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DEVELOPMENT OF A TOOL TO OPTIMISE DEMAND RESPONSE IN THERMAL POWER PLANTS. SIMPLEX METHOD AND GRG: APPLICATION TO ISLAND POWER SYSTEMS

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Abstract

The penetration of renewable energy in island environments poses a series of challenges, such as stability, demand response and security of supply, among others. In this thesis, we will study the current conditions of the electrical energy demand in Gran Canaria and its electrical production system. Based on the data and characteristics of the different combustion energy production units existing in the two power plants of Gran Canaria, a tool will be proposed to optimise the energy production system using combustion technology (non-renewable) and combine it with energy production using renewable energy sources that meet the expectations in terms of dynamic response, safety, scalability and integration with renewable energy systems, reduction of greenhouse gases and reduction of production costs. This tool will be based on operational research, mathematical optimisation methods, specifically the Simplex Algorithm and the GRG, and will propose the different existing combinations in order to achieve energy production that satisfies demand, minimising fuel consumption and greenhouse gas (GHG) emissions, optimising the power available in Gran Canaria.

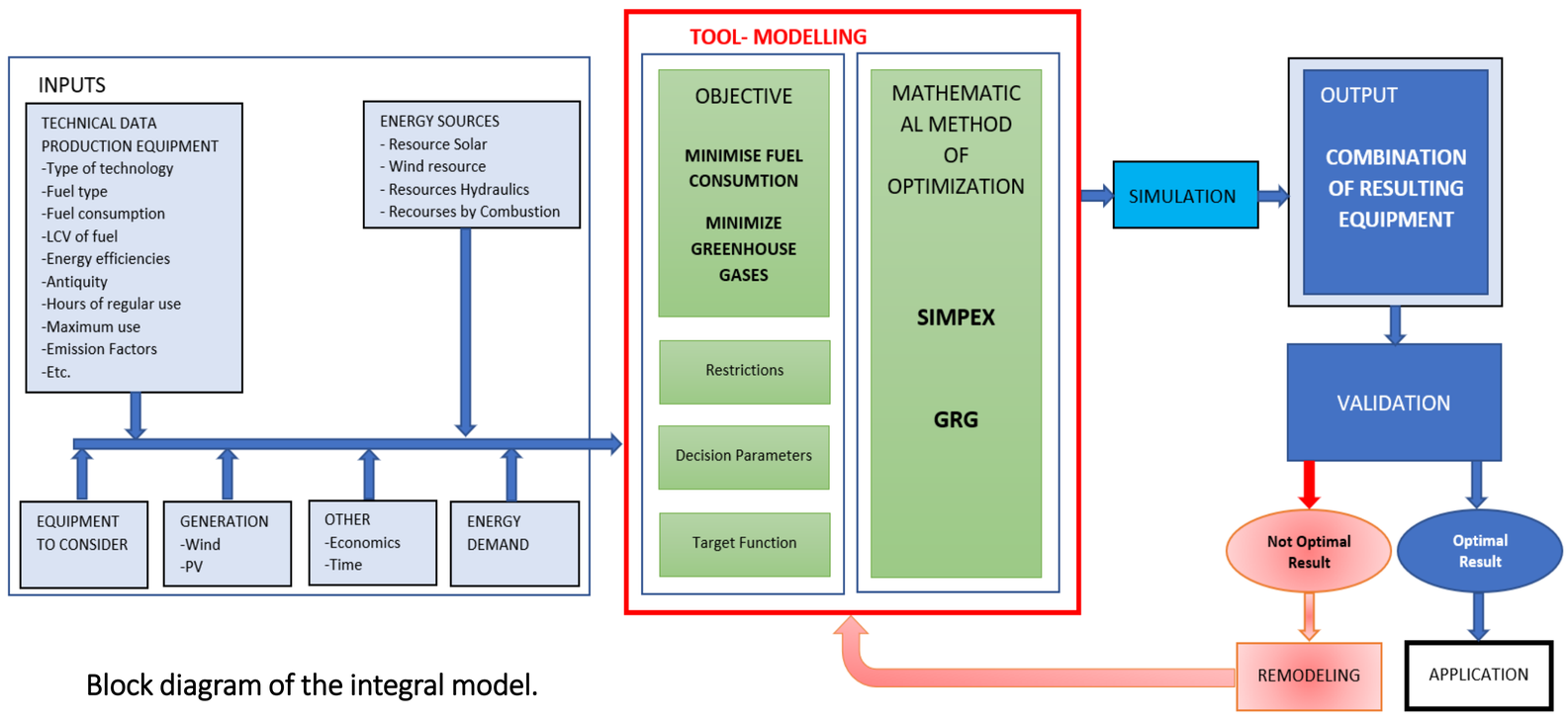
Technology Type	Fuels			GHG		
	Fuel	Diesel	Diesel Oil	CO_2	CH_4	NOx
	(t)	(t)	(t)	(tCO_{2eq})	(tCO_{2eq})	(tCO_{2eq})
Steam turbine	160,119.0	129.0	0.0	524,382	427.0	1,260.0
Diesel engine	37,852.0	1,561.0	0.0	128,793	105.0	310.0
Gas turbine	0.0	21,781.0	0.0	68,710	58.0	172.0
Combined cycle	0.0	334,369.0	0.0	1,054.799	897.0	2,648.0
Total	**197,971.0**	**357,840.0**	**0.0**	**1,776,684.0**	**1,487.0**	**4,390.0**

Fuels used (t) and GHG produced (tCO2eq). Gran Canaria, year 2021

Objective

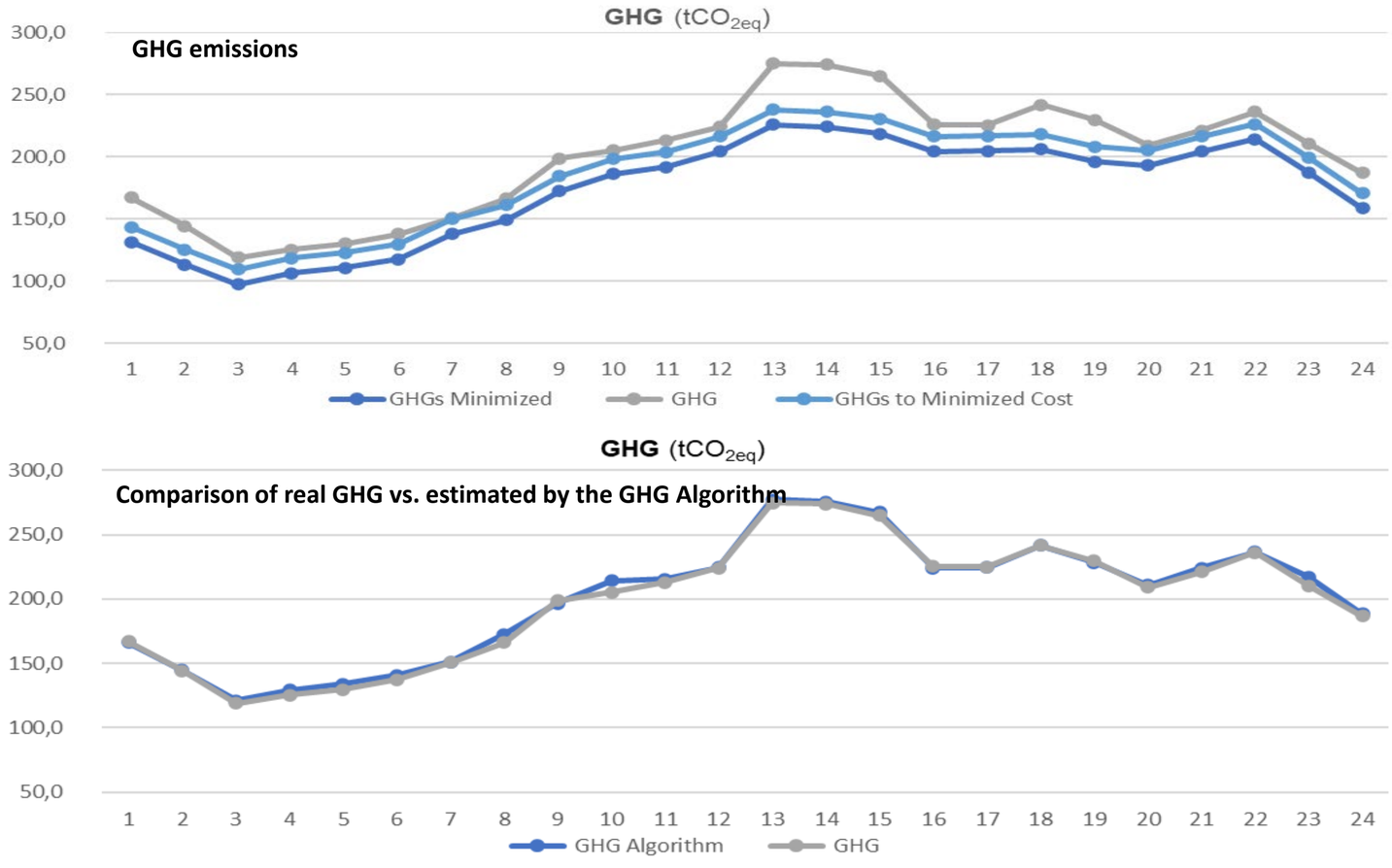
The objective of this work is to create a tool that relates all the variables of energy production through thermal systems, minimising costs and emissions and covering the energy demand that cannot be met by energy production from renewable sources. For the application of this study, the energy data of the island of Gran Canaria and its generation system for the year 2021 were available. This tool will optimise the energy production system using combustion technology (non-renewable) and combine it with energy production using renewable energy sources that meet the expectations in terms of dynamic response, safety, scalability and integration with renewable energy systems.

Methodology



Block diagram of the integral model.

Results



Algorithm	Real data	Real Combination of Technologies simulated with the algorithm		Combining technologies for get the Minimized Cost		Combining technologies for obtain the minimized GHG	
	amount	amount	% Difference from Actual	amount	% Difference from Actual	amount	% Difference from Actual
GEI (tCO_{2eq})	4.781,0	4,828.3	0.979	4,442,7	7.616	4.393,0	8.833
Cost (€)	590.416,9	592,532.9	0.357	534,401.6	10.482	541.161.7	9.102

Result of GHG and Cost estimates for August 17, 2021, for different combinations of technologies.

- The algorithm developed is a valid and effective tool for the management of production facilities, offering the optimal combination for the best optimisation of the variables studied.
- The algorithm shows that there is one ideal solution for cost optimisation and another for GHG reduction. The results of both approaches significantly improve the performance of the production equipment mix. In addition, the algorithm facilitates a third compromise solution that jointly optimises both cost and GHG emissions.
- The algorithm and its methodology successfully address the dual problem posed, with operations research playing a crucial role prior to programming.
- The algorithm, using Simplex and GRG methods, confirms that even with a large number of variables, an optimal value can always be found, provided the problem is solvable. These methods are crucial to the decision-making process as they consistently identify the optimal solution that maximises the objective function. As a result, Simplex and GRG methods ensure effective and efficient solutions to complex production facility management challenges.

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