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Feasibility Study of a PV Hydro Hybrid System, With Photovoltaic Panels on Floating Structures

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Abstract: This paper intends to contribute, presenting a feasibility study for the implementation of a PV hydro hybrid system in Laranjeiras dam, in southern Brazil, with photovoltaic panels on floating structures. The study was carried out using software HOMER, which exported 8 760 annual values of solar radiation for the city of Três Coroas, and the power to be generated by the hydroelectric plant was determined from 8 760 hourly values of the Canastra turbinated flow, which were made available by CEEE. The study determined that the operation of the hybrid system would be optimal, by installing a hydroelectric plant at the foot of the dam, with 1 497 kW of installed capacity, operating with photovoltaic panels on the dam's water mirror, with a minimum capacity of 180 kW installed, and with 400 kW as a limit to purchase and sale energy to grid, to meet consumer demand up to 40 MWh/d. This combination would result in an initial cost of US $ 3 984 885 / kW and an energy cost of US $ 0.026 / kWh.

1. Introduction

With this serious energy crisis, the vast majority of people in the world are living below the poverty line, and especially in the rural areas [1]. Energy is central to nearly every major challenge and opportunity the world faces today, so, access to energy for all is essential [2].

Nevertheless, energy is the dominant contributor to climate change, accounting for around 60% of total global greenhouse gas emissions [2]. This fact is very worrying because the share of renewable energy in the world energy matrix was not more than 20% by 2015 [3]. That is why global interest and investments in renewable energy sources has increased considerably in recent years. These technologies have the advantage of using locally available resources, reducing dependence on external energy sources. Another good advantage of this energy is to meet rural energy demand, reduce the pollution of the environment, respond to climate change, and promote the development of the local business with small factory [4].

However, most renewable energy technologies suffer from an intermittent characteristic due to the diurnal and seasonal patterns of the natural resources needed for power generation [3]. In this context, hybrid systems based on complementary energy resources can be used as a tool for management of renewable resources [5]. A possible complementarity between energy resources can help reduce the risks of the hybrid system fails during periods of reduced energy availability and may also contribute to the installed capacities are lower. Methodologically, this paper was carried out using software HOMER, aiming to contribute presenting a feasibility study of a PV hydro hybrid system to be installed in Laranjeiras dam, in southern Brazil

2. Simulations with HOMER, the Micropower Optimization Model

HOMER [6] is a software for optimization of hybrid systems on micro and small scale. It was originally developed by U.S National Renewable Energy Laboratory (NREL) and is available for universal access in its Legacy version. HOMER simulates a system for power generation over the time period of 25 years at intervals of 60 minutes, presenting the results for a period of one year [7] [8].

In this paper, PV modules with costs between 4000 US$/kW and 2000 US$/kW were considered as suggested by [9]. The installation of photovoltaic panels on floating structures, as suggested by [10] [11], raise the cost by 30%. The PV system has a useful life of 12.5 years, and was considered 80% of initial cost to the cost of switching the photovoltaic system at the end of the 12.5 years' service life, due to the possibility of recovering 20% of the PV system, with the sale of the system that will be in operation. The annual O&M cost for the photovoltaic system to be adopted will be 5% of the installation cost of the hybrid system considered as an optimal solution, which results in a value of 3200 US$/kW.

The engine room of the hydropower plant represented by the "Hydro" button will be located at the foot of the dam, with a useful life of 25 years. The hydroelectric cost was considered as a sensitivity variable with values of 750.000.00 US$/kW, 900.000.00 US$/kW and 1050.00 US$/kW, as recommended by [1]. In addition, was considered 80% of initial cost to the cost of switching the hydroelectric plant, due to the possibility of recovering 20% of the value of the hydroelectric plant with the sale of the equipment that was in operation. The annual cost of O&M for the hydroelectric plant has a typical value of 4% of the installation cost according [1]. In this context, the power supplied by the grid will obey the table of values determined by [12], with a cost of 0.100 US$/kWh outside peak hours and 0.500 US$/kW at peak hours, while the sale occurs with values of 0.080 US$/kW outside peak hours and 0.250 US$/kW at peak hours.

Figure 1 shows the mean incident solar radiation in a horizontal plane for each month, the deviations around these averages and maximum and minimum values are shown. The maximum insolation occurs in January, while the minimum occurs in June. Moreover, figure 2 shows the hourly variation of the flow rate with an average of 9 171 L/s, where the maximum flow values occur in September and October, while the minimum occurs in March.

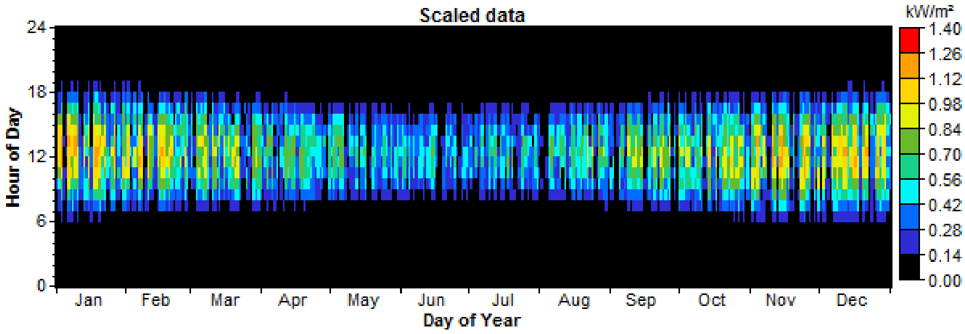

Figure 1. Time values of the solar radiation incident on a horizontal plane, obtained with HOMER.

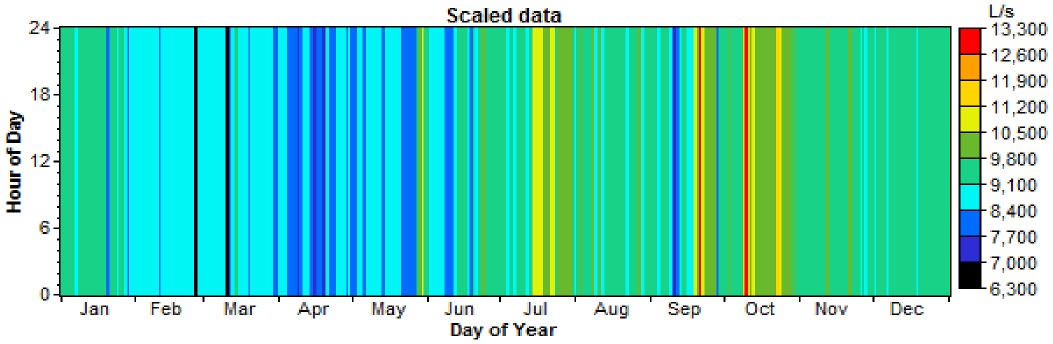

Figure 2. Hourly flow series obtained, through 8 760 hours per year, for the year 2015.

3. Results and Discussion

The simulations results of the proposed hybrid system (figure 3), connected to the grid to sell surplus energy and to buy energy in case of insufficiency, indicate some optimal solutions, as shown in figure 4, which indicates the monthly averages of electricity generation per year. The purchase and sale of energy o the grid in the national interconnected system has been taken into account in all cases, with less dependence on the grid in October, and the participation of photovoltaic solar energy within the system under study is much lower in July, but for the present study it was considered as a solution a system that does not depend on the energy coming from grid.

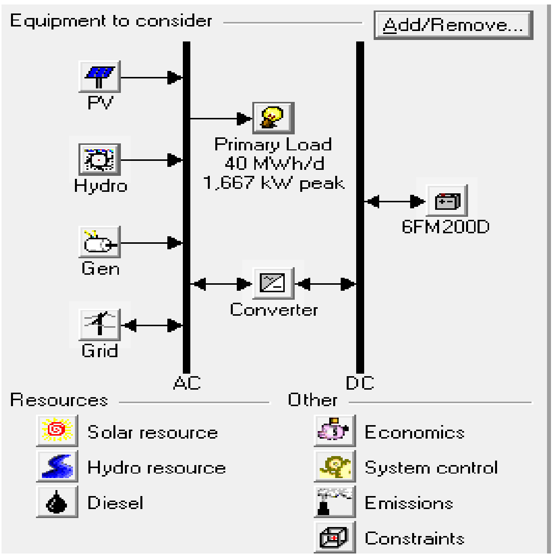

Figure 3. Schematic diagram of the hybrid system proposed in this paper.

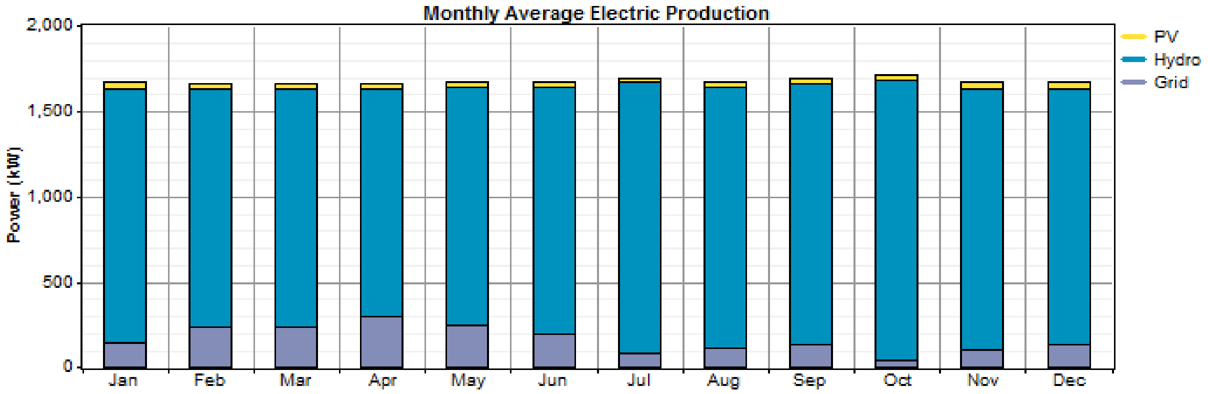

Figure 4. Simulations results, with monthly averages of electricity generation per year.

In case of low incidence of solar radiation and/or low flow rate, the solution to buy energy from the grid should be preferred. On the other hand, in cases of high incidence of solar radiation, multiples of 30 kW for the photovoltaic system become viable options to supply the load, eliminating the option of storage of energy in batteries, which was not recommended in the viable solution presented by HOMER.

Figure 5 shows the optimization space for the initial cost of the hydroelectric plant as a function of the demand of the consuming loads, for the system of Figure 3, with a maximum cost of PVs, acquired for 3.200 US$/kW, with an average flow of 9 171 L/s, and a power limit to purchase and sale to the grid equal to 400 kW to meet consumer loads up to 40 MWh/d. The results showed two solutions: the connection to the grid and hydropower plant, with or without photovoltaic modules.

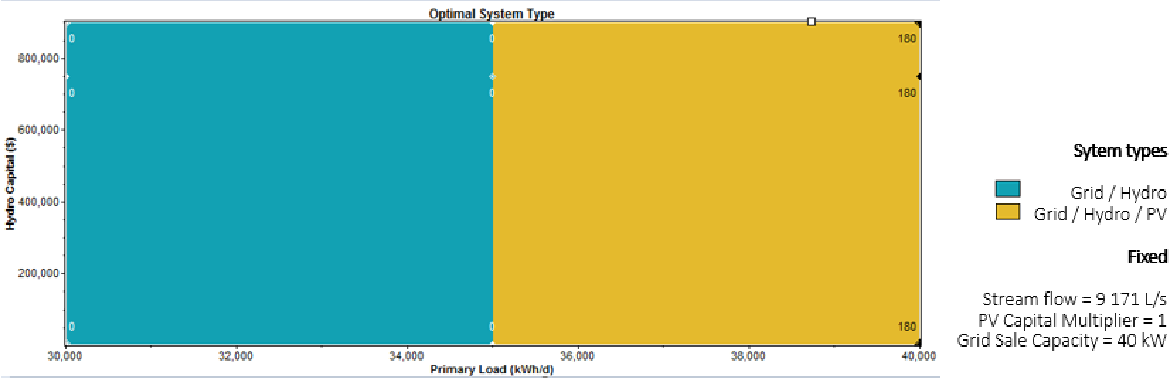

Figure 5. Results for the simulation of the complete system of figure 3 connected from the grid, with maximum cost of PVs

Figure 6 shows the optimization space for the initial cost of the hydroelectric plant as a function of the cost multiplier (0.25) of photovoltaic panels purchased at 3.200 US$/kW, and a flow rate of 9 171 L/s, with a power limit for purchase and sale of the network equal to 400 kW, to avoid failures to meet the demand of the consumer loads. The results indicated two solutions: the connection to the grid and hydropower plant, with or without photovoltaic modules. As shown in Figure 6, lowering to 25% of the cost of PVs increases the number of solutions including PVs with powers up to 540 kW.

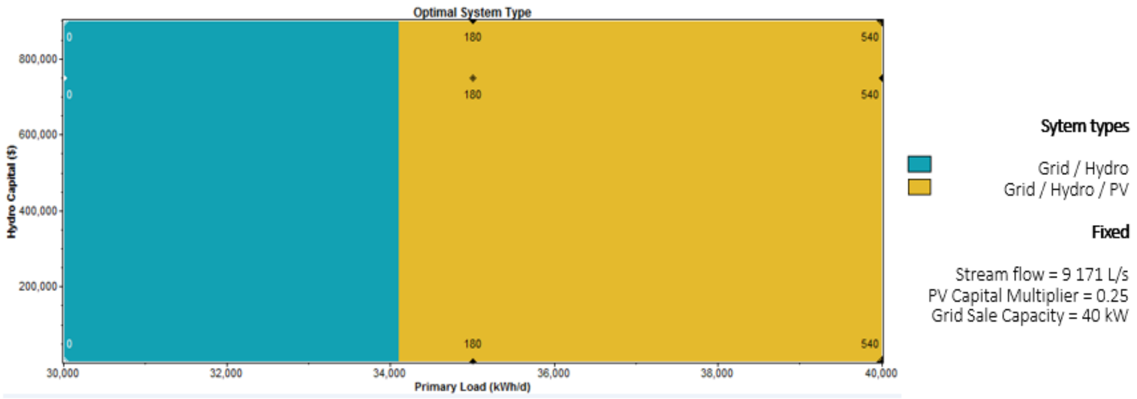

Figure 6. Results for the simulation of the complete system of figure 3 connected from the grid, with PV capital multiplier equal to 0.25

Figure 7 shows the optimization space for the cost of the hydroelectric plant as a function of the cost multiplier (0.15) of photovoltaic panels purchased at 3200 US $/kW, an average flow rate of 9 171 L/s, with 400 kW as a limit to purchase and sale energy to the grid. The results showed all optimization space indicating solutions containing PVs.

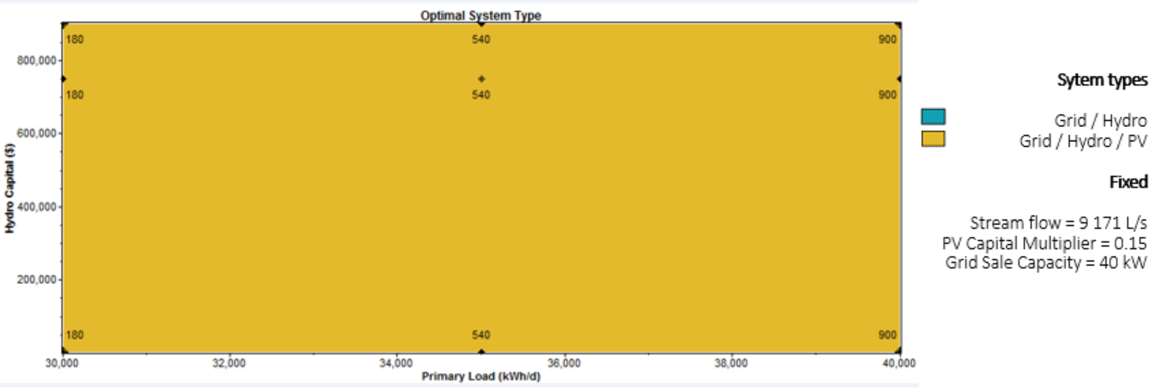

Figure 7. Results for the simulation of the complete system of figure 3 connected from the grid, with PV capital multiplier equal to 0.15

4. Final remarks

This paper presented the main results of the feasibility study, which is the first step in the design of the hybrid system to be implemented in Laranjeiras dam, in southern Brazil to generate energy. The feasible solution, recommended the installation of photovoltaic panels of 180 kW capacity, added to the hydropower with 20 m of height, an average flow of 9 171 L/s, to generate 1 497 kW and with 400 kW as a limit to purchase and sale energy to the grid, to supply stably 40 MWh/d. This combination will results in an initial cost of 3 984 885 US$/kW and an energy cost of 0.026 US$/kWh, which is within the range defined by [13].

Photovoltaic modules allow a greater supply of energy during the daytime period, but these will require overnight power supplies, which can be obtained from the hydropower and/or from the supply obtained in the interconnected national system. As mentioned by [14], these results should serve as a horizon for policy makers to encourage the use of renewable energies, specifically solar energy, with a governmental incentive of 15% and 25% of the total cost of acquisition of the photovoltaic panels.

However, other studies can assess whether the use of reversible reservoirs and historical series from other years can increase these extra supplies, as well as study the possibility of inserting another energy resource to maximize the use of available energy resources in the region.

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