DESIGN AND OPERATIONAL CONTROL OF THE AGIOS EFSTRATIOS ISLAND MICROGRID

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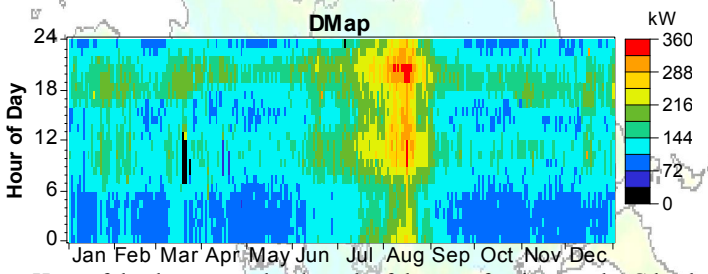
The study deals with the design. operational control, simulation and sensitivity analysis of a Microgrid consisting of Wind turbines, Photovoltaic systems, storage of electricity to follow the load demand of the non-interconnected island of Agios Efstratios, in the Aegean sea, Greece. It is a research-demonstration project funded by the Greek state and EU structural funds, where mature technologies in Renewable Energy Sources (RES), storage and energy management will be used.

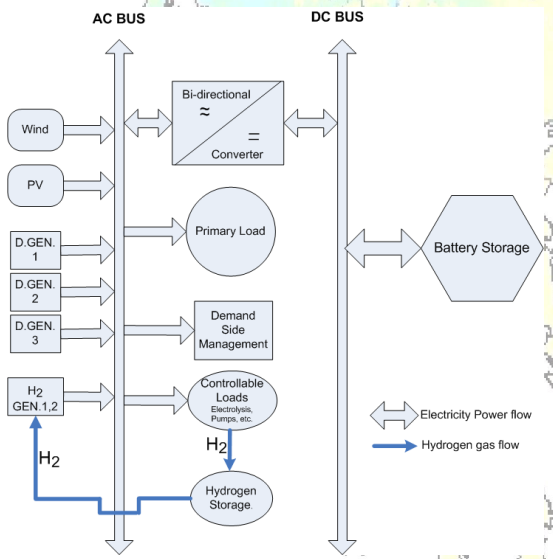
The innovation of the project is mainly in the integration and operational control of variable renewable energy generators and storage, the appropriate management of the resources and of certain non-critical loads aiming at 100% RES contribution and not less than 85% of the annual electricity demand. The proposed system will substitute local production of the existing thermal power plant where expensive and polluting diesel fuel is being used.

The new power system will use the existing grid infrastructure incorporating RES and storage units and all the necessary monitoring, control and communication new infrastructure in order to maintain power availability, quality, reliability and safety respecting the technical requirements of the Public Power Corporation (PPC) and the Hellenic Distribution Network Operator (HEDNO) which are respectively the owners and operators of the existing thermal generation units and electric grid on the island. The current plan is to evaluate the three offers received, after the call for international offers expired in February 2014. The realization of the project is expected to start in the beginning of 2015.

In this paper the existing power system and load profile and historic data are presented. Then the potential of solar and wind energy resources and the selected sites on the island are described. Afterwards the RES Electrification power system operation approach and modes of operations are suggested. Finally, modeling, simulation and sensitivity analysis regarding the capacity of the various components, i.e. PV system, Wind turbines, battery storage and energy demand, follows using the HOMER software. The simulation is performed with 1 hour time step for one year, considering suggested components for the proper operation of the island microgrid and subsequently technical and economic issues are discussed.



Hour of the day versus day /month of the year for the actual AC load in the island for the year 2010 (see attached color scale).



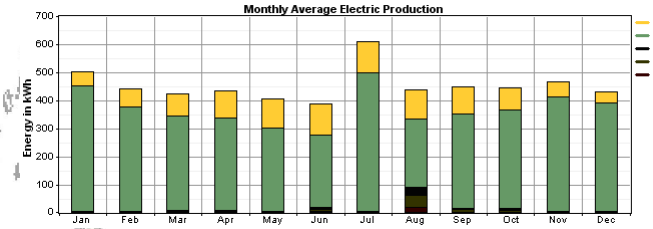
Basic block diagram of Agios Efstratios RES Electrification system including Hydrogen components.

Primary Load in MWh/day	Annual Average wind speed in m/sec	Scenario	PV (kW)	Number of Wind Turbines 330kW/each	Gen1 Max. Capacity (kW)	Gen2 Max. Capacity (kW)	Gen3 Max. Capacity (kW)	Number of 2V Cells of 6 kWh each	Converter (kW)	Dispatch strategy	Initial capital in Euro	Operating cost (Euro/yr)	Total Net Present Cost in Euro
3.345 (1220 MWh/year)	9	1	300	1	90	220	90	480	300	LF	1,632,000	116,237	3,117,895
		2	500	1	90	220	90	480	300	LF	1,932,000	96,680	3,167,897
		3	200	2	90	220	90	480	300	LF	2,082,000	123,409	3,659,587
		4	100	2	90	220	90	480	300	LF	1,932,000	135,650	3,666,059
5.352 (1953 MWh/year)	9	5	700	1	90	220	90	720	300	LF	2,448,000	195,845	4,951,560
		6	700	1	90	220	90	840	300	LF	2,556,000	187,378	4,951,325
		7	500	2	90	220	90	600	300	LF	2,640,000	183,159	4,981,385
		8	500	1	90	220	90	600	300	LF	2,040,000	253,704	5,283,186

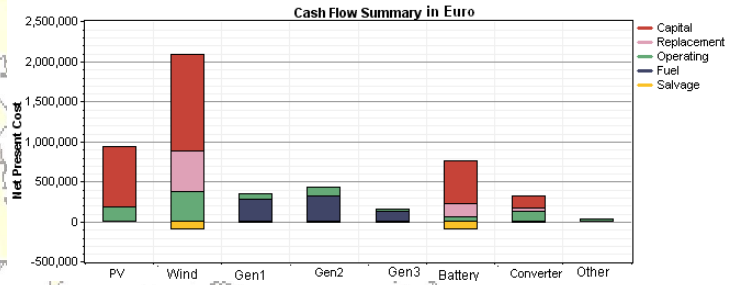
Primary Load in MWh/day	Annual Average wind speed in m/sec	Scenario	Cost of Electricity in Euro/kWh	Renewable fraction	Excess Electricity kWh/yr	Unmet Load kWh/yr	Total Diesel Gen. prod in kWh/yr	Diesel used in Liters	Gen1 operation hrs	Gen2 operation hrs	Gen3 operation hrs	Battery Autonomy hr	Battery Through-put kWh/yr	Battery Life/yr
3.345 (1220 MWh/year)	9	1	0.200	0.925	796,747	0	91,268	29,601	697	318	271	12	198,797	20
		2	0.203	0.959	1,041,996	0	50,368	16,199	346	186	135	12.4	215,699	20
		3	0.234	0.952	2,190,942	0	58,125	18,674	387	226	156	12.4	155,454	20
		4	0.235	0.932	2,067,169	0	83,025	26,711	555	321	233	12.4	162,425	20
5.352 (1953 MWh/year)	9	5	0.199	0.907	684,129	3,133	181,494	65,974	1,205	561	572	11.62	361,783	20
		6	0.199	0.915	662,900	3,133	165,875	60,211	1,099	510	516	13.56	378,910	20
		7	0.200	0.935	1,926,926	2,546	127,627	46,380	847	391	409	9.69	272,761	20
		8	0.212	0.857	516,040	3,600	280,118	102,007	1,781	901	910	9.69	291,030	20

PV-GIS (c) EC JRC 2002-2005

Selected HOMER simulation results according to the assumptions and sensitivity analysis considered.



Monthly average electricity production for all generating units, for Scenario 7, on previous Table.



Lifetime cash flow for each system component for scenario 7.

Year or Scenario	Variabale cost of electricity in €/MWh	Fixed cost of electricity in €/MWh	Total cost of electricity in €/MWh
2002	--	--	373.46
2008	312	331.65	643.65
2010	225	331*	556
2012 **	--	--	444
2013**	--	--	420.82
Scenario 1 (3.345 MWh/day)	--	--	200
Scenario 3 (3.345 MWh/day)	--	--	234
Scenario 5 (5.352 MWh/day)	--	--	199
Scenario 7 (5.352 MWh/day)	--	--	200

*: Assuming that the fixed cost did not change between 2008 and 2010
**: Data from Regulatory Energy Authority (RAE)

Historic data for electricity production cost of the power station in Agios Efstratios (sources: PPC and RAE) compared to simulation results.

CONCLUSIONS

The system simulation and comparison with historic electricity production data show that the implementation of a RES based power system for the island is cost effective, with a LCOE less than half the conventional diesel fuel powered system electricity cost for the previous 10 years.

The design of the new system has to take into account the reliability issues of the most important components in order to avoid lengthy disruptions of microgrid operation and significantly reduce the use of diesel fuel. The autonomous microgrid of Agios Efstratios could be an example and a real life "laboratory" for high penetration of renewables with central RES main components in distribution grids. Furthermore, the microgrid is designed and will be realized to be transparent to the Hellenic island network operator (HEDNO), which plans to install advanced Energy Management Systems (EMS) in the non interconnected islands.