Investigation Into PV as an Enabler for Inis Oírr to Become Energy Independent

Roger Miori Perim
National University of Ireland - Galway
r.mioriperim1@nuigalway.ie

Keywords: Electrical Engineering; Physics and Energy.

Abstract
This research focuses on the development of a domestic standalone photovoltaic system using Matlab Simulink software in order to simulate the energy generation and load/energy storage device profiles for different climate conditions. The model is based on one of the Aran Islands and all system characteristics were provided by Aran Island’s households for a more realistic simulation.

1. Introduction
The energy consumption in the world has more than doubled in the last forty years, coming from 6,100 Mtoe in 1973 to 13,541 in 2013, and several reasons are told to explain these figures, the population growth, the wealthy increase in some nations and the development of emerging countries. Nowadays, the usage of fossil fuels (coal, oil and natural gas) is bigger than it was ever before, which represents 82% of all energy consumption in the world (in 2015) [1].

As known, fossil fuels are the main reasons for the growth in GHG (Greenhouse Gases) emission and this factor is very harmful for the environment. Climate, vegetation, fauna and ecosystems can be affected by the temperature increase provoked by this factor. In order to mitigate those issues, some agreements have been set around the world, such the Kyoto Protocol and the Paris Climate Accord, and as established in these agreements, the European Union has to achieve some goals in short and long terms.

Some other sources of energy, called renewables, are being used to decrease the GHG emissions. The most used ones are: wind, solar, biomass, hydro, geothermal and nuclear. These technologies were developed to decrease the usage of fossils fuels to produce energy. With the development of renewables, a large amount of green energy can be injected into the grid resulting in a less dependency on fossil fuels price variations and in the mitigations of CO₂ emissions.

This project aims to develop a modelling tool that predicts the performance of various PV installation configurations on Inis Oírr (one of the Aran Islands off Galway/Clare), for the purpose of identifying the most suitable PV technological solutions that will enable the island to become independent of fossil fuels by 2020. As a first step in this direction, the model will focus on PV sources and different energy storage types, including batteries, immersion heating, storage heating and air-source heat pumps. Models at two levels will be considered: domestic installations designed for typical residential houses and a larger community based installation designed to serve a larger electrical load. In addition to increasing the utilization level of PV production in both cases, another aim will be to enable grid-independent operation in the event of a mains power outage.

2. Methodology
To develop solar photovoltaic systems, it is necessary to understand the aspects that influence the power generation. The photovoltaic (PV) energy is generated by the direct conversion of sunlight into electricity by solar cells through an effect called photovoltaic effect. The amount of energy generated is directly related to the solar irradiation which means that the greater the solar irradiation, the greater the energy production from the panels.

A solar cell can be modeled using the following electrical circuit (Figure 1). The basic equations to model a solar system are [2]:

![Figure 1: PV cell equivalent circuit](https://via.placeholder.com/150)

\[
I_s = I_{sc}(AM0) \times (1 + (I_{sc} - I_{oc}) \times R_s) / E_{in} \times (1 + \alpha_{oc}(T_c - T_0)) \quad (1)
\]
\[
I_{mp} = I_{mp} \times \left[ (I_{mp} + I_{mp} \times (V_{mp} - V_{oc})) / E_{in} \right] \quad (2)
\]
\[
V_{oc} = V_{oc} + N_e \times (T_c - T_0) \quad (3)
\]
\[
V_{mp} = V_{mp} + N_e \times (T_c - T_0) \quad (4)
\]
\[
P_{mp} = I_{mp} \times V_{mp} \quad (5)
\]
\[
FF = P_{mp} / (I_{mp} \times V_{mp}) \quad (6)
\]

Where:
\[
E_{in} = I_{sc} / [I_{mp}(1 + \alpha_{oc}(T_c - T_0))] \quad (7)
\]
\[
\delta(T_c) = \theta_c / (T_c + 273.15) \quad (8)
\]
\[
I_s = I_{sc} \times (I_{sc} + I_{mp} \times (V_{mp} - V_{oc})) / (1 + (I_{sc} - I_{oc})(T_c - T_0)) \quad (9)
\]
\[
I_{sc} = I_{mp} \times (I_{mp} + I_{mp} \times (V_{mp} - V_{oc})) / (1 + (I_{mp} - I_{oc})(T_c - T_0)) \quad (10)
\]

The MPPT (Maximum Power Point Tracking) is a technique used to maximize the power generation for diverse climate conditions. In the incremental conductance method, a prediction of a change in the PV output voltage is made measuring incremental changes in the array current and voltage. The maximum power point is observed when the incremental conductance is the same as the array conductance. The method algorithm can be seen on Figure 2 [4].
3. Description of Experiment
The presented experiment is based on real information given by one household of the Aran Island to better understand and simulate new solar PV system. Figure 3 shows a Matlab Simulink model of a standalone PV system which contains 10 panels of 265 W each distributed in 2 string in parallel with 5 panels in series each. The inputs of the system, solar irradiance and temperature, were set as non-constant values for a realistic simulation.

The system contains a boost converter with MPPT which is linked to the energy storage device and to a universal bridge that is linked to the house loads. The energy storage device used was a 12 V lead-acid battery (240 Ah) with an initial state-of-charge set to 85%. The loads are represented by a subsystem which contains 7 different loads which varies from 500 W to 750 W resulting in a final load of 5,000 W, which can be seen on Figure 4.

4. Results
The result that can obtained through this model is a simulation, in function of the climate conditions, of a domestic solar PV system with an energy storage device. Through this model, the energy production, converter efficiencies, energy storage device characteristics and loads profiles can be determined to better understanding the system feasibility.

5. Conclusion
The Matlab Simulink model generates a good overview of the system function and shows reliable results of energy output and components characteristics. The next step, currently being undertaken, is to improve the currently model, testing different climate and energy storage device scenarios and make an economic feasibility for the system.

6. References