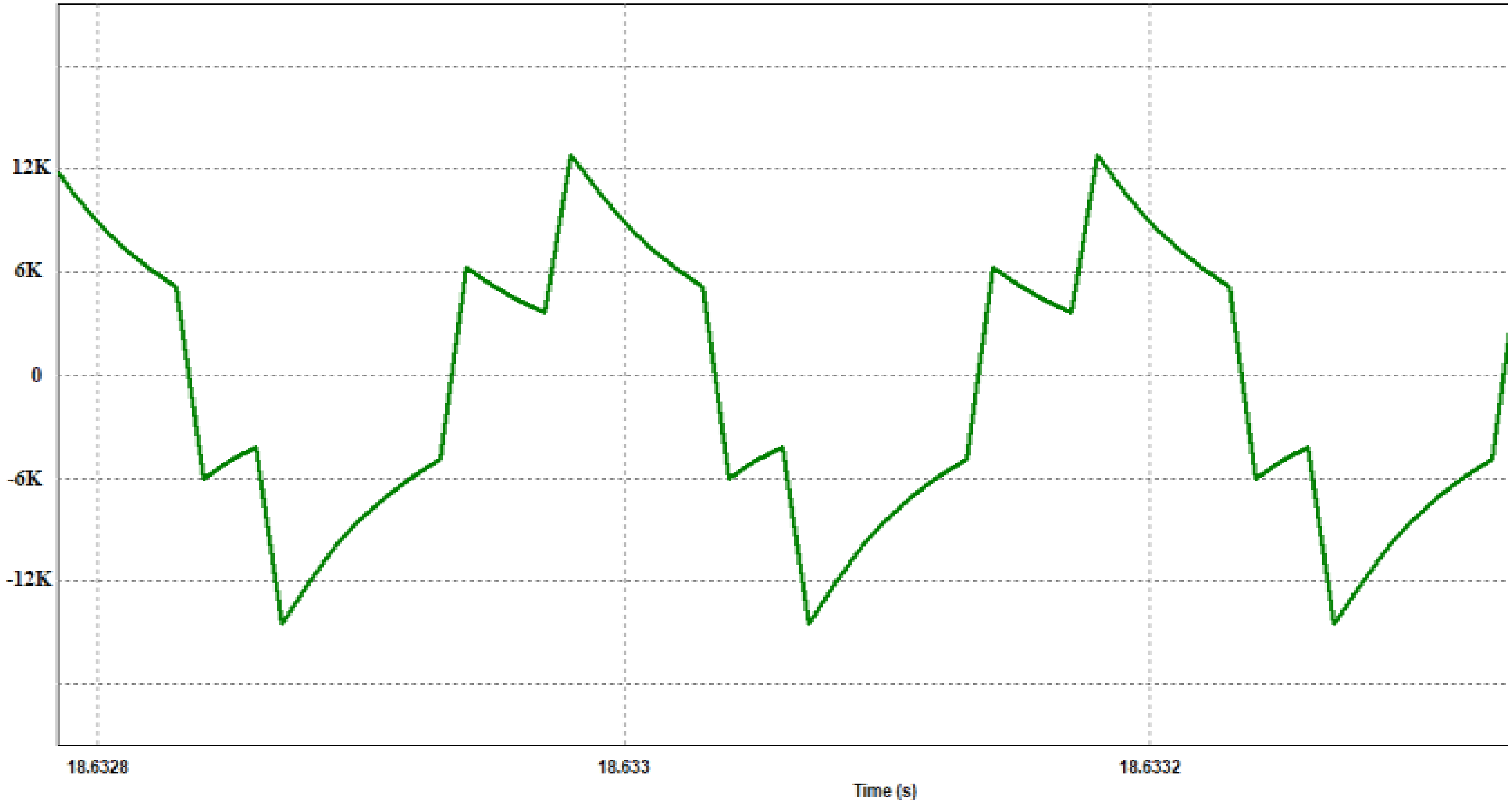


Fig. 8. AC voltage from the transformer

Peak shaving application (Power factory modeling)

- As the circuit modeled using PSIM software could not be tested for peak shaving applications.
- Another identical model was implemented in Power factory software for peak shaving applications.

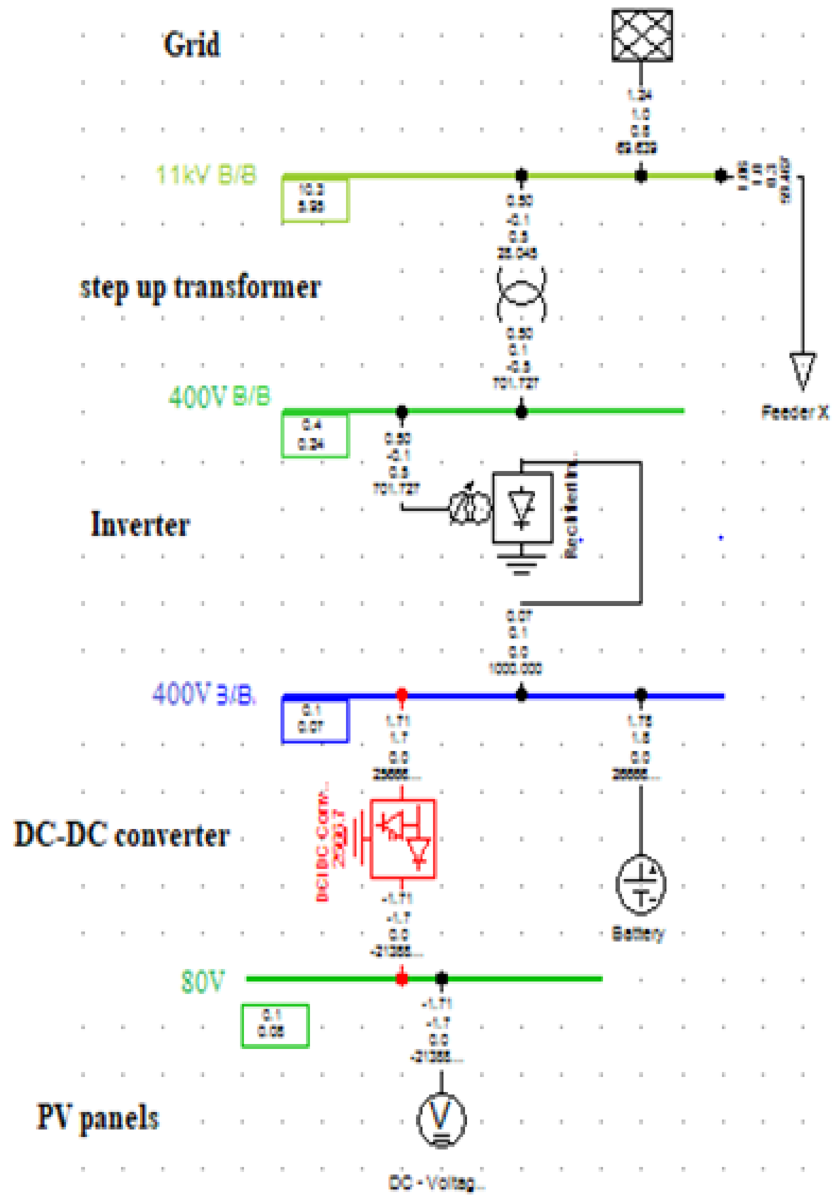


Fig. 9. Power factory modeling

Effects of connecting PV System with Battery Storage to Feeder X

The model presented in Fig. 9 was connected to a Feeder X which experiences low voltages.

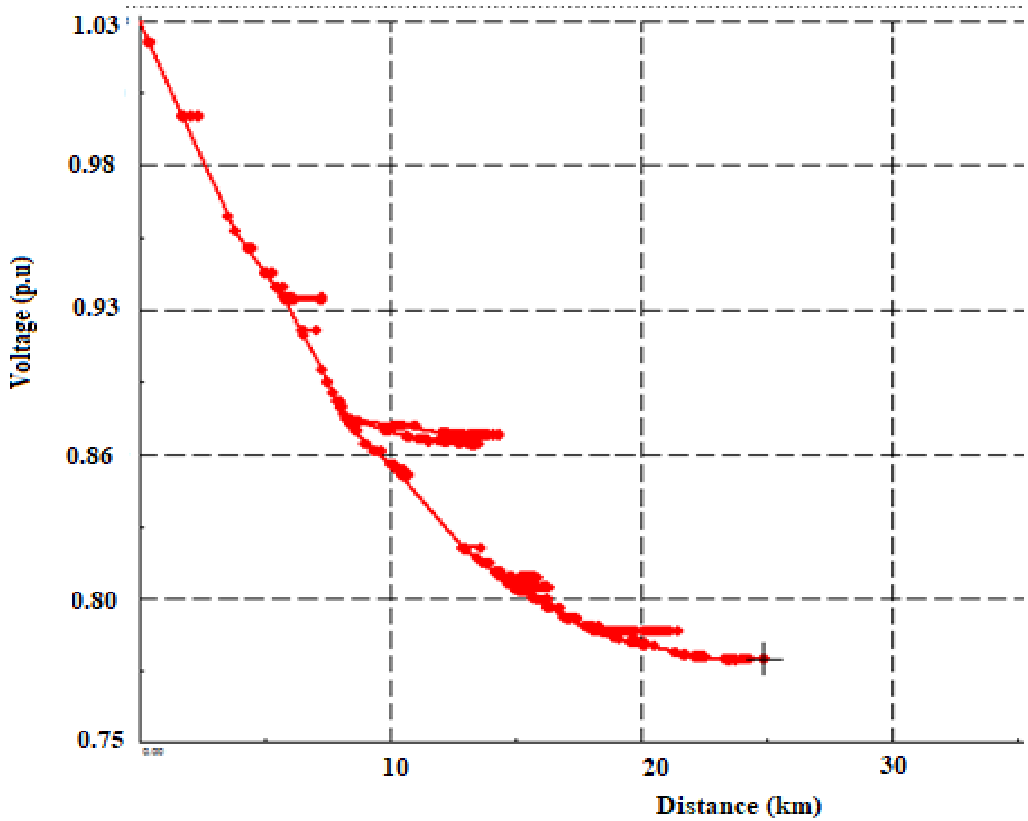


Fig. 10. Voltage profile of feeder X before hybrid system is connected

To **improve the voltage profile** of the feeder X, the hybrid system was connected at a point in the feeder where the voltages were at 0.945 per unit voltage. Fig. 11 shows the voltage profile.

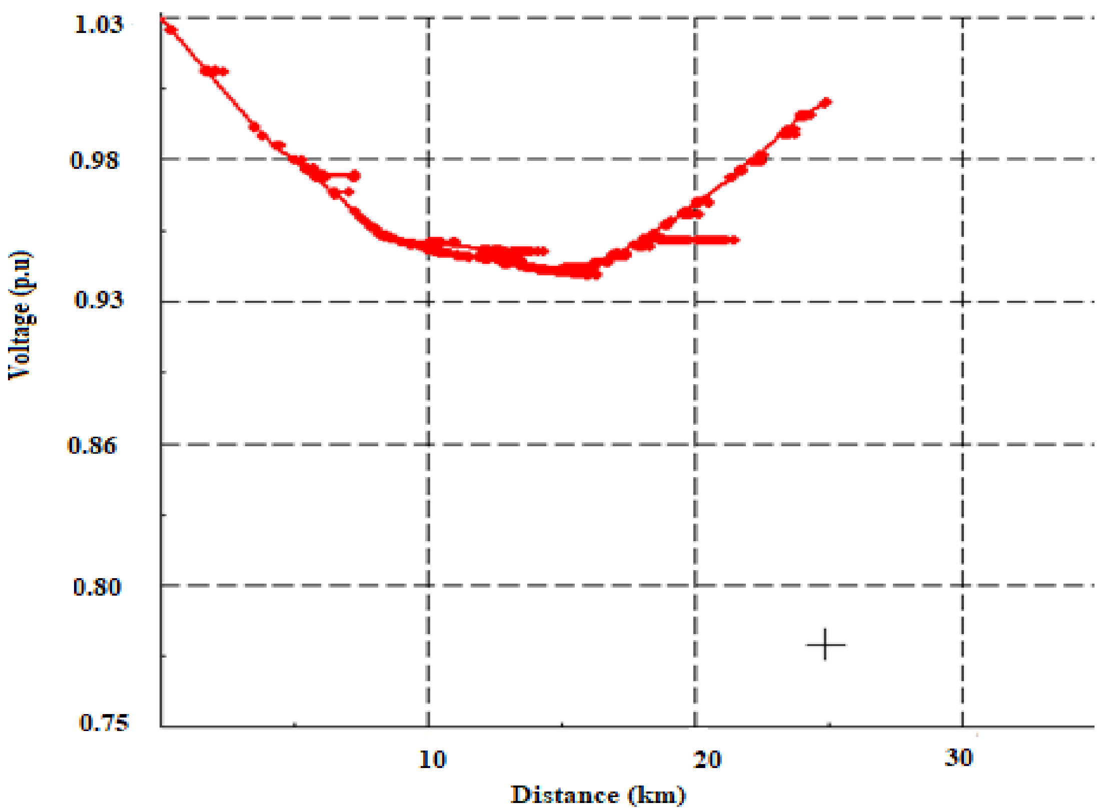


Figure 11. Feeder X voltage profile after hybrid system is connected.

Conclusion

- The PV and battery system are modeled developed in the study to assess the performance of renewable energy technologies in a hybrid system.

- The PV model is simulated with temperature and irradiance variation and the output of the boost converter is regulated.

- The hybrid system made up of PV and battery successfully improved the voltages of feeder X that was experiencing low voltages.

- The outcomes of the study show that the model is suitable for a grid-connected hybrid power system.

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