CHAPTER FOUR
APPLICATION, SIMULATION & RESULTS

4.1 Introduction

The generation system which is hybrid solar-diesel, with the diesel system as the backup source of power, and the solar system as the primal operating source of power using the solar panels during the day hours to supply the grid and charge the batteries, and the batteries during night hours to supply the grid.

If for any reason the solar system could not match the load demand the auto transfer switch will put up the backup diesel generator into the grid to match the load, which can happen for a lot of reasons such as rain fall or cloudy skies… etc.

4.2 System Equipments

- Solar Panels.
- Power inverters.
- A power charger.
- Batteries.
- Diesel generation set.
- Transformers.
- Three auto transfer switches (ATS).

4.3 Etap Simulator

4.3.1 Overview

ETAP is the most comprehensive solution for the design, simulation, and analysis of generation, transmission, distribution, and industrial power systems.

ETAP organizes your work on a project basis. Each project that you create provides all the necessary tools and support for modeling and analyzing an electrical power system.

A project consists of an electrical system that requires a unique set of electrical components and interconnections. In ETAP, each project provides a set of users, user access controls, and a separate database in which its elements and connectivity data are stored.

4.3.2 Toolbars

- AC Edit Toolbar

The AC Edit Toolbar contains AC elements. Just click and drag elements to place in One-Line diagram. From the AC Toolbar you can bring the Inst. Toolbar (AC Instrumentation).

Figure 4.1: AC edit toolbar

- DC Edit Toolbar

The DC Edit Toolbar contains both AC-DC and DC elements.

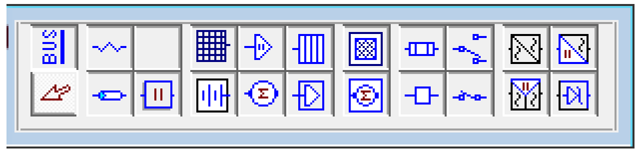

Figure 4.2: DC edit toolbar

4.3.3 Modes

- Edit Mode

Edit mode enables you to build your one-line diagram, change system connections, edit engineering properties, save your project, and generate schedule reports in Crystal Reports formats. You can select this mode by clicking the Edit button (graphically represented by a pencil). The Edit toolbars for AC Elements, DC Elements, and Instrumentation Elements will be displayed to the right side of the ETAP window.

Figure 4.3: Modes toolbar with edit mode selected

This mode provides access to editing features that include:

- Dragging and Dropping Elements

- Connecting Elements
- Changing IDs
- Cutting, Copying, and Pasting Elements
- Moving Items from System Dumpster
- Inserting OLE Objects
- Cutting, Copying, and Pasting OLE Objects
- Merging Two ETAP Projects
- Hiding/Showing Groups of Protective Devices
- Rotating Elements
- Sizing Elements
- Changing Symbols
- Editing Properties
- Running Schedule Report Manager

- Study Mode

Study modes enable you to create and modify study cases, perform system analysis, view alarm/alert conditions, and view output reports and plots. When a study mode is active (selected), the toolbar for the selected study is displayed on the right side of the ETAP window. By clicking the buttons on the study toolbar, you can run studies, transfer data, and change display options. The available study modes and associated study toolbars are shown in figure 4.4.

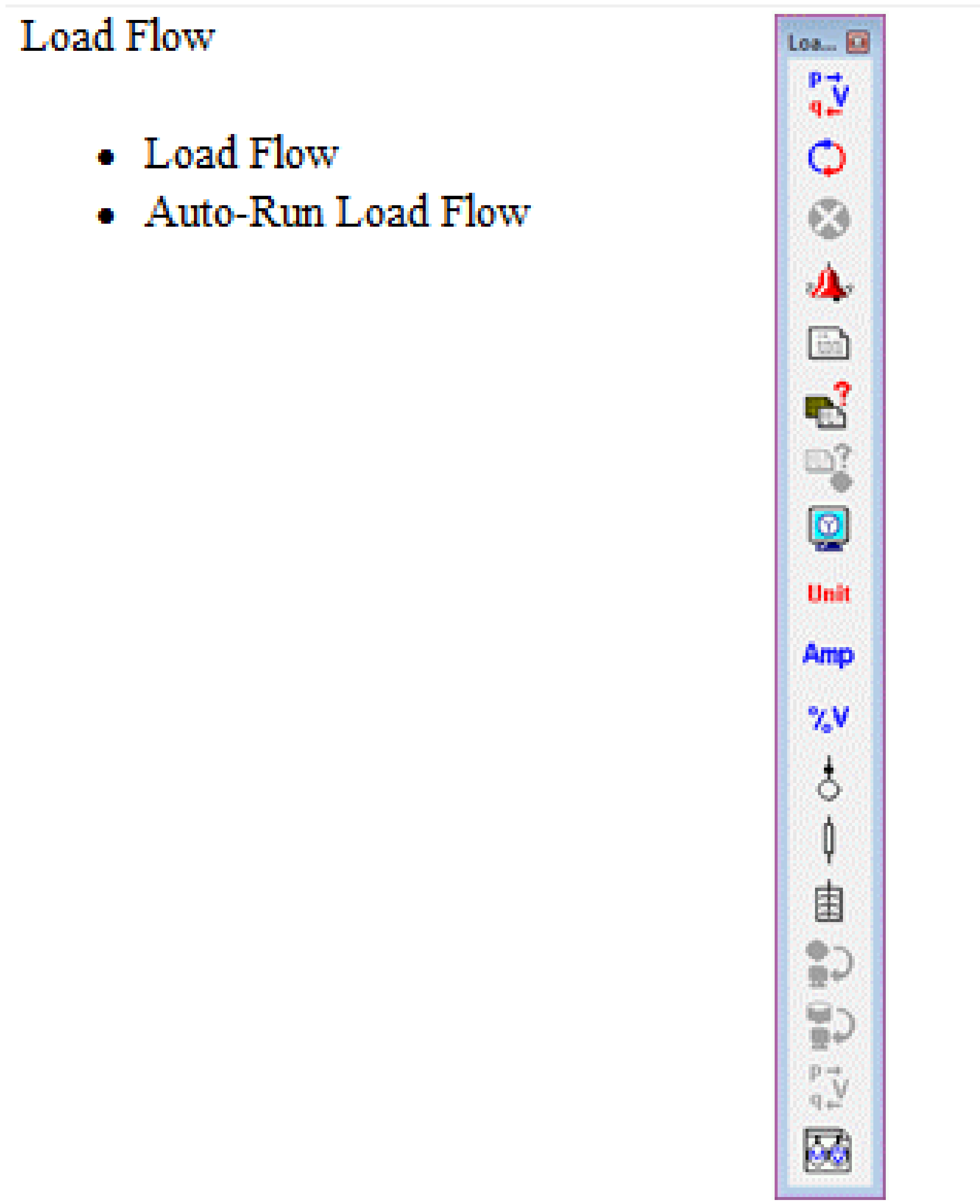

Figure 4.4: Study mode toolbar

4.4 Simulation

The research simulation consists of five different cases.

4.4.1 Case One

This case is represented in figure 4.5.

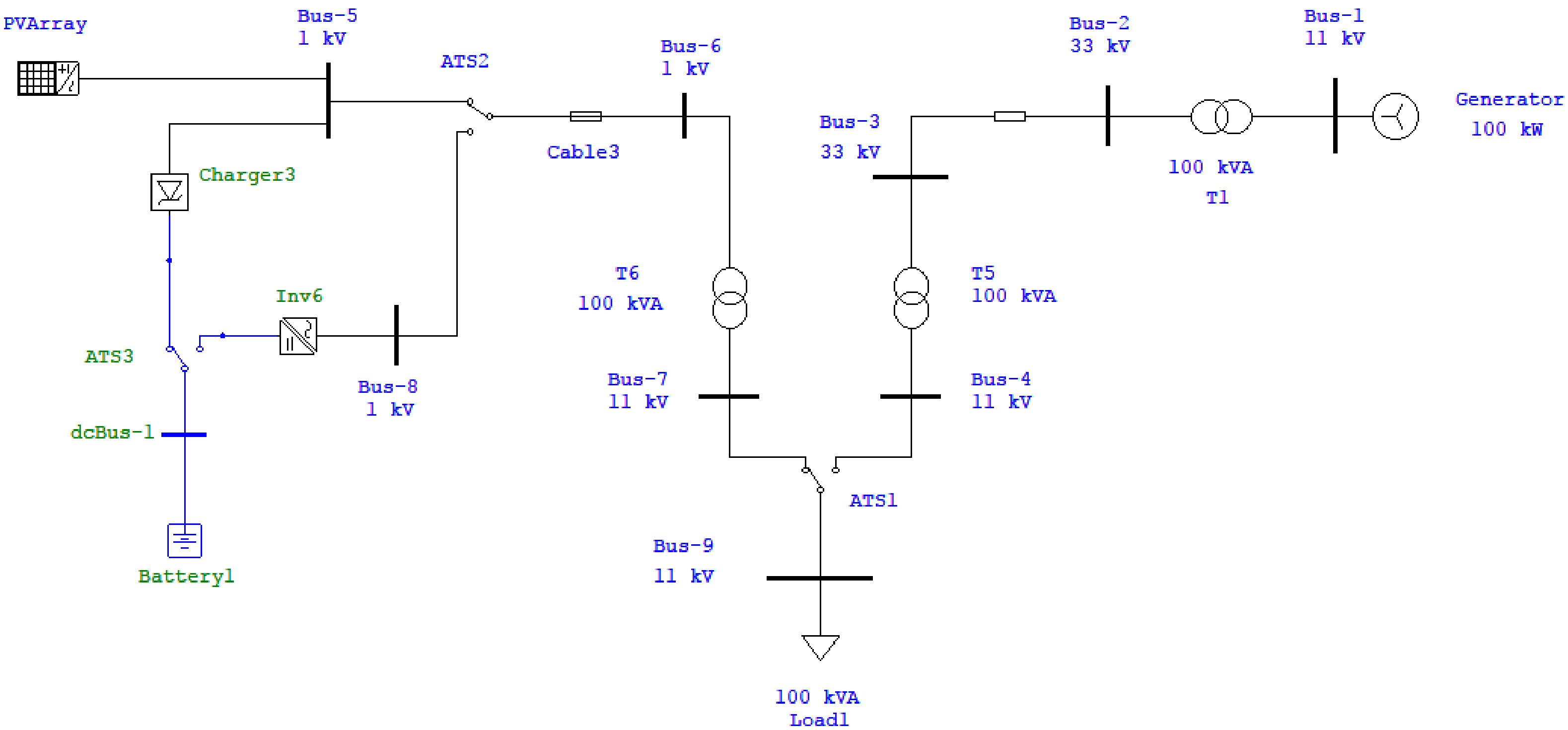

Figure 4.5: Case one

In this case the system show it feeds the load form the PV array and in the same time charging the battery banks.

ATS3 is set to position (A) charging the batteries

ATS2 sets in position (A) feeding the load from the PV array

ATS1 is set in position (A) feeding the load from the solar system as long as it provide enough energy (primary side).

4.4.2 Case Two

This case is represented in figure 4.6.

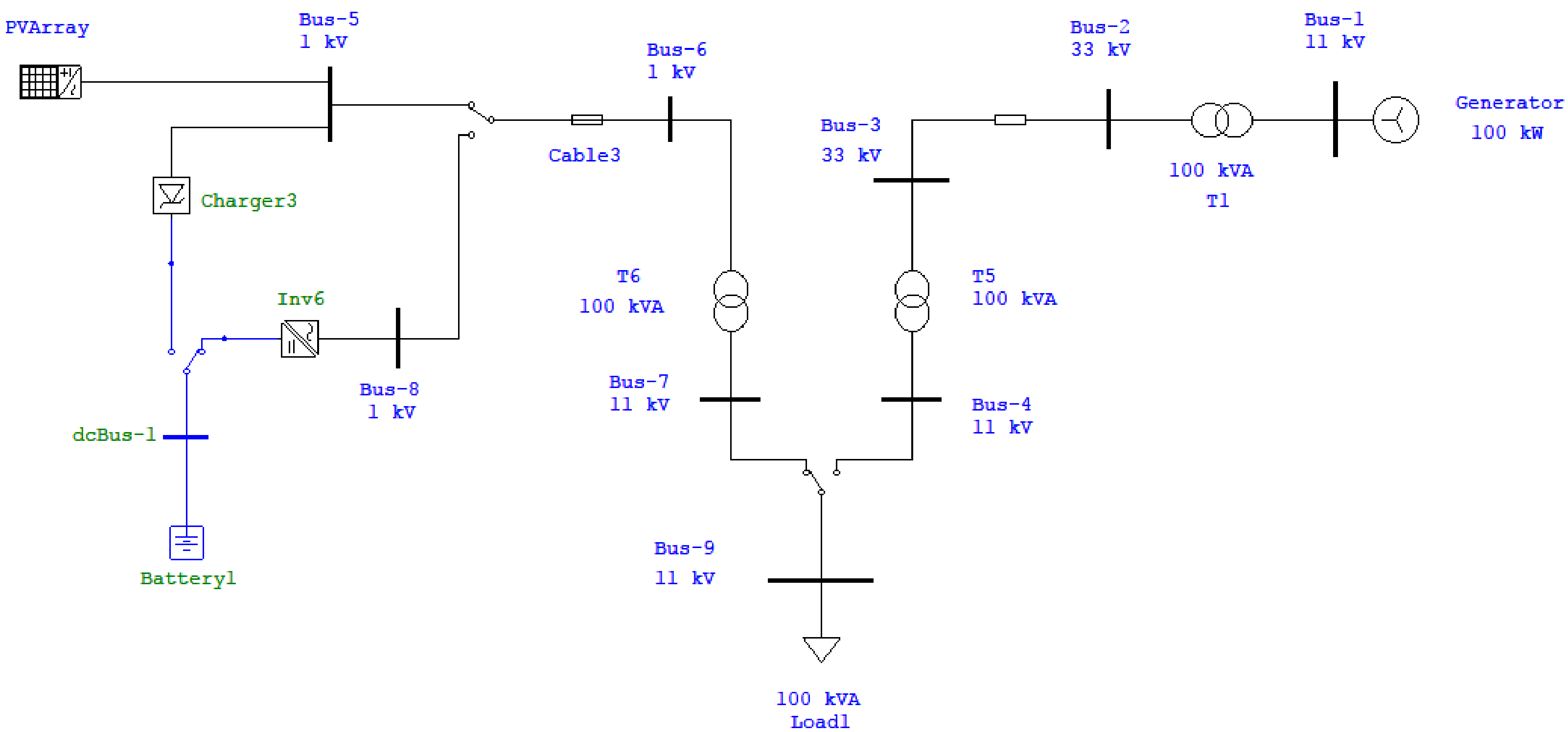

Figure 4.6: Case two

In this case the PV array continues to supply power to the load, but the batteries are now fully charged.

ATS3 changes to position (B) which indicates that the batteries are now full

ATS2 remains in position (A) supplying the load from the PV array

ATS1 remains in position (A).

4.4.3 Case Three

This case is represented in figure 4.7

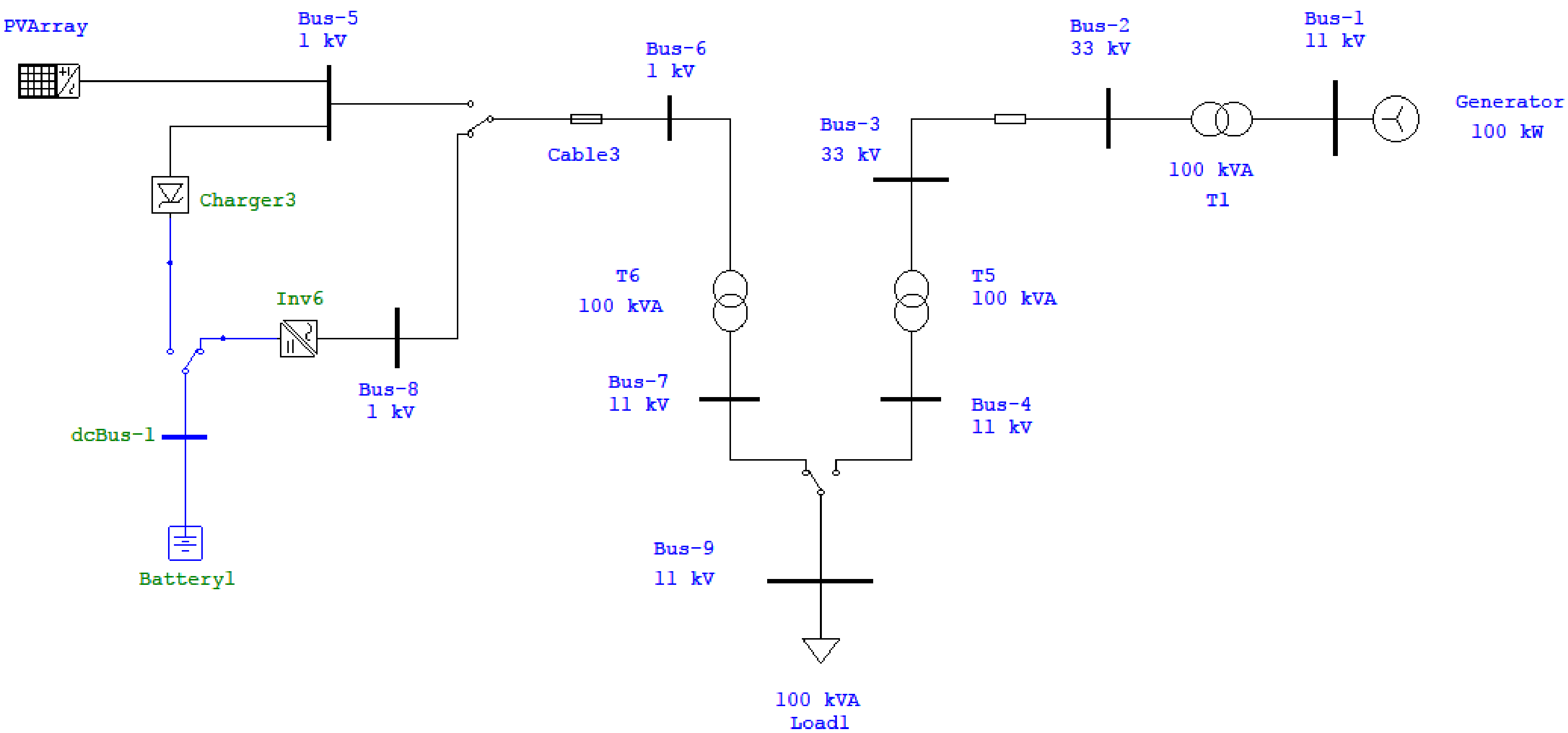

Figure 4.7: Case three

In this case the power produced by the PV array wasn't enough to supply the load so the system checked if the batteries are full before changing the supply direction to the backup generator.

The batteries are now feeding the load with power and the PV array was disconnected.

ATS3 is set to position (B), which means the batteries are fully charged.

ATS2 changes to position (B), which means that the load is now being supplied by the battery banks.

ATS1 remain in position (A).

4.4.4 Case Four

This case is represented in figure 4.8.

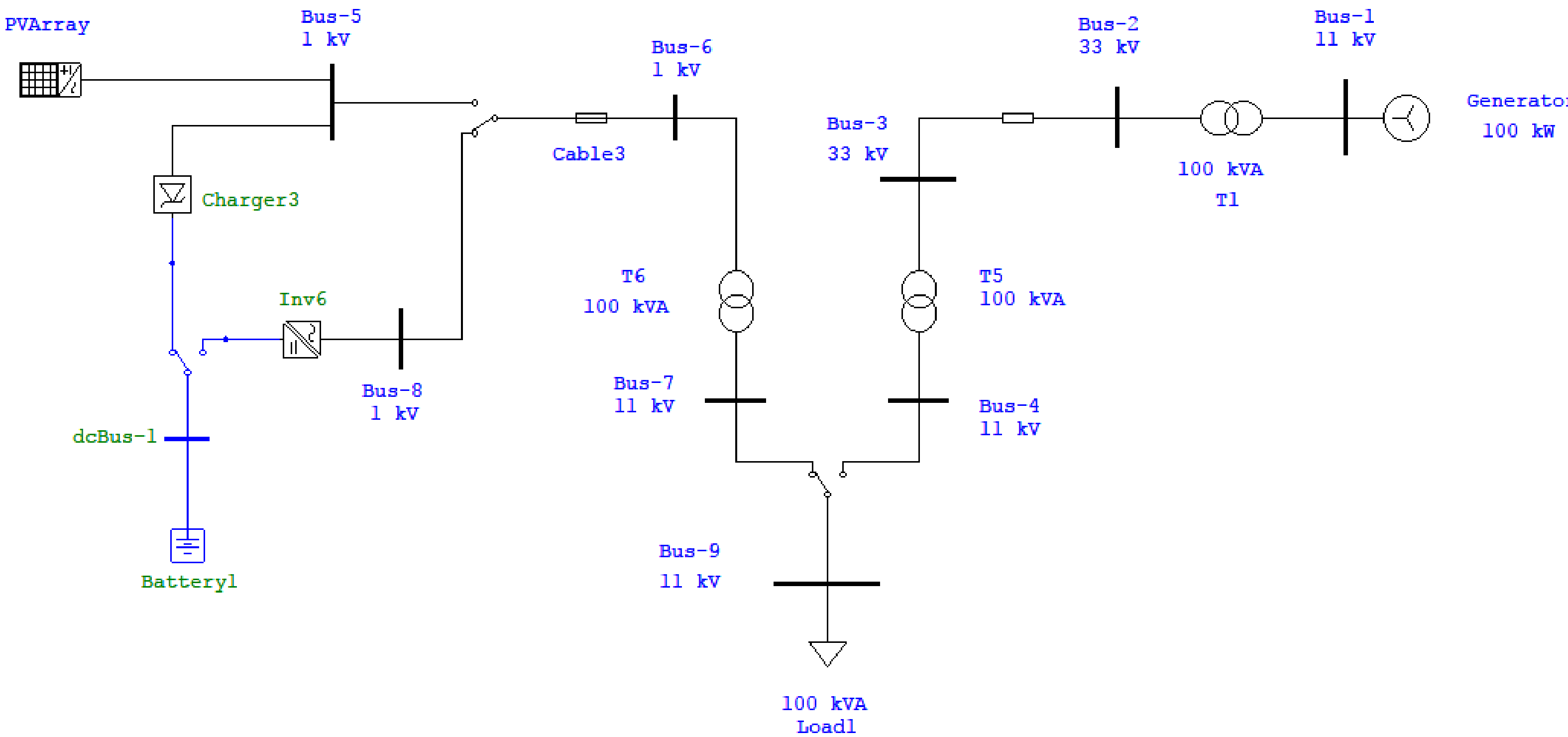

Figure 4.8: Case four

In this case the system is waiting for a response from the primary side before changing to backup. Also the PV array can not supply the load with enough power it still can charge the batteries which are still waiting to be fully charged by the PV array. This case rarely occurs in cloudy days when the sun disappears for a long time (days of autonomy).

ATS3 changes to position (A), which means the batteries, need to be charged again.

ATS2 remains in position (B), which indicates that the PV array cannot supply the load but it may charge the battery banks.

ATS1 remains waiting for a response from the primary side before changing to the backup side.

4.4.5 Case Five

This case is represented in figure 4.9.

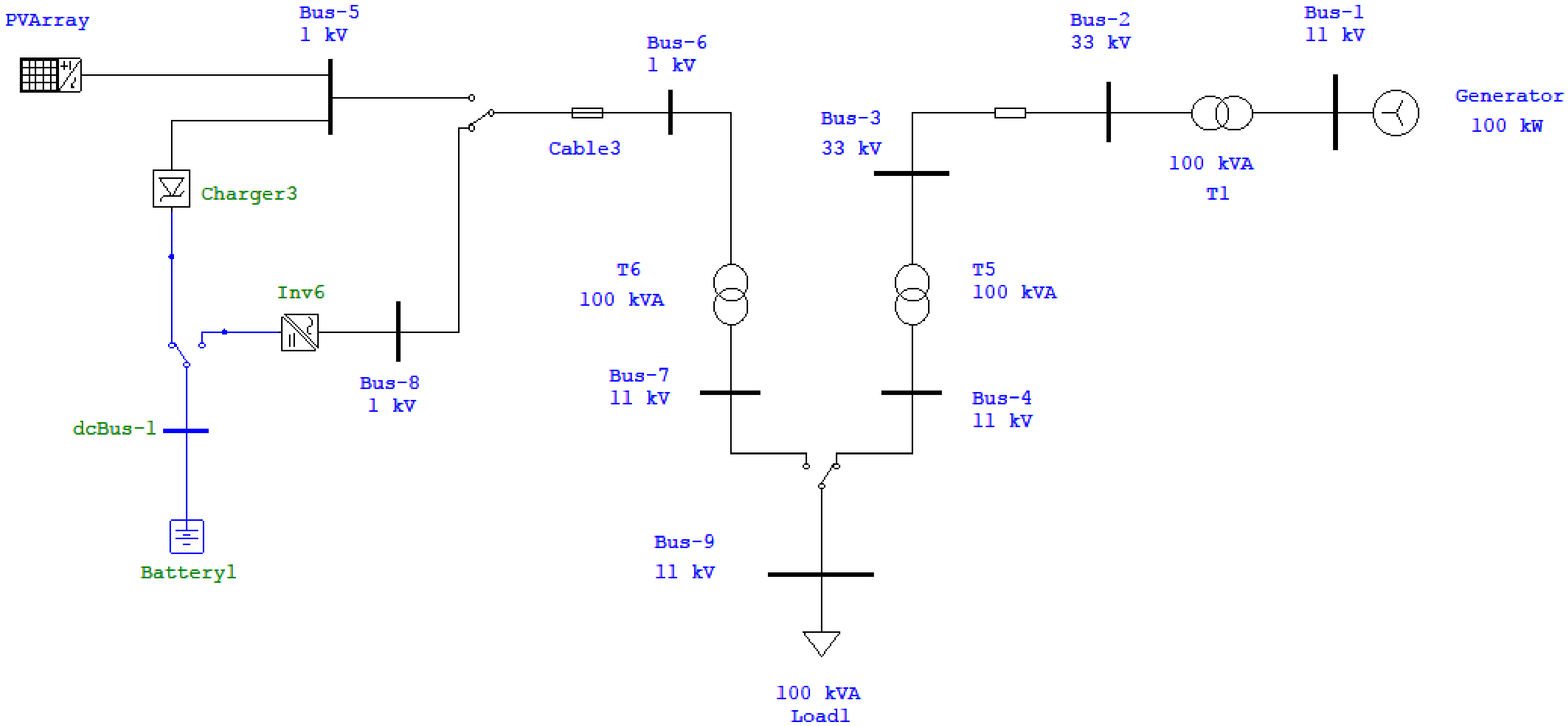

Figure 4.9: Case five

In this case the system is now feeding the load from the backup generator because the PV array cannot provide enough power and the batteries are yet to be fully charged.

ATS3 remains in position (A), which means the batteries need to be charged.

ATS2 remains in position (B), because the PV array cannot supply the load with enough power.

ATS1 changes to position (B), which means that the load is now supplied from the backup generator.

4.5 Results

Load flow analyses were run for the cases discussed in the previous section.

4.5.1 Case One

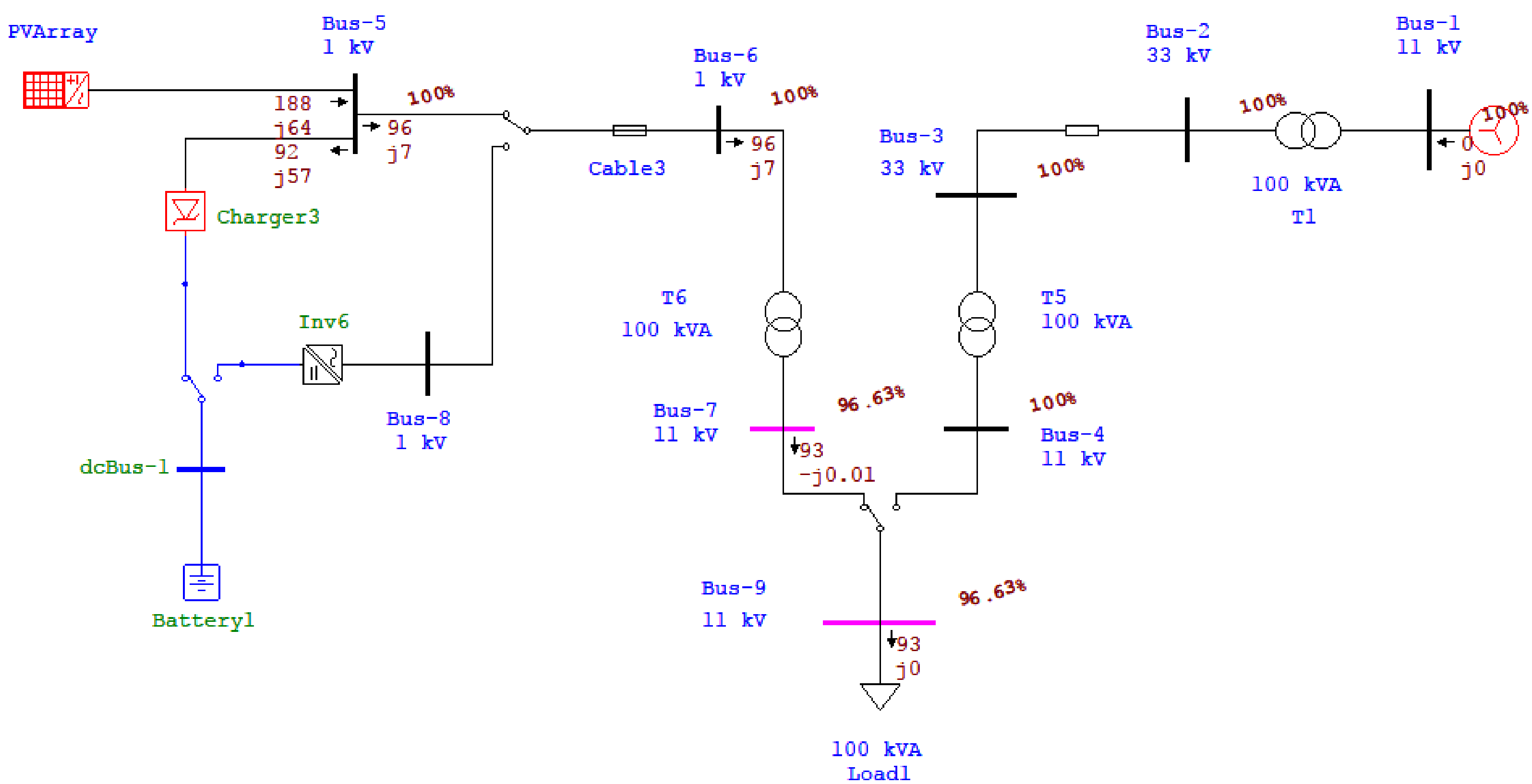

Figure 4.10: Case one's load flow analysis

Analysis shows that the PV array feeds the load with the amount of 93 kW with approximate efficiency of 96.63%.

The PV array also is charging the batteries in the same time.

ATS3 is set to position (A) charging the batteries.

ATS2 sets in position (A) feeding the load from the PV array.

ATS1 is set in position (A) feeding the load from the solar system.

4.5.2 Case Two

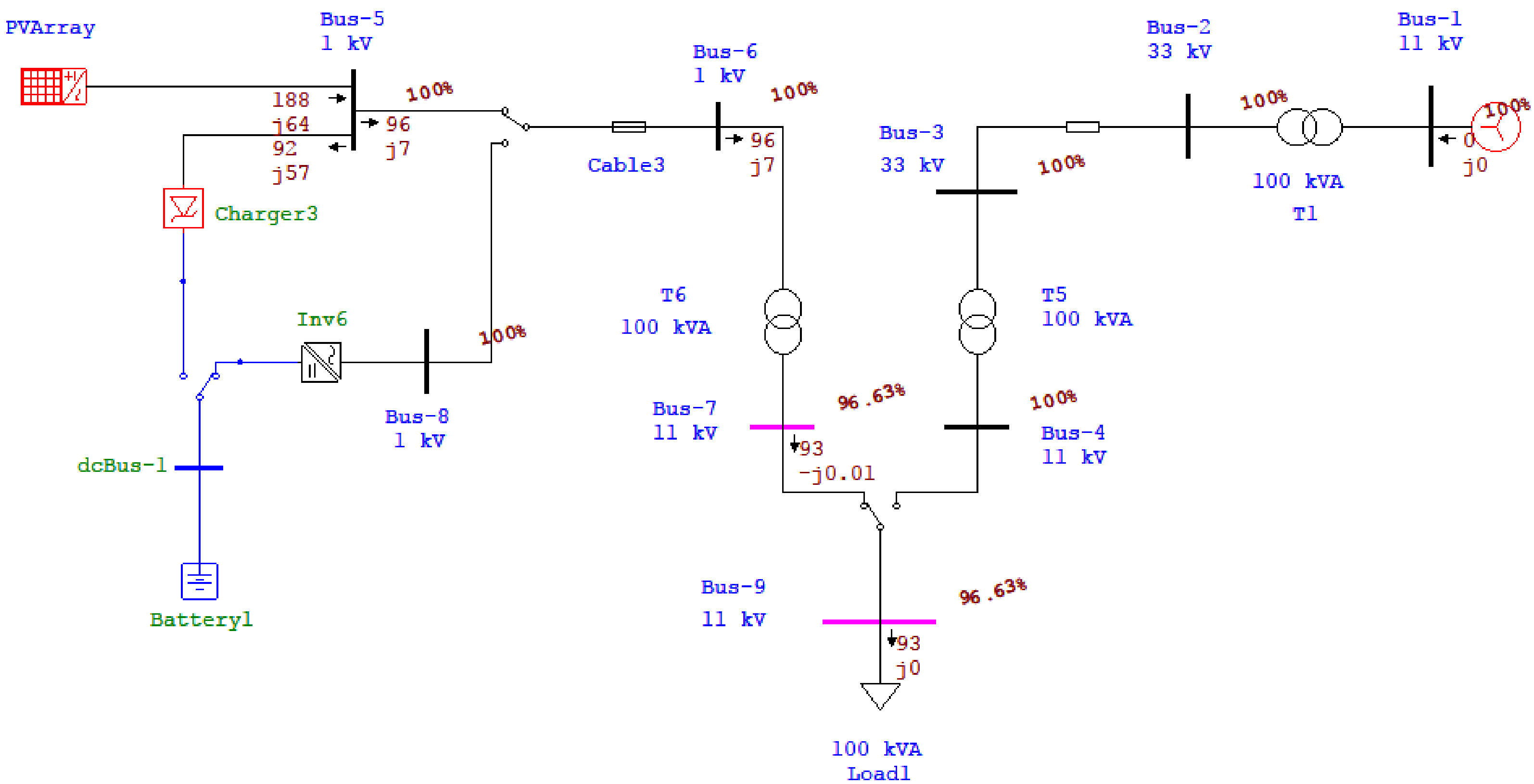

Figure 4.11: Case two’s load flow analysis

Analysis shows that the PV array is still feeding the load with 93 kW at efficiency 96.6%, but the batteries are now fully charged.

ATS3 changes to position (B) which indicates that the batteries are now full

ATS2 remains in position (A) supplying the load from the PV array

ATS1 remains in position (A).

4.5.3 Case Three

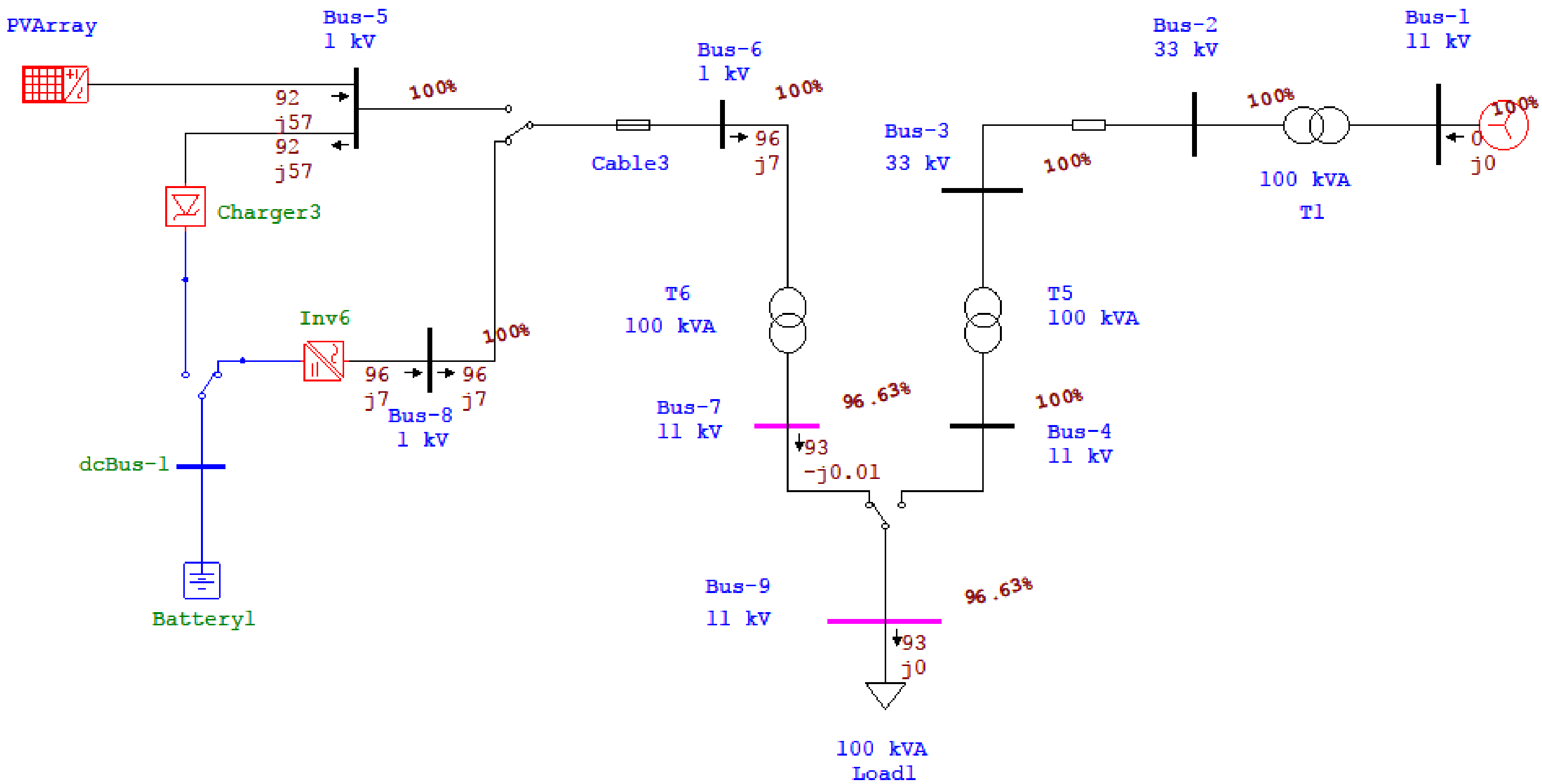

Figure 4.12: Case three's load flow analysis

In this case the batteries are feeding the load with 93 kW of real power and the PV array is out of service.

ATS3 is set to position (B), which means the batteries are fully charged.

ATS2 changes to position (B), which means that the load is now being supplied by the battery banks.

ATS1 remain in position (A).

4.5.4 Case Four

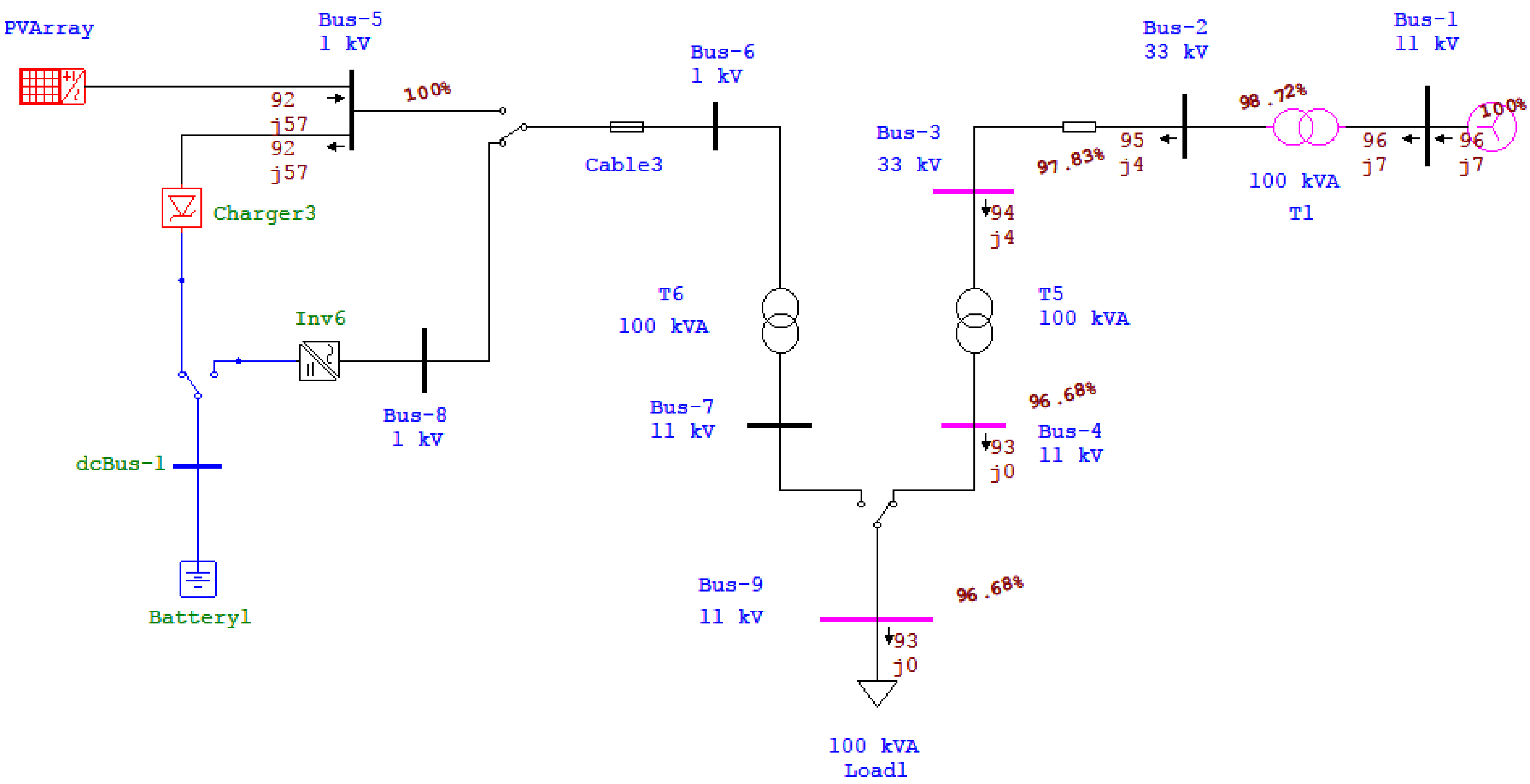

Figure 4.13: Case four's load flow analysis

In this case neither the PV system nor the batteries can provide enough power to supply the load so with the help of ATS1 the load changes to the backup generator, which is now feeding the load with 95 kW real power with efficiency of 97%.

ATS3 remains in position (A), which means the batteries need to be charged.

ATS2 remains in position (B), because the PV array cannot supply the load with enough power.

ATS1 changes to position (B), which means that the load is now supplied from the backup generator.

4.6 Calculations

The solar panels used in the PV array were manufactured by Q.CELLS, their type is poly-crystalline with 60 cells per panel and rated power of 230 watt.

The total number of panels needed is 500 panels connected 25 in series and 20 of parallel, which approximately give 115 kW dc and 733 volts.

Number of batteries strings is 25 with total 20625 AH and 51 volts, which approximately give 96 kW.

According to the national Authority of electricity the power consumed by one person is 124 kWh per year. So for a village populated by 5000 people the total power consumption would be:

124 * 5000 = 620,000 kWh per year

Gives a daily consumption of, 620,000/365 = 1,698.63 kWh

Which means the power needed, 1,698.63/24 = 70.77 kW

4.61 Sustainable Development

The village in which the system was installed has a population of five thousand people, given an increasing rate of 4.5%, the system would be capable of providing power to the village for at least ten years to come, shown in table 4.1.

Years	Population	Annual energy per person	Annual Total Energy	Rating In kW
1	5000	124 kWh	620000 kWh	70.77
2	5225	124 kWh	647900 kWh	73.96
3	5450	124 kWh	675800 kWh	77.14
4	5675	124 kWh	703700 kWh	80.33
5	5900	124 kWh	731600 kWh	83.51
6	6125	124 kWh	759500 kWh	86.7
7	6350	124 kWh	787400 kWh	89.88
8	6575	124 kWh	815300 kWh	93.07
9	6800	124 kWh	843200 kWh	96.25
10	7025	124 kWh	871100 kWh	99.44

Table 4.1: load growth against increasing population

Table 4.1 shows that the system is set to supply the village with enough power for the upcoming ten years with 4.5% population increasing rate.