ENERGY EFFICIENCY IN SMART GRIDS. GAME THEORY

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THESIS OBJETIVE

- To systematize the state of the art decision-making models associated with game theory applicable to electric markets.
- To obtain a feasible solution to the model of optimization of the supply chain of the energy.
- Implement cooperative game theory in the formation of coalitions of this optimization model, as well as the equitable distribution of profits among the participants of the game. Develop a programming algorithm for the energy supply model that is verifiable with other optimization models by means of the generation and comparison re obtained results.

RESEARCH PLAN

1. Literature Review of Game Theory
2. Definition of deployment scenarios
3. Simulation of electrical systems using Game Theory
4. Dissemination of results through publications in international conferences, workshops and journals
5. Documentation

MOTIVATION OF THE WORK

The emergence of large-scale distributed power generation, as well as the recent interest in smart grid where the nodes or microgrid are autonomous decision makers has brought to surface many interesting game theoretic problems that arise from the competitive and cooperative interplay of the different smart grid. Further, the need for self-organizing, self-configuring, and self-optimizing networks eventually led to the use of many game theoretic concepts in smart grid communication [1, 2].

In a game theoretic framework, one can distinguish between two main categories: Non-cooperative [3, 4] and cooperative game theory [5, 6]. While non-cooperative game theory mainly deals with modeling competitive behavior, cooperative game theory is dedicated to the study of cooperation among a number of players. Cooperative game theory mainly includes two branches: Nash bargaining and coalitional game theory. In this dissertation, we restrict our attention to the latter, although the former can also be quite useful in different scenarios (the interested reader is referred to [3] for details on Nash bargaining solutions).

Coalitional game theory mainly deals with the formation of cooperative groups, i.e., coalitions, that allow the cooperating player to strengthen their positions in a given game. In consequence, the recent interest in the cooperative paradigm in Smart Grids, implied that the adoption of coalitional games-based approaches is quite natural. In this context, coalitional games prove to be a very powerful tool for designing fair, robust, practical, and efficient cooperation strategies in electrical networks. However, most of the research in the electrical community has been focusing on either non-cooperative games [2, 5] or on applying standard coalitional game theory models and techniques to study very limited aspects of cooperation in networks such as stability under ideal cooperation or fairness. This is mainly due to the sparse literature that tackles coalitional games as most pioneering game theoretical references such as [1,3,6] focus on non-cooperative games.

SIMULATION RESULTS

Nº	Location [km]		Power [MW]	Demand [MW]	Energy Price
1	1,8	2,6	20	172,2	1
2	1,6	4	92,7	36,1	1
3	-1	3	53,4	8	1
4	2,8	-3,3	200	65,7	1
5	4,7	0,4	24	59,4	1
6	-3,4	2,8	57	15	1
7	3,5	-4	39	72,2	1
8	-1,4	-0,6	10	70	1
9	-3,8	-3,2	32	100	1
10	-2,8	2,2	22	162,9	1

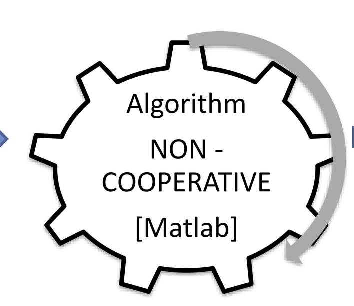
Tab.I Input Data of Smart Grid.

Resistance $[\Omega/km]$	Voltage [MV]	Voltage [LV]	Threshold Distance
R	U_0	U_1	D_u
0,2	50	22	5

Tab.III Data feeders and threshold distance

Nº	Location [km]		Power [MW]	Loss Constant	Energy Price
0	0	0	100	0,02	1

Tab.II Substation data for the coalition game



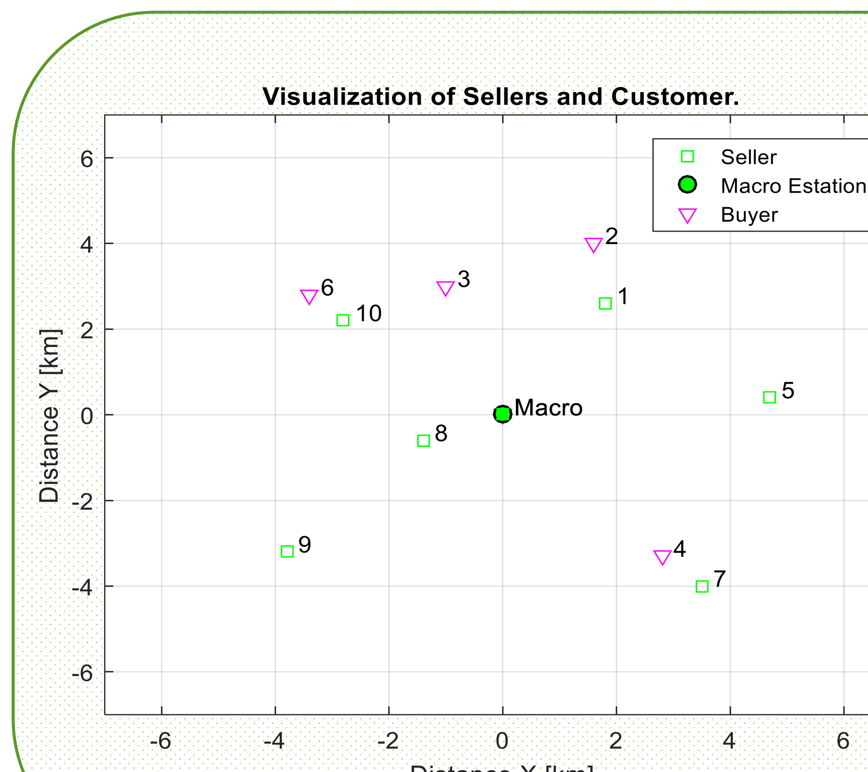
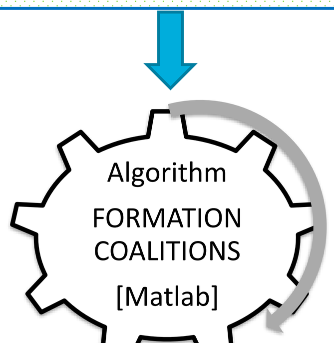


Fig.1 Power grid.

Nº	Excess Power / Demand P_i/D_i [MW]	Power Flow L_{io} [MW]	Power Losses P_{io} [MW]	Individual Payments $\emptyset_i$
1	-152,2000	162,0883	9,8883	-9,8883
2	56,6000	54,4870	2,2361	-2,2361
3	45,4000	44,0290	1,4294	-1,4294
4	134,3000	126,2559	8,9307	-8,9307
5	-35,4000	36,6394	1,2394	-1,2394
6	42,0000	40,6068	1,4616	-1,4616
7	-33,2000	34,3907	1,1907	-1,1907
8	-60,0000	61,6978	1,6978	-1,6978
9	-68,0000	71,4586	3,4586	-3,4586
10	-140,9000	150,3462	9,4462	-9,4462

Tab.IV Results of the non-cooperative model

Average current power losses = 4,0911 [MW]



- *The reduction in losses are 35.208% when Customers choose to form coalitions.*
- *In the analysis average of losses generated for the cooperative case for a fixed number of N Smart Grids, a loss reduction of up to 50% less than the non-cooperative case is seen..*

Average power losses = 2,6507 [MW]

Fig.2 Formation of coalitions.

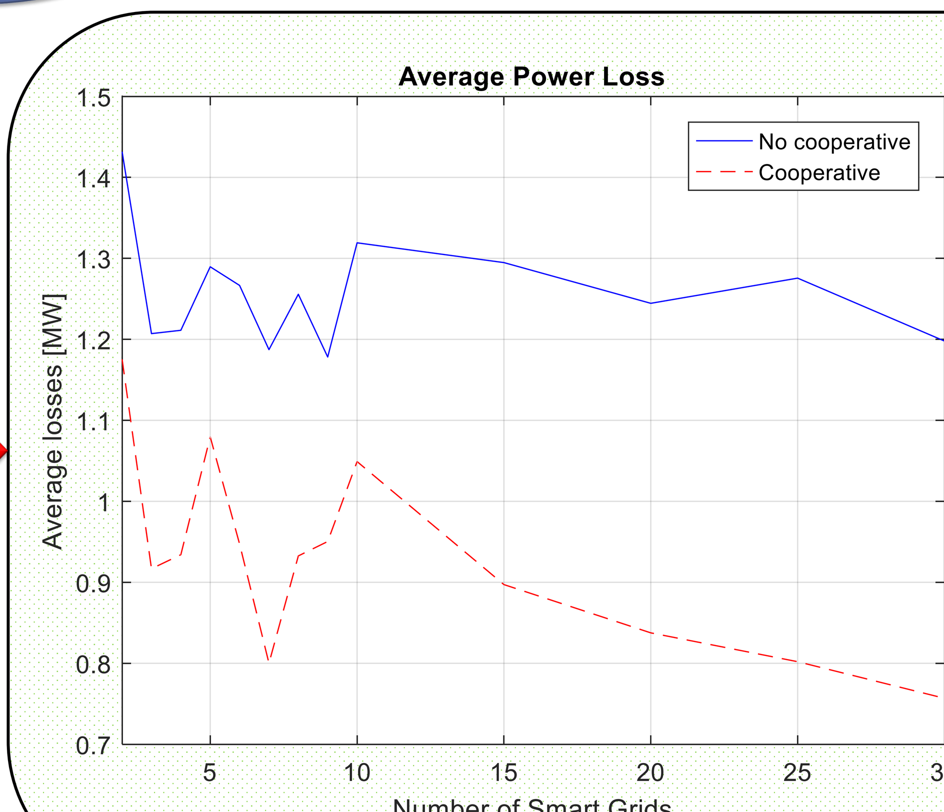


Fig.3 Evolution of the losses of power when incorporating the Smart Grids.

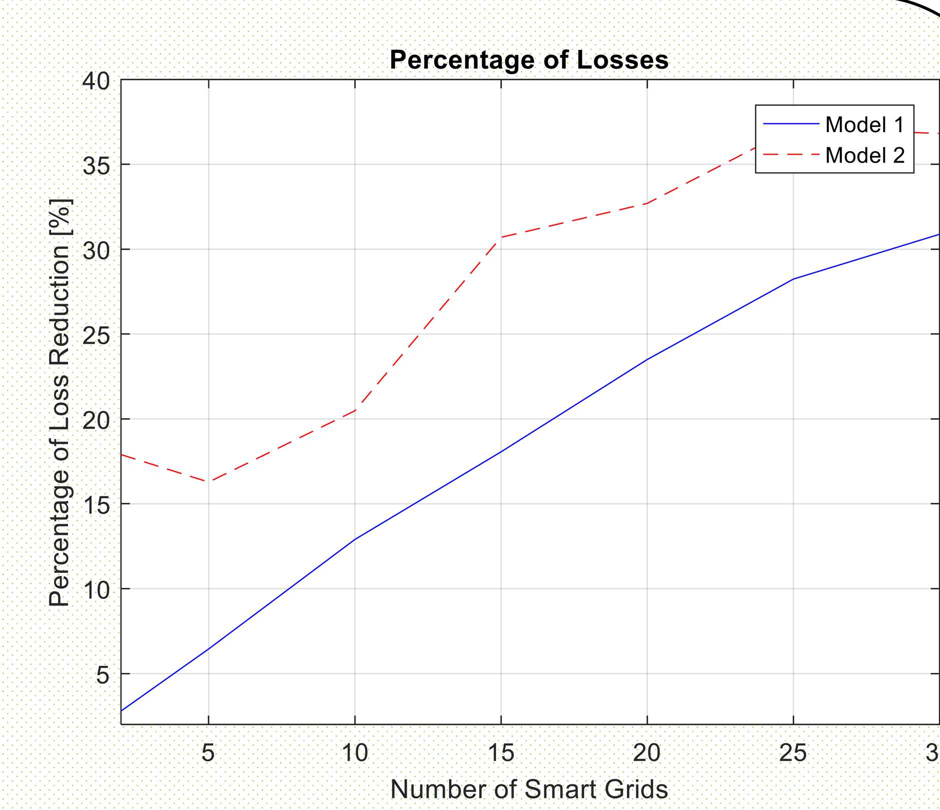


Fig.4 Reduction of power losses with real restrictions.

DISSEMINATION OF RESULTS (in the last year)

- **Publication in journals:**

[1] R. D. Medina, D. X. Morales, A. A. Romero and **J. B. Cabrera**, "Assessing power transformer final failure consequences using fuzzy logic," *2017 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)*, Pucon, 2017, pp. 1-7. doi: 10.1109/CHILECON.2017.8229538

[2] R. D. Medina, D. X. Morales, M. A. Toledo and **J. B. Cabrera**, "Power transformer risk index assessment for an asset management plan," *2017 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)*, Pucon, 2017, pp. 1-7. doi: 10.1109/CHILECON.2017.8229535

[3] R. D. Medina, J. Narváez, **J. B. Cabrera**, D. X. Morales and M. A. Toledo, "Applications of geothermal energy in the ecuadorian context: Case study: Baños of cuenca — Ecuador," *2017 IEEE PES Innovative Smart Grid Technologies Conference - Latin America (ISGT Latin America)*, Quito, 2017, pp. 1-5. doi: 10.1109/ISGT-LA.2017.8126754

[4] **J.B. Cabrera**, D.X. Morales and G.I. Araujo, "Disminución de pérdidas de potencia en sistemas fotovoltaicos", Killkana Técnica, 2018, ISSN: 2528-8024, ISSNe: 2588-0888.

[5] J.B. Cabrera, D.X. Morales, P. Arias and G.I. Araujo, "Pérdidas por efecto del polvo y suciedad en sistemas fotovoltaicos", 2018, ISSN: 2728-777X, Accepted.

[6] **J.B. Cabrera**, M.Veiga "Concepts Games Theory applied in Smart Grids", send to Journal (*Technology and Economics of Smart Grids and Sustainable Energy*), Springer. Review.

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[2] Saad, W.; hsn,Z.;H.Vicent,P, Communications Workshops (ICC), 2011 IEEE International Conference on , 2011.

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[4] K. Apt y A. Witzel, «A generic approach to coalition formation,» International Game Theory Review, vol. 11, nº 3, pp. 347-367, 2009.

[5] S. Ayan Mondal, «Dynamic Coalition Formation in a Smart Grid: A Game Theoric Approach,» IEEE, 2013

[6] K. Apt y A. Witzel, «A generic approach to coalition formation,» International Game Theory Review, vol. 11, nº 3, pp. 347-367, 2009

NEXT YEAR PLANNING

1. Write thesis memory
2. Thesis defense