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Summary of the paper
FEASIBILITY ANALYSIS AND OPTIMIZATION OF GRID-CONNECTED MICROTURBINE/FUEL CELL/PV HYBRID ENERGY SYSTEM

Sofija Nikolova-Poceva

Faculty of Electrical Engineering and Information Technologies,
Ss. Cyril and Methodius University in Skopje,
Republic of North Macedonia

PROPOSED RESEARCH

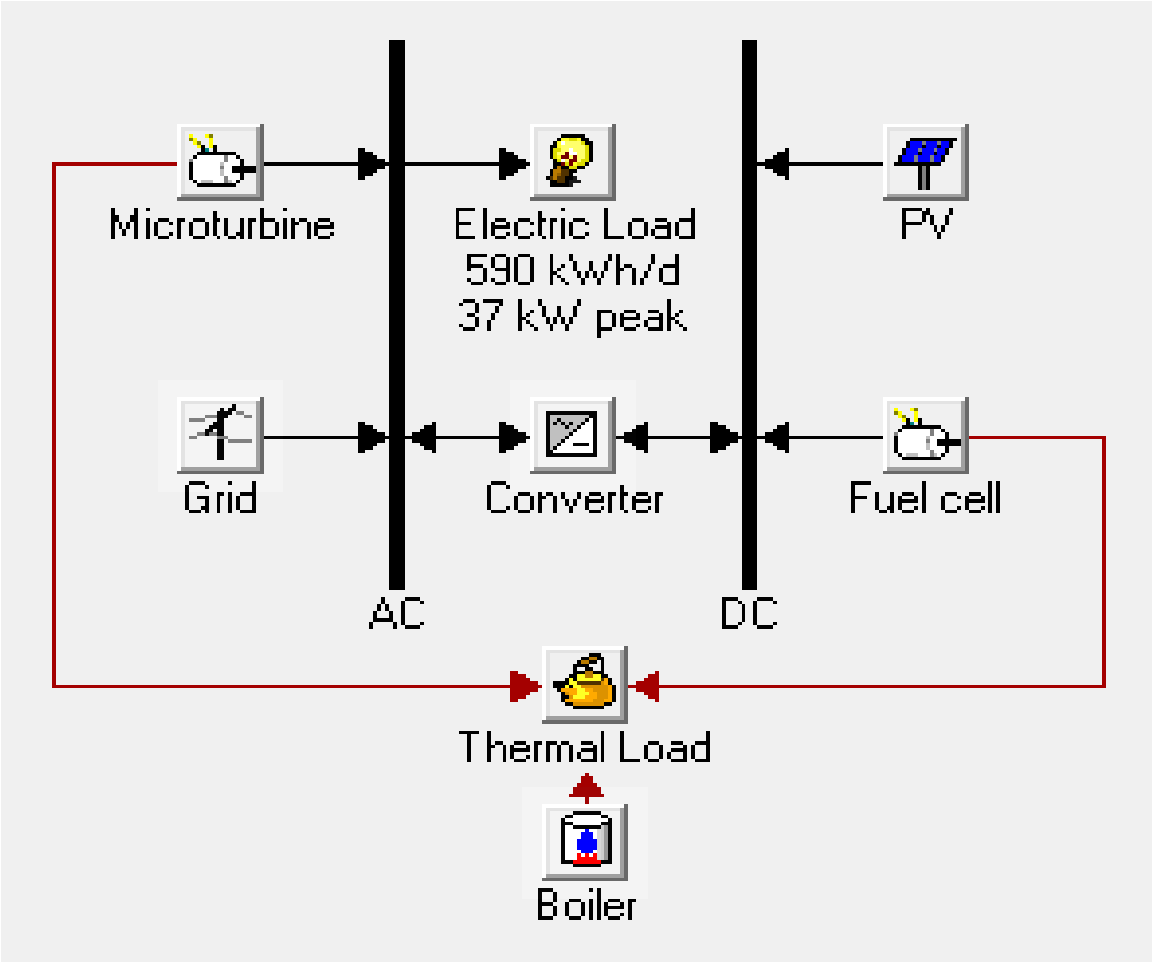
- A grid-connected combined heat and power system, consisting of microturbine (MT), fuel cell (FC), photovoltaic system and inverter has been analyzed.

- The objective of the study - to obtain the optimal configuration of the system, which should satisfy the given electrical and thermal load, respecting the total net present costs.

- The system has been modelled in HOMER software and this tool was used to perform simulation, calculation and optimization.

- Emissions of pollutants have been analyzed too.

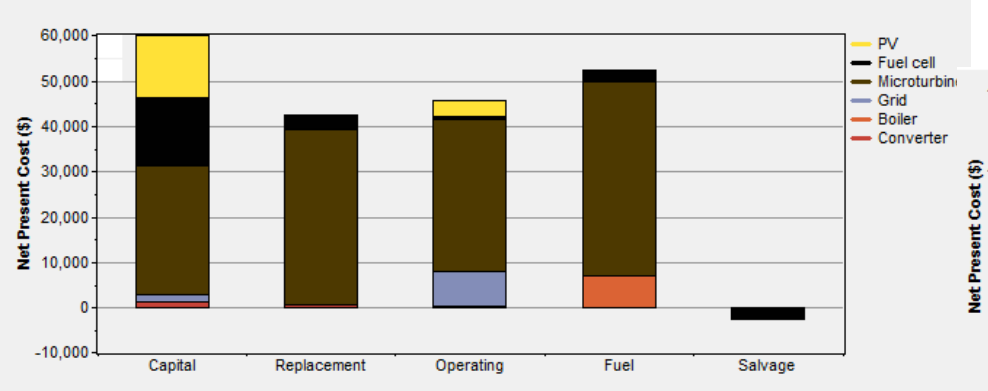
PROPOSED RESEARCH



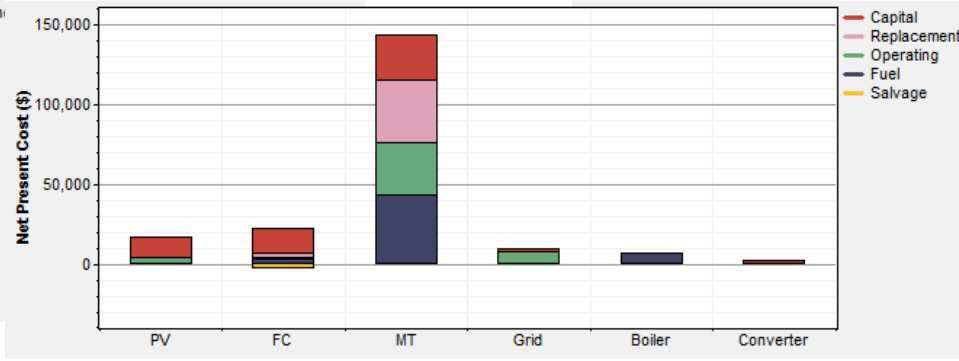
Schematic representation of the hybrid energy system under consideration

Results

- Basic generation scenario, for a grid-connected hybrid energy system:
  - 30 kW microturbine, 5 kW fuel cell, 5 kW photovoltaic system and 5 kW inverter
- The net present cost for the whole hybrid system – 197,781 $
- The renewable fraction - 0.0298
- Levelized Cost of Energy – 0.068 $/kWh



Net present cost by cost type



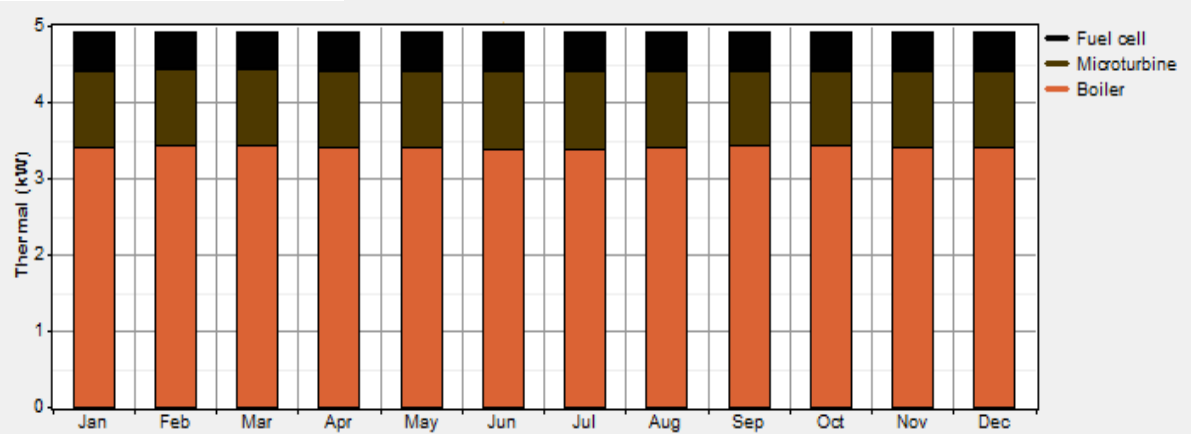
Net present cost by component

Results

- Basic generation scenario, for a grid-connected hybrid energy system

Electricity production of MT/FC/PV system

Component	Production (kWh/yr)	Fraction
PV array	7,847	4%
Fuel cell	6,838	3%
Microturbine	202,877	92%
Grid purchases	2,542	1%
Total	220,104	100%



Monthly average thermal production

Results

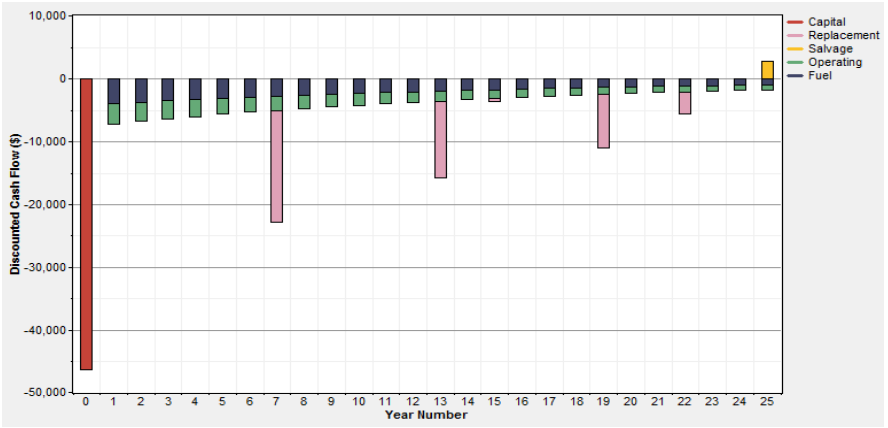
- Second analyzed case - systems with the presence and absence of PV, MT and FC and allowed multiple generators to operate simultaneously
- 2 feasible solutions of the system are generated, sorted by total net present cost:
  - MT/FC system
  - MT/FC/PV system

Feasible solutions sorted by total net present cost for the second analyzed case

PV (kW)	FC (kW)	MT (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Natural gas (m3)	FC (hrs)	MT (hrs)
	5	30	5	10	$ 46,306	10,729	$ 183,464	0.063	0.00	28,020	1,825	8,760
5	5	30	5	10	$ 59,856	10,789	$ 197,781	0.068	0.03	27,317	1,825	8,760

Pollutant emissions

Pollutant	Emissions (kg/yr)	
	MT/FC/PV	MT/FC
Carbon dioxide	52,732	54,086
Carbon monoxide	154	159
Unburned hydrocarbons	17.1	17.6
Particulate matter	11.6	12
Sulfur dioxide	140	143
Nitrogen oxides	1,378	1,421



Discounted cash flow over the project lifetime for the optimal system (MT/FC)

Results

- Third analyzed case - the possibility for inclusion of multiple generators in the system and multiple generators to operate simultaneously **is not allowed**,
  - the system with MT and FC will not be listed in this case.
- Also, the following inputs for the components are added: fuel cell size: 0 kW, 5 kW and 10 kW, inverter size: 5 kW and 10 kW, and grid purchase capacity: 10 kW, 20 kW, 30 kW, 40 kW.

	PV (kW)	FC (kW)	MT (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Natural gas (m3)	FC (hrs)	MT (hrs)
			30	5	40	$ 31,306	11,976	$ 184,404	0.063	0.00	27,083		8,760
	5		30	5	40	$ 44,856	11,998	$ 198,232	0.068	0.03	26,406		8,760
		10		10	40	$ 34,056	44,435	$ 602,088	0.215	0.00	14,039	8,760	
	5	10		10	40	$ 47,606	43,480	$ 603,428	0.216	0.03	13,720	8,760	

Categorized feasible solutions sorted by total net present cost for the third analyzed case

CONCLUSION

- The study found the following key points:
  - For grid purchase capacity of 10 kW the cost effective system is with microturbine (30 kW) and fuel cell (5 kW), without photovoltaic system. The difference of net present costs between MT/FC/PV system and MT/FC system is 14,317 $. But, on the other hand by operating of the MT/FC hybrid energy system the pollutant emissions are higher than in case of MT/FC/PV system.
  - If the microturbine and fuel cell are not allowed to operate simultaneously in the system then the grid purchase capacity should be greater than 10 kW in order to have feasible solution in this case. Under considered inputs in this case:
    - The cost effective system is with 30 kW microturbine connected on grid with 40 kW purchase capacity.
    - From the categorized feasible solutions next systems sorted by total net present cost is with 5 kW PV and 30 kW MT connected on grid with 40 kW purchase capacity, system with 10 kW FC connected on grid with 40 kW purchase capacity and the last one is the system with 5 kW PV and 10 kW FC.
    - In the system with integrated fuel cell there is feasible solution only if the grid purchase capacity is 40 kW.