DESIGN AND ANALYSIS OF "PV-SYSTEM - LOAD - UTILITY GRID" AC MICRO-GRID SYSTEM

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Abstract. *During last two-three decade the interest to Microgrid is increasing because of its advantages over conventional utility grids. Microgrid is a smart way to use renewable resources to generate electricity because it has advantages over traditional utility grids. Even though microgrid has some benefits, it must work with a lot of constant power loads that have negative incremental impedance and make the system very unstable. In this paper, the Microgrid consisting of the filter (RLC), converter P&O algorithm, and PID controller have been designed to meet the needs of the system with utility grid. Also, stability analysis of the system is considered in MATLAB/Simulink.*

Keywords**:** *Microgrid, PV-systems, P&O algorithm, PID-controller.*

1. Introduction

A microgrid is a localized group of electricity sources and loads that work as a single entity that can be controlled. It is connected to the regular utility grid so that it can help out if there is more demand. Depending on how it is built and how the economy is doing, it can be run on its own and can be cut off from the utility grid in case failures or outages [1, 2].

Microgrid is a better choice for the power system of the next generation for a number of reasons. First of all, most businesses, professional organizations, and educational institutions need a reliable power backup because power from the utility grid is unpredictable and often goes out. Private power generation, energy storage systems, and diesel engines are all very expensive ways to get extra power [3, 4].

2. Microgrid system description

As energy from photovoltaic arrays are not stable and depend on the amount of Irradiation and Temperature highly using these systems in grid-connected form has the effect of disturbing the power system and may harm the load and electrical device which sometimes can reach human interfaces and life-death.

So, for this purpose, we analyzed the stability of the PV on-grid system with the load connected in PV and grid sides. The equipment needed for a stable system was designed during the Simulink of the system in the MATLAB program.

We have chosen to design the 100 kW PV array with the grid-connected source of 25kV/50MVA. The Powergui used in Simulink is in discrete mode with sample time=1e-6 s. The whole system worked under 50 Hz frequency. The single-line diagram of the grid-connected PV system is shown in Fig. 1.

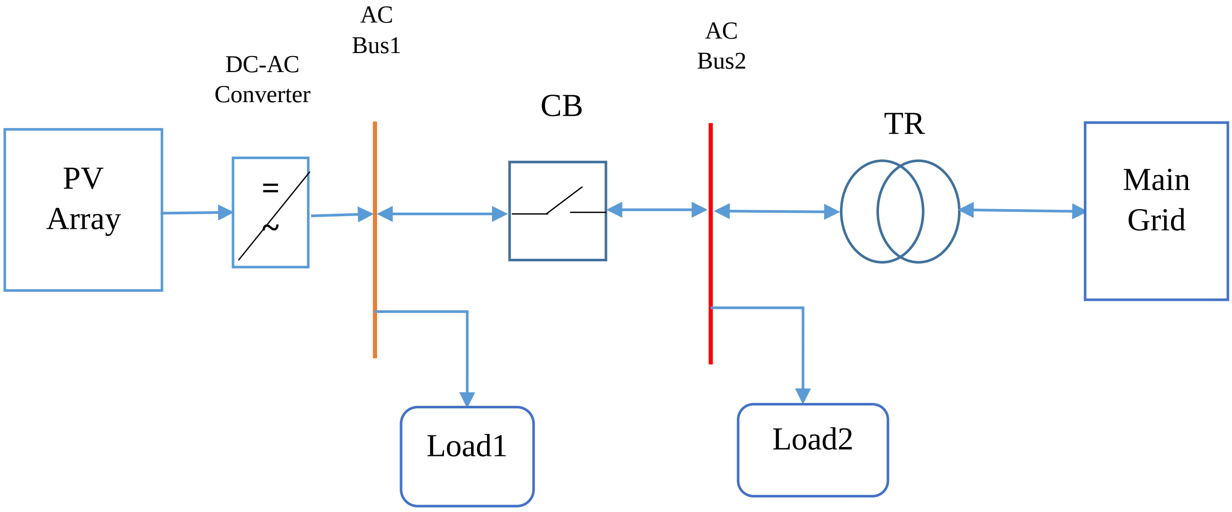


Fig. 1. Single-line diagram of the grid-connected PV system

First, we designed the 100 kW PV array with the required N_{ser} and N_{par} that gives the required output voltage and power. Second, we have chosen the filter for the DC voltage ripples of the PV array. Then we connected the system with DC to-AC converter to have AC power for the converter we made the control logic and for the PV array measurement, we have written the P&O algorithm. At last, after connecting the system with the load, the system is coupled with the grid side by a three-phase breaker. The grid side is composed of feeders, a transformer, and the main grid source.

The technical description of Microgrid components used in this work is summarized in Table 1.

Table 1

The technical description of Microgrid components

Name	Description
PV module	Samsung SDI LPC235SM-02, Nser=25, Npar=17
Parallel-C Filter	1000e-6 F
onverter	DC to AC two-level converter
Series-LC filter	L= 500e-6 H, C= 100e-6 F
Parallel Load	80 kVA, 10 MVA
Breaker	Three-phase breaker
Feeder	2 km, 5 km
Grounding Transformer	40 MVA, 440 V
Transformer	Step down (Y) 25 kV to (D) 440 V, 40 MVA
Three-phase Source	25 kV, 50 MVA, 50 Hz

2.1. Filters and Converter

The output voltage of PV fluctuation, so we used C=1000e-6 F as a parallel connection to stabilize the voltage ripples. After that, a 2-level DC to AC converter has used the change the input dc voltage and current to output three-phase voltage and current with help of the P&O algorithm and PID controller logic. Then the AC output of the converter is connected to the LC filter with L=500-6e H, and C=100e-6 F to stabilize the AC fluctuations of converter voltage, current, and power. The schematic of the filters and converter connection is shown in Fig.2.

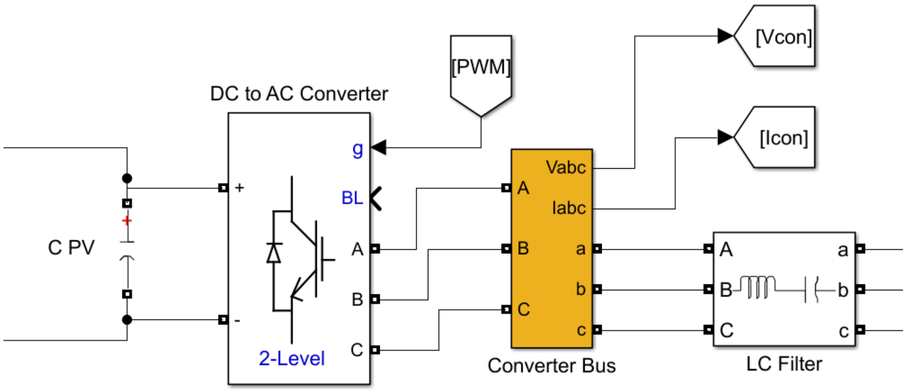


Figure 2: Filters and converter connection in MATLAB/Simulink

2.2. PV array

In this system, we have used 500 as the constant of Irradiation and 25°C as the constant temperature for PV better performance. To have 100 kW output with Samsung SDI LPC235SM-02 modules of PV, we have chosen 930 V as the DC output voltage of panels and found out that Nser=25 and Npar=17 give us the best estimation of outpower.

2.3. MPPT Algorithm

In PV systems, controllers are generally applied to manage the power injected into the grid. Maximum power point tracking is one of the features that some of these controllers have up to 30% more power-efficient than conventional controllers. In large systems, MPPT algorithms have a great effect. For a solar module, MPPT monitors voltage and current to maximize power and thus absorb it [5-7].

The working principle of the above algorithm is based on the perturbation and observation algorithm which in this process a variable change (perturbs) and the effect of that change on other variables is examined (observation). Perturb and Observe Algorithm(P&O) is shown in Fig. 3 [6,7].

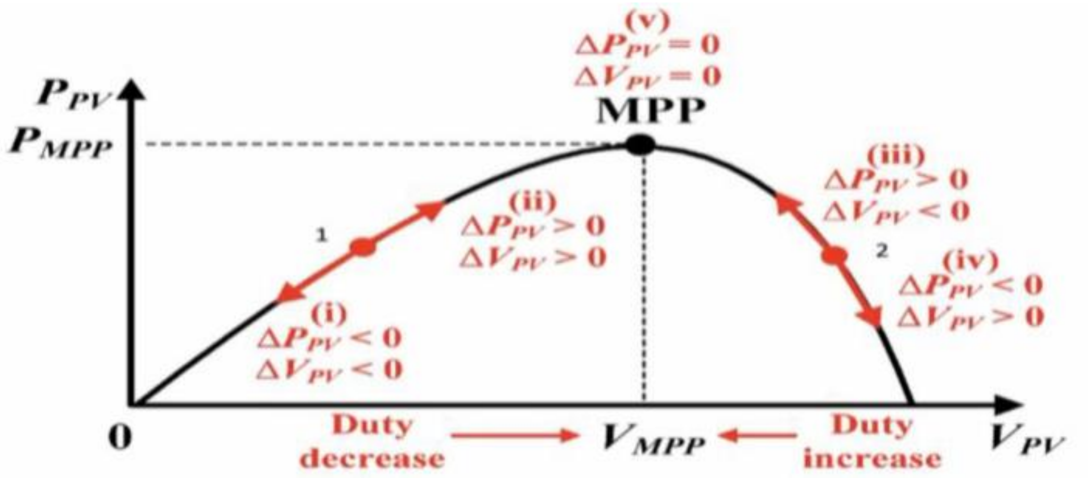


Fig.3. P&O algorithm

2.4. Converter Control logic

As the V_{dcref} is formed from the P&O algorithm, it is checked with the converter current (I_{con}) and the bus voltage (V_{abc}) of the grid side. The result of the control logic is triggered back to the converter as a PWM signal, which maintains the level of voltage and current for the grid and loads side. The control logic of the converter is shown in Fig. 4.

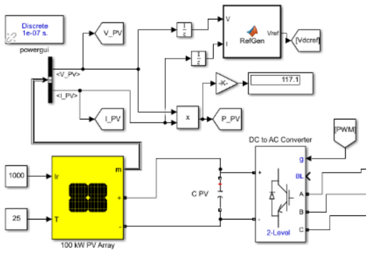
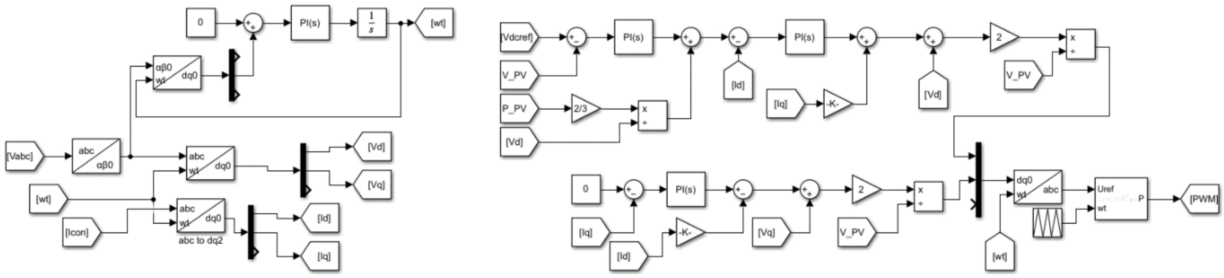


Fig. 4. Control logic of the converter



2.5. Loads

In this system, we have used two parallel loads. The first load is 80 kVA, 440 V which is fed by the PV array and the second load is 10 MVA which is fed by the grid source.

2.6. Three-phase Breaker

For the protection of our system due to high disturbances or faulty occurrences, we have included a circuit protection three-phase breaker to connect/disconnect the PV side from the grid side (the breaker is closed in a normal situation, but the breaker opens due to an error) [8, 9]. CB is shown in Fig.5.

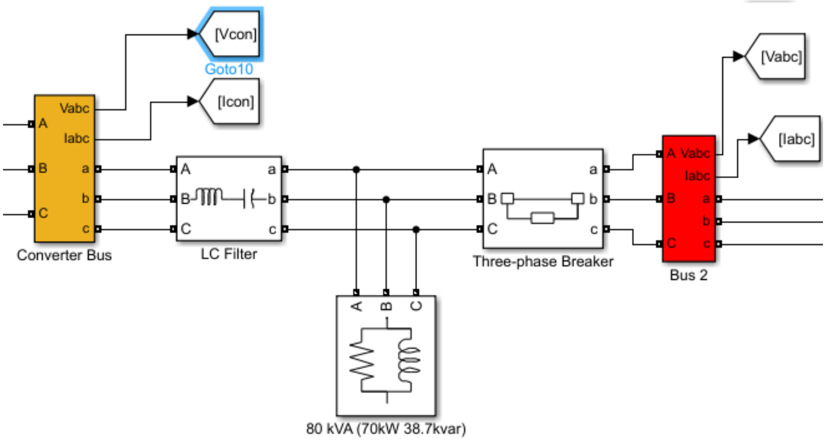


Fig. 5. Circuit breaker, PV-array and grid diagram in MATLAB/Simulink

2.7. Transformer

To establish a convenient connection between utilities of three-phase and the PV array connection with the Grid we have used a step-down three-phase two-winding transformer with 25 kV Y/440 V Delta, 40 MVA, Rm= 500 ohms, Lm= 500 H.

2.8. Main Grid

In this design, a three-phase source is applied that plays the role of an infinite network V=25 kV, f=50 Hz, for a 3-phase short-circuit level at the base voltage of 50 MVA. We need a transformer to be able to supply the transmission voltage. To supply the transmission voltage from the main grid, a three-phase transformer (two windings) is considered, to which two ends of the compensator are connected [10, 11]. Also, the saturation effect for transformers is available. The whole transmission line applies to be 7 km in the design. The main grid and transformer connection with feeders are shown in Fig.6.

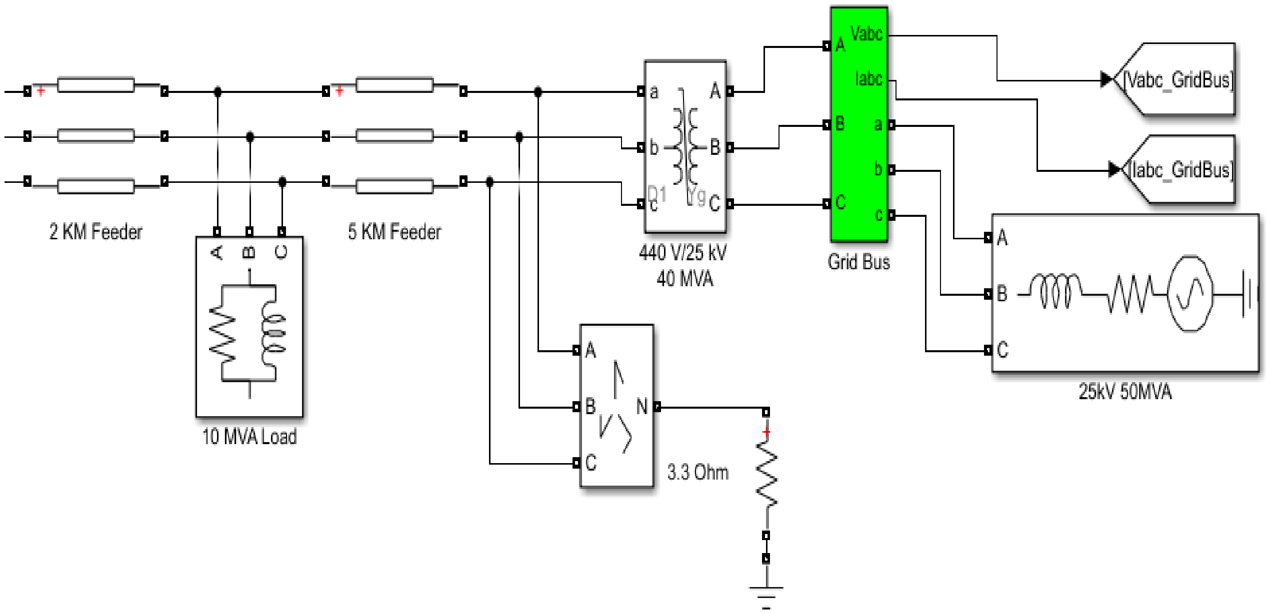
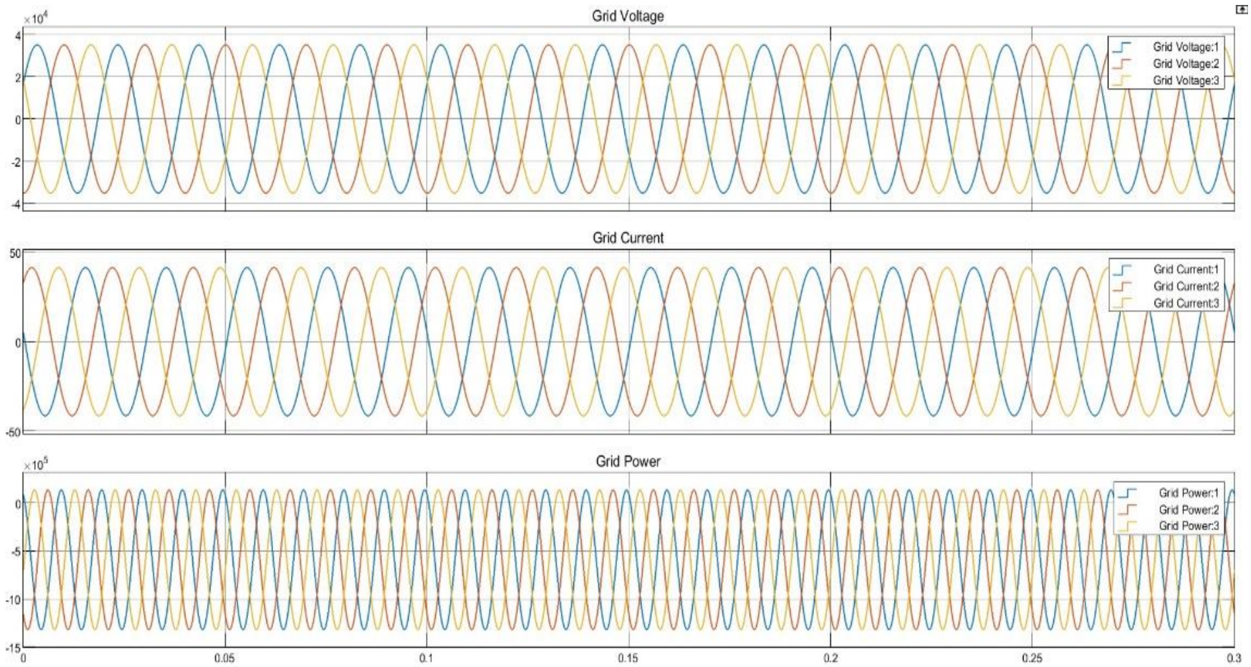


Fig.6. Main grid and transformer with feeder connection

3. Result and Discussion:



As the main grid has regular sinusoidal waveforms, which transfer the same form of waves to the transformer and the loads it maintains the same until another source of power has connected with the grid. The voltage, current, and power of the grid are shown in figure 7.

Figure 7: Voltage, current and power of main grid

The transformer changes the main grid from 25 kV to 440 V for all AC buses of the system. As we connect the 100 kW PV array to the system voltage, current and power of the system have become disturbance with PV source power. So, to establish stability again we added filters and a converter to gain a stable response from both sides. Figure 8 shows the response of bus 2 signals under the effect of both PV and the main grid.

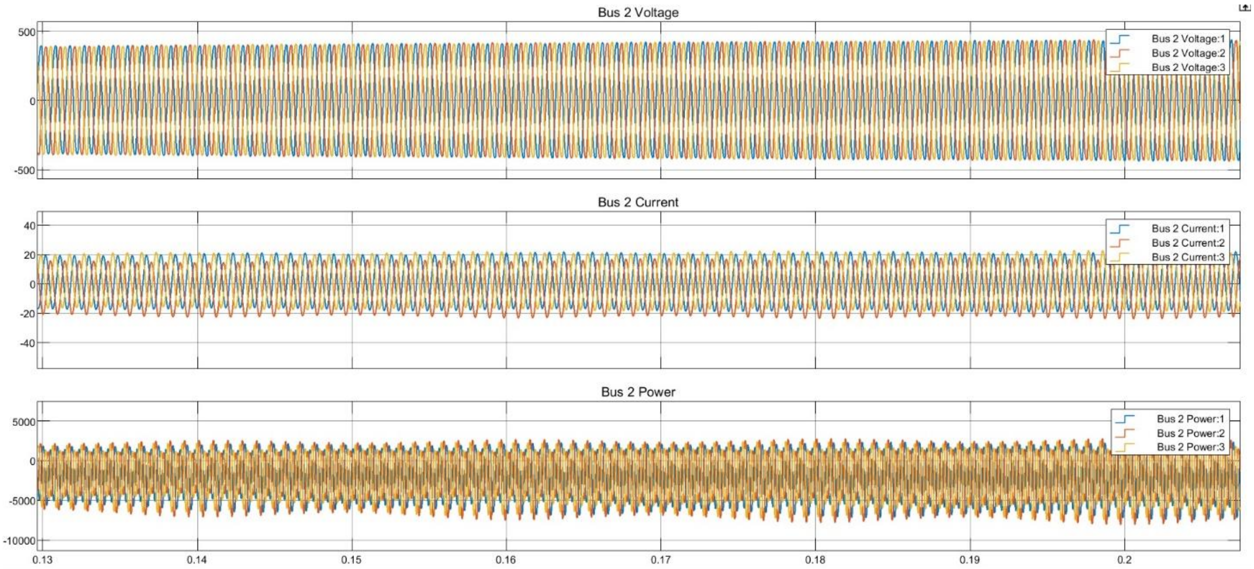


Fig.8. Voltage, Current, and Power of Bus 2

The converter works as the changer of DC power to AC three-phase power. So as the input DC power increases the converter output also increase but the output voltage tends to remain around 440 V of the system. Fig. 9 shows the converter signal contribution during the PV and the main grid connection.

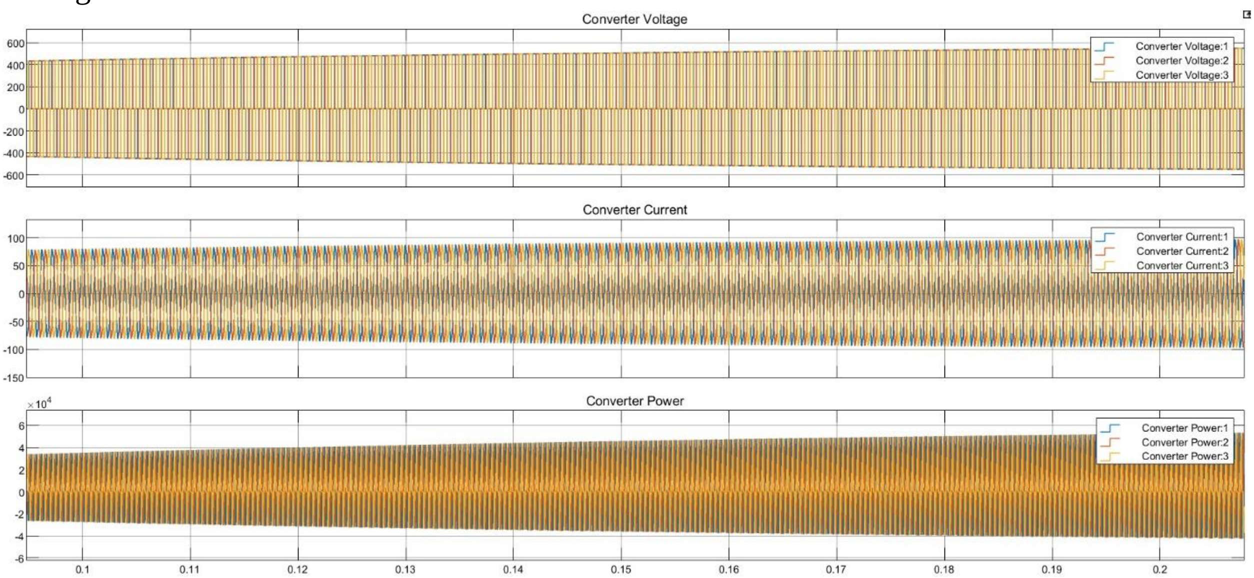


Fig. 9. Voltage, Current, and Power of the converter

4. Conclusion:

AC Microgrid consisting of PV, inverter, loads, and connected to utility grid have designed and stability analysis of the system have implemented in this work. To have better performance of utilities under solar power and grid-connected system we have to design the filter (RLC) and converter P&O algorithm and PID controller in accordance with our system needs. Solar power is based on the Irradiance of solar energy on panels and the hourly temperature of the area where the system is installed. It is very important to maintain the power for AC utilities under the same frequency (f= 50 Hz) and same bus voltage (V= 440 V) of the system. Because of differences in the system behavior, we have to protect the grid and the PV from faulty and disturbance by the circuit breaker.

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