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Minimization of Operational Cost for an Islanded Microgrid using a Real Coded Genetic Algorithm and a Mixed Integer Linear Programming Method

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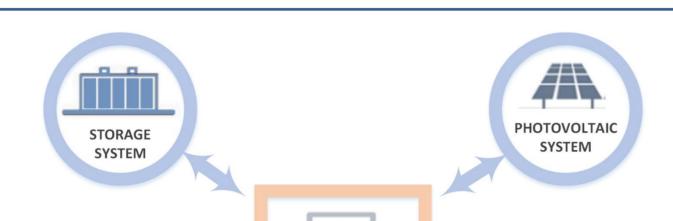
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1. Introduction

Two different algorithms were applied to achieve the optimal scheduling of a PV panels-geothermal-biomass smart microgrid. Both methods, the Genetic Algorithm (GA) and the Mixed-Integer **Programming (MILP)** solution, are widely used to solve single-objective multioptimization variable constrained problems.



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BIOMASS

GENERATOR

3. Proposed Methodology

START

Deterministic algorithms, such as MILP, use a few specific rules to improve solutions step by step. On the other hand, GA represents a

2. Microgrid Description

The proposed microgrid contains two generators (geothermal – 3kW and biomass – 3kW) and a PV system (14 panels, 250 kWp/each). A storage system is also required (8) batteries, 250Ah, 12V). The consumer is a vegetable greenhouse. The sizing of the proposed microgrid takes into consideration the meteorological and geographical data of the city Oradea, in Romania.

品音

RESIDENTIAL LOAD: GREEN

HOUSE

The Virtual Power Producer is a vital part of the Supervisory Control and Data Acquisition System (SCADA) which is responsible for the communication and control. All presented units are connected; they communicate with the SCADA through an RS-485 network.

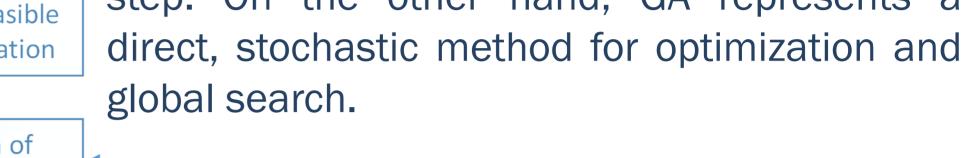
4. Mathematical Formulation

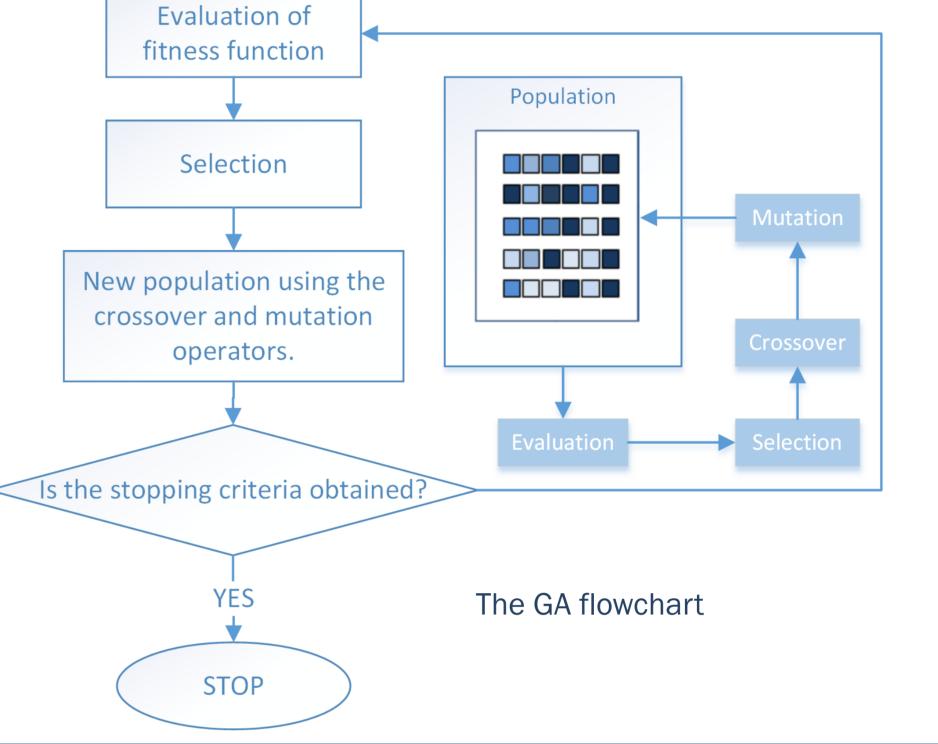
The economic dispatching and optimal scheduling of the connected units in power systems is a fundamental issue. The aim is to minimize the operation cost considering the limitations and restrictions of the system.

In this paper, this issue is handled as a multi-variable single-objective constrained optimization problem which can be solved using GA or MILP methods.

Ø Generate feasible initial population **/IRTUAL POWER** PRODUCER **₹** GEOTHERMAL GENERATOR

The proposed smart microgrid





Objective function:	$C_{\min} = \sum_{t=1}^{24} \left(E_s(t) \times C_s + E_{geo}(t) \times C_{geo} + E_{bio}(t) \times C_{bio} + E_{bat} \times C_{bat} + E_{un}(t) \times C_{un} - E_{ex}(t) \times C_{ex} \right)$
Power balance:	$E_{s}(t) + E_{geo}(t) + E_{bio}(t) + E_{bat}(t) + E_{und}(t) - E_{ex}(t) - E_{L}(t) = 0$
Solar, geothermal and biomass energy limits:	$0 \le E_s(t) \le E_{s_{max}}(t), \ 0 \le E_{geo}(t) \le E_{geomax}, \ 0 \le E_{bio_{max}}(t) \le E_{bio_{max}}(t)$
Charge- and discharge limit of batteries:	$-3500 \le E_{bat}(t) \le 1000$
The batteries' state balance:	$P_{\text{storage}}(t) = P_{\text{storage}}(t-1) - E_{\text{BDsch}}(t) + E_{\text{BCh}}(t), \ 0 \le P_{\text{storage}}(t) \le P_{\text{S}_{\text{max}}}$

Where Es, Egeo, Ebio, Ebat, Eun and Eex are, respectively, energy generated by PV panels, geothermal- and biomass generators, power discharged and charged in batteries, the undelivered and excess energy. EL represents the hourly demand by loads. Pstorage and Ps_max are the actual storage power and the maximum allowed storage power. Cs, Cgeo, Cbio, Cbat, Cex and Cun are the cost coefficients.

5. Results & Conclusion

Energy Manageme uts:	nt				Den te Mil	-						Den ha Con	-11-				-		(Month	Geo [W]	Bio [W]	MILP [€/day]	GA [€/day]	MILP [sec]	GA [sec]
oad Profile [kWh]		Psolar_calc	Weather Properties: Month:	Average Daily Radiation [kWh/m2/day]:	Hours Results MIL	-	Ebio [Wh]	Battery Ba Discharge Ch	tery arge Undelin	vere Excess	Pstorage	Hours [W	v Egeo	Ebio [Wh]	Battery Bat Discharge Cha	tery arge Unde	livere Excess	Pstorage			0	0	36.59	36.59	1.3	16.4
Hours [Wh]	Hours	s [Wh]		0.98	1 0	0 250	0	0 0	0		20000 20000	1 0	0	0	0 0	0	0	20000 20000			1500	0	17.36	17.36	1.1	15.8
250	2	0	Number of days: 1 Average Tempe	erature [*C]:	3 0	2800	0	0 0	0		20000	3 0	254	2546	0 0	0	0	20000		December	1500	1500			27	
2800	3	0	0.1		4 0	2700	0	0 0	0		20000	4 0	0	2852	0 152	0	0	20152		December	1500	1500	7.11	7.14	3.7	15.6
2700	4	0	Minimum Temperature [*C]:	Maximum Temperature [*C]:	5 0	0	0	0 0	0		20000	5 0	0	0	0 0	0	0	20152			3000	0	6.39	6.50	3.7	15.8
0	5	0	-2.31	2.6	6 0	300	0	0 0	0	0	20000	6 0	20	317	0 36	0	1	20188			2000	2000	6.01	6 5 6	1 1	16.0
300	6	0	Location Properties	Energy prices:	7 0	600	0	0 0	0	0	20000	7 0	0	600	0 0	0	0	20188			3000	3000	6.21	6.56	1.1	16.2
600	7	0	Latitude	Solar [E/kWh]: 0.05	8 0	3000	400	0 0	0	0	20000	8 0	2932	468	0 0	0	0	20188			0	0	32.19	32.10	1.1	16.2
3400	8	0	47.04 ● N ○ S	Geo [E/kWh]: 0.25	9 30		200	0 0	0		20000	9 300		202	0 0	0	0	20188			1500	0	14.85	14.90	3.2	15.9
3500 600	9	300	Longitude	Bio [E/kWh]: 0.30	10 64		0	0 43	0		20043	10 643		0	0 43	0	0	20231			1000	0	14.00	14.90	3.2	15.9
	10	643 917	21.55	Excess [E/kWh]: 0.0	11 91 12 10		0	0 317	v		20360 21319	11 917		0	0 317	0	0	20548		March	1500	1500	5.98	6.70	5.0	15.7
600 100	12	1059	● E ○ W	Undelivered [E/kWh]: 1.5	13 10		0	0 126			22579	12 105 13 103		0	0 939	0	0	21507 22345			3000	0	5.55	5.94	6.8	16.0
200	13	1038	Batteries:	Battery Charge 0.55 [E/kWh]:	14 85		0	0 859			23438	14 856		0	0 864	0	0	23209			3000	0	5.55		0.8	
0		859	Storage battery limit:	Battery Disch 0.65	15 56		0	0 562			24000	15 562		0	0 562	0	0	23771			3000	3000	5.34	6.04	0.8	15.7
0	15	562	24000 Storage battery	[E/kŴh]:	16 21		0	0 0	0		24000	16 217	50	34	0 0	0	1	23771			0	0	27.52	27.47	5.9	16.3
300	16	217	maximal DISCHARGE limit:		17 0	0	0	0 0	0	0	24000	17 0	1	0	0 0	0	1	23771			U	U				
0	17	0	1000	Geothermal Generator limit 3000	18 0	200	0	0 0	0	0	24000	18 0	60	368	0 228	0	0	23999			1500	0	12.47	12.62	5.9	15.8
200	18	0	Storage battery maximal CHARGE limit:	Biomass Generator limit:	19 0	3000	500	0 0	0		24000	19 0	2874	626	0 0	0	0	23999		July	1500	1500	5.19	5.74	12.7	15.9
3500	19	0	3500	3000	20 0	3000	600	0 0	0		24000	20 0	2999	601	0 0	0	0	23999		July		1000				
3600	20	0	Initial state of battery: 20000		21 0	3000	600	0 0	0		24000	21 0	2995	605	0 0	0	0	23999			3000	0	4.75	5.13	13.2	16.0
3600 3700	21	0		Energy Scheduling	22 0	3000		0 0	0		24000	22 0	2994	706	0 0	0	0	23999			3000	3000	5.64	5.19	1.2	15.9
3700	22	0	GA Properties		23 0	3000	500	0 0	0	0	24000	25 0	2990	510	0 0	0	0	23999			3000	3000	5.04	0.10	1.2	10.0



The aim of the present paper was to compare different optimization and global search methods. Clearly, further studies are needed to examine the functioning of this algorithm using other software and to also introduce other methods. Furthermore, it should be examined whether the traditional and metaheuristical procedures are trapped in local minima.

The results presented in this paper might be valuable for future research in energy management systems.

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