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Pump Hydro Storage in the Integration of Intermittent Renewables in Water Drinking Systems

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INTRODUCTION & AIM

This research aims to study the best technical-economical solution for a hydropower and pump-storage system on Madeira Island. The system is composed of three reservoirs and two pipes. The first reservoir is situated in Covão, at the highest point of the system, where the water enters via a canal, with a flow rate of 0.3 m^3/s. The remaining reservoirs are located in Socorridos, where a turbine and pump exist, and another in Santa Quitéria, which contains another turbine. The first and the second pipes link Covão to Socorridos, and Socorridos to Covão, respectively. The water flows from Covão to Socorridos, where part of it is hydropower and the remaining part is hydropower in Santa Quitéria. The pumping operation occurs only between Socorridos and Covão. From Covão to Socorridos there is only one pipe, and because of that it is necessary to optimise the best periods to hydropower and pump the water in Socorridos, to obtain the highest Net Present Value.

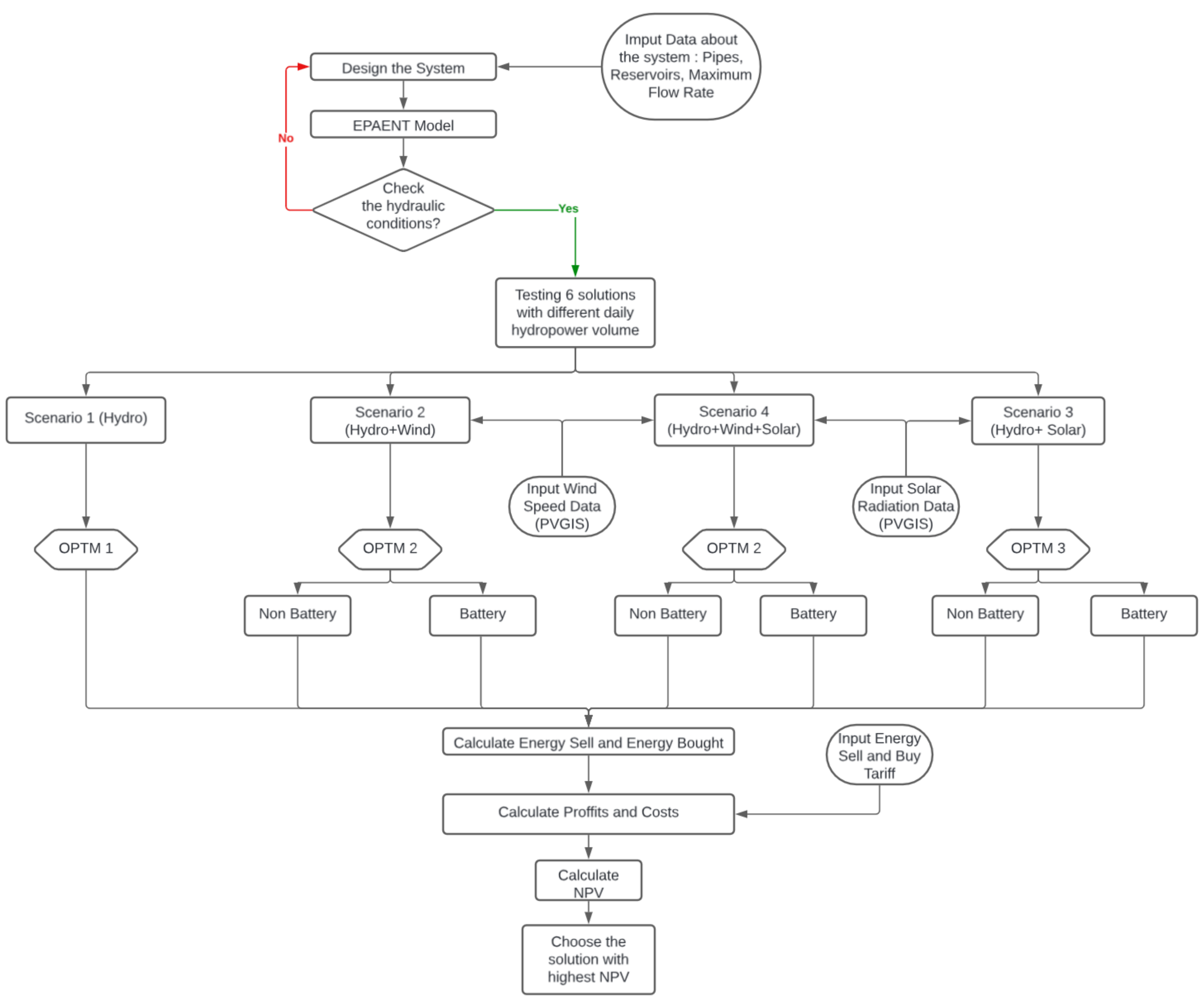
EPANET was used to test the hydraulic conditions (velocity and pressure), for the maximum flow rate (Covão- Socorridos (6m^3/s), Socorridos – Covão (2.8 m^3/s) and Socorridos- Santa Quitéria (1m^3/s)), which corresponds to the most dangerous situation.

To compensate the pumping costs, it was studying the integration of wind turbines and solar panels in a small area of 5 hectares, near Covão. Three Scenarios were considered (Hydro+Wind, Hydro+Solar, Hydro+Wind+Solar), each of them with six different solutions, varying the daily hydropower volumes in Socorridos reservoir (V=35 167 m^3, V=38 260 m^3; V=40 000 m^3, V=80 000 m^3, V=100 000 m^3, V=130 000 m^3). The integration of batteries in each of the solutions is also analysed.

In the optimisations, it was used the Solver, to estimate the operation of the system. The minimum number of wind turbines and solar panels, necessary to satisfy the consumption, is determined, for each solution.

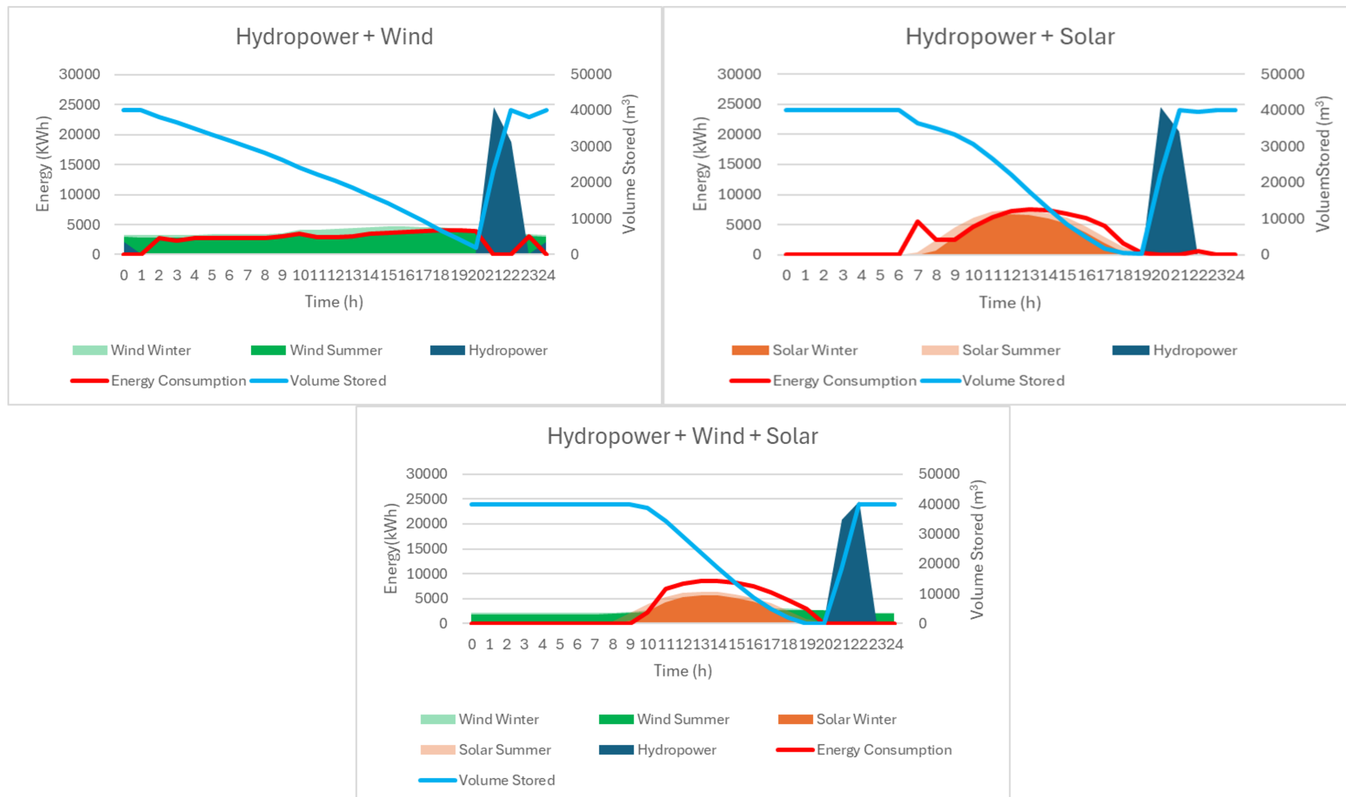
METHODOLOGY

To obtain the optimal solution, some procedures were followed. It started with the design of the system (diameter of the pipes, turbine and pump curves) in EPANET, where the hydraulic conditions were tested. Checked the hydraulic conditions, optimisations were carried out for each scenario and each solution, with and without the integration of the battery. In this part, some input data (wind speed, solar radiation and the prices of each component of the system), were uploaded to run the simulations. From the results obtained, the energy sold and bought for each solution was calculated, and the respective costs and profits were determined. Finally, the NPV was established, and it was selected most profitable solution.



RESULTS & DISCUSSION

The hydropower and pumping operation differs for the different scenarios. In this case with was analysed the example when the daily hydropower volume in Socorridos was equal to 40 000 m^3. With only the operation of hydropower, the water is turbine during the peak-rate hours and the pumping operation occurs frequently in the off-peak hours. However, with the integration of other intermittent renewables, the pumping operation is different. Wind power provides a significant amount of energy throughout the entire day, which provokes that for Scenario 2, the water is pumping during the day. For Scenario 3, that integrates Hydro and Solar, the water is pumping during the sunshine hours. Finally, for Scenario4, which integrates Hydro+Wind+Solar, the pumping operation is very similar to the obtained in Scenario 3, but in this case, part of the water can be pumped and the end of the afternoon, thanks to the contribution of wind turbines.



The calculation of NPV shows that solutions of Scenario 3 (Hydro+Solar), are less economically attractive, compared with those contained wind turbines, because in most of the cases, the solar panels are insufficient to satisfy the pump consumption energy. On the other hand wind turbines, can sell a lot of excess energy during the day. The major part of the benefites, provides from water supply. The integration of batteries can reduce the number of wind turbines, especially in solutions with high daily hydropower volumes. Comparing the NPV of these solutions, with that obtained for solutions without batteries, it is possible to observe that in most of the cases, the integration of batteries reduces the NPV.

CONCLUSION

The systems composed of Hydro and Wind, are the most profitable, in comparison with those that have solar panels. To satisfy the pump consumption, solar panels need larger areas. The integration of batteries reduces in the majority of the cases the NPV, because the energy sell to the grid by wind turbines and solar panels, is much lower.

FUTURE WORK / REFERENCES

For future works, can be developed new optimisations, that integrate other types of renewable energies to offset the pumping costs and that take into account long-term forecasts of population growth in Covão and Santa Quitéria. The study of a new system, that includes two penstocks between Covão and Socorridos, which enables pumping and hydropower water at the same time. Finally, it can be considered new tariffs of energy, because in this case it was considered constant tariffs over time.