POLITECNICO DI TORINO
Master of Science Program in Electrical Engineering

Supervisor: Prof. Filippo Spertino
Candidate: Felipe Molina

Control software for micro energy community management

Introduction

These last decades international efforts are being made towards the reduction of global carbon dioxide emissions, as the effects of climate change have been showing. These efforts are made with the objective of reducing the emissions and contain the global rise of temperatures. New policies and regulatory frameworks are being made to encourage the renewable energy projects, increase the energy efficiency of the consumption, encourage self-sufficiency projects, and involve the people on energy transition.

In this context, the PhotoVoltaic Zero Energy Network (PVZEN) project has been developing. The PVZEN project is an innovative multidisciplinary project that involves different departments of Politecnico di Torino. The project consists of the design and construction of a building that meets the requirements of a nearly zero energy building (nZEB). This is achieved by reaching high levels of energy efficiency, reducing its overall consumption. Moreover, the project is characterized for having three active users each one with their own photovoltaic modules, electrical loads and electrochemical storage systems. The users can operate both as a system of three independent users or as an interconnected micro-grid where they are able to exchange energy, an important characteristic for the development of this thesis as it improves the system's self-sufficiency. In addition to this, the load has two main characteristics that enhance the systems energy efficiency. First of all, it is intended to be used by students during the day, a condition that matches the photovoltaic production, improving the direct consumption from the module's generation. On the other side, the heat and cooling requirements are electrified by using heat pumps, subsequently transforming all the energetic requirements into an electricity load demand.

The main objective of this thesis is to develop and test a software capable of reading the measurements of the three users' power profiles, elaborate a control logic capable of deciding which configuration the system should operate and communicate this decision to the system. To test the software, it will be used in a simulation of three different days with different weather conditions to determine its impact on the systems' behavior.

PVZEN electrical system

As said previously, the system consists of three active users each one with their own photovoltaic modules, electric load consumption and electrochemical battery storage as shown in the following pictures.

Figure 1 PV modules and installed inverters

Moreover, the system also has the capability to interconnect the three users thanks to the inverters' ability to work in a master-slave operation mode, as the AC output connection from one inverter can be used to transfer energy to other inverter through its AC input connection. This mode was intended to be used to connect a generator or the grid, but in this context will be used to connect the output of another inverter. The electrical wiring is summarized in the following figure

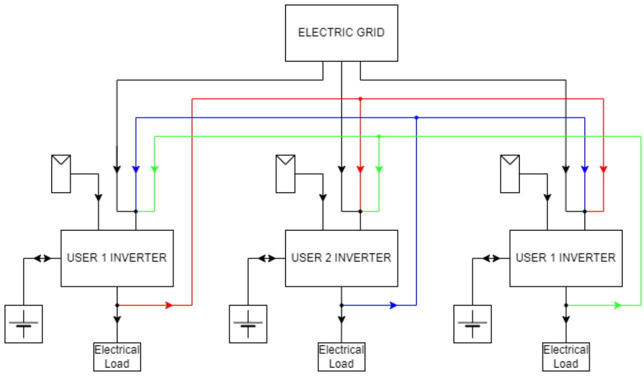

Figure 2: Electrical wiring connections of the system

The electrical interconnection between users, is done by using switches that will be physically controlled by a programmable logic controlled (PLC) that will receive the software's instructions on what configuration the system must operate. This will allow the users to exchange energy among them if a user is in deficit and other user has a surplus of power to share. The logic behind the power balances in the system can be seen in the following diagram

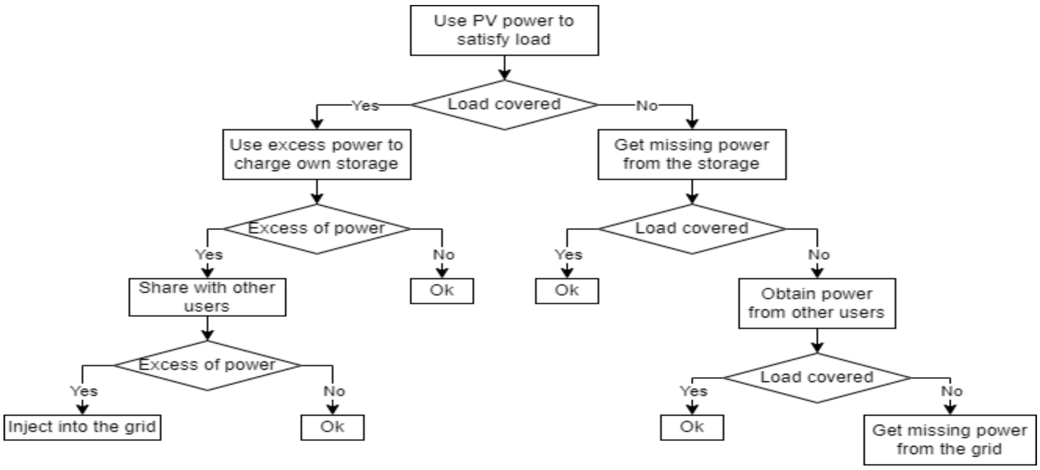

Figure 3 Flowchart of the power balances in the system

Software

The software developed in this thesis was programmed in MATLAB's App Designer, as it allows to both create a graphical user interface (GUI) as to program scripts that can elaborate data. The software itself consists of a three-step program: reading, control logic and writing, as shown in the following scheme.

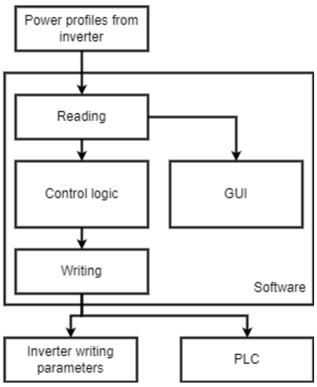

Figure 4: PVZEN software's scheme

The software begins by reading, via Modbus communication protocol, the power profiles measured from the inverters. This information is then sent to the GUI that plots the users' power profiles. Specifically, it plots the photovoltaic generation, load, battery exchange and grid exchange power. Therefore, this information is received by the control logic, that elaborates the power balance for each user independently and determines if each one of them has a surplus to share or a deficit that needs to be covered. Based on this information the control logic determines the system's configuration that will allow the users to exchange energy and updates the state of charge of the user's batteries. Finally, this information is sent to the PLC that will physically perform the control desired connection. Simultaneously, the program communicates via Modbus with the inverters, writing additional information of the control.

Results

The software was used to simulate the system's behavior on three different days: 21st, 22nd and 24th of December 2021. Considered a cloudy, a sunny and a partly cloudy day respectively. This was done by storing the inverter's measurements and importing this information so the software can read each timestep's information as it's a real-time measurement. The main objective was to see how the system behaves on different generation and load profiles and how the batteries can charge or discharge power according to the situation. Some interesting results are shown in the following pictures of the user 1 profiles for the sunny and cloudy day respectively.

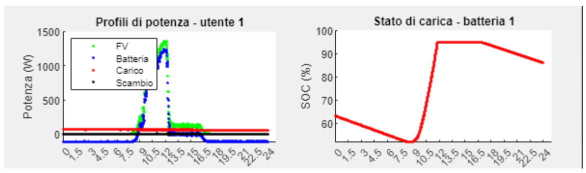

Figure 5 User 1 simulation for the 22nd of December

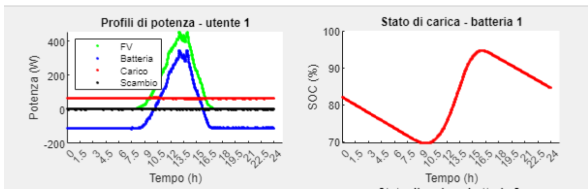

Figure 6 User 1 simulation for the 21st of December

It is noticeable the differences on the photovoltaic production, the sunny day also is characterized for limiting its production when the battery is fully charged unlike the profiles for the cloudy day that don't present this phenomenon. In addition to this, it can be seen the effect of the storage on self-sufficiency as they discharge its power when the photovoltaic generation don't cover the load.

Conclusions

A control software was developed to monitor and manage the energy exchanges on the PVZEN project to improve its energy efficiency. The software is characterized for following three steps: reading, control logic and writing, that allow the software to achieve this objective. Moreover, a GUI was created to help visualize the different power profiles of the users. Finally, it was used to simulate the system's behavior and visualize the effect of the storage system on the system's self-sufficiency.