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.

SIMULATION RESULTS

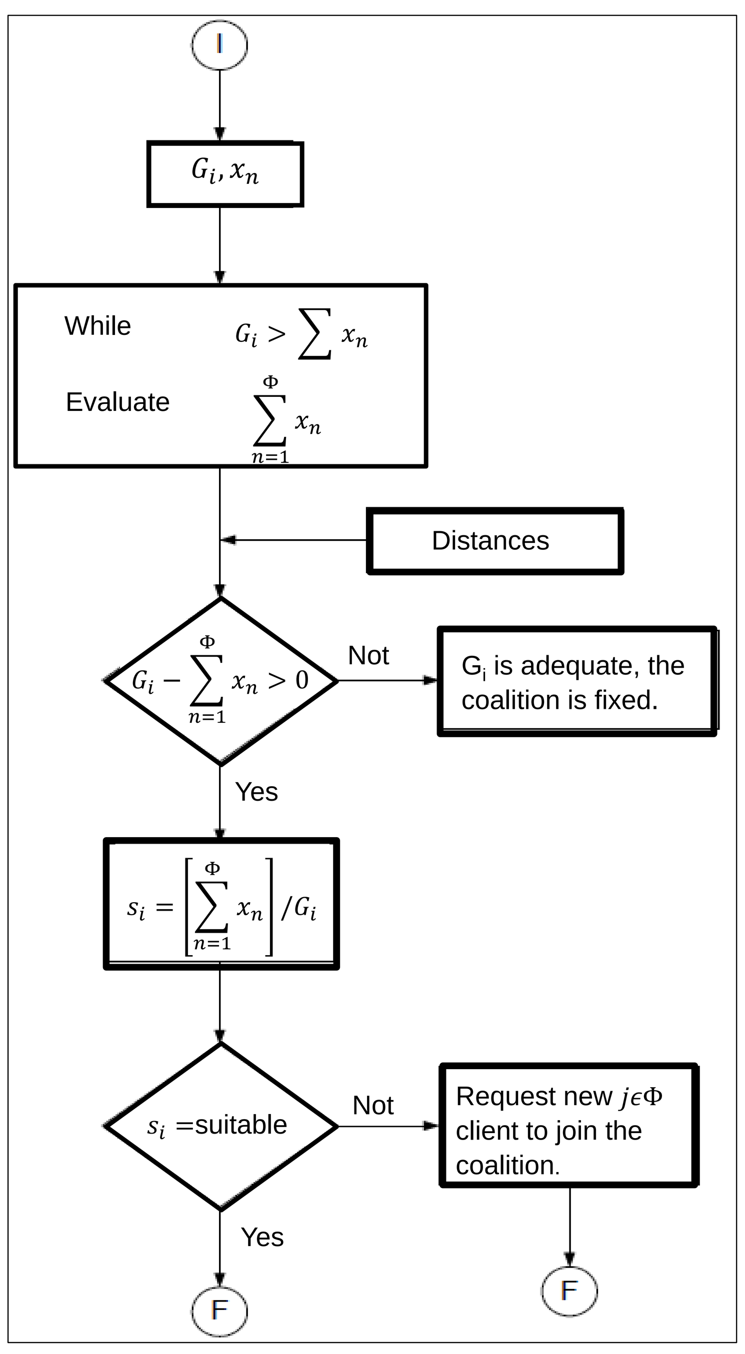

Fig.1 Flow chart of the algorithm for the power grid.

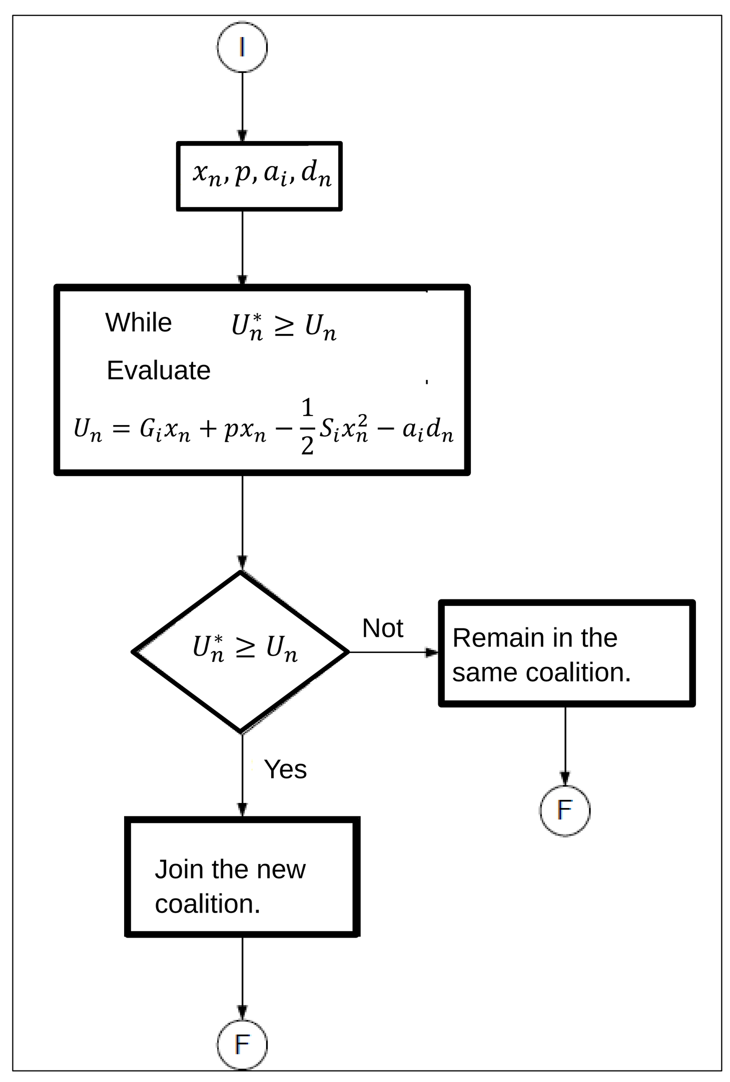

Fig.2 Flow chart for the client algorithm.

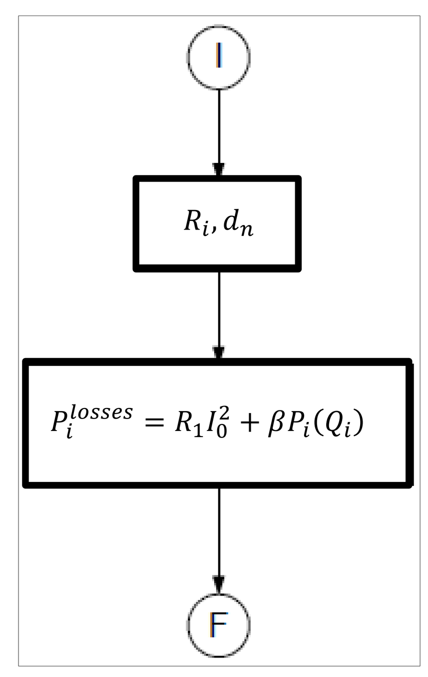

Fig.3 Flow chart to determine power losses in the power grid.

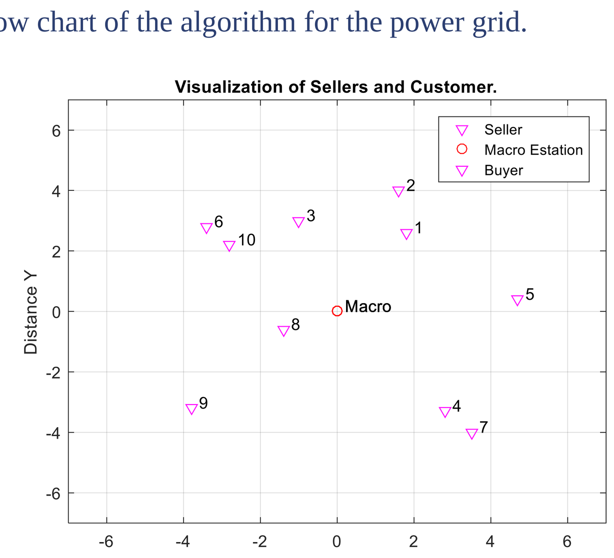

Fig.4 Model of the electrical distribution network.

Fig.5 Formation of coalitions.

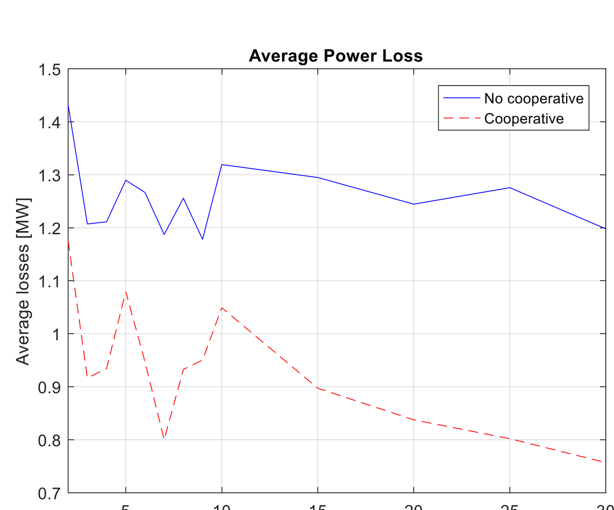

Fig.6 Evolution of the losses of power when incorporating the Smart Grids.

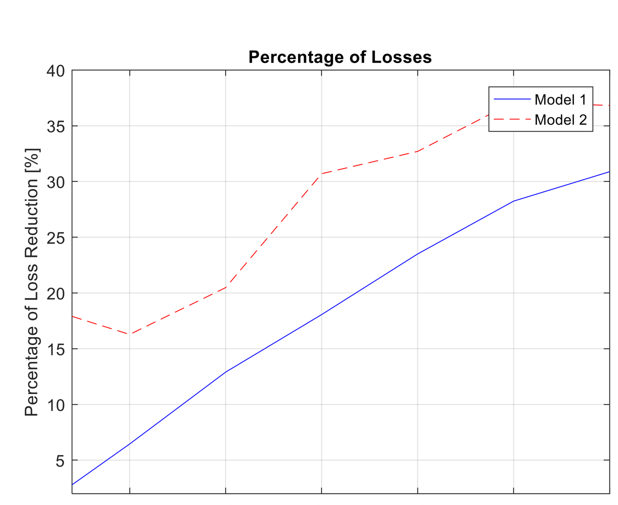

Fig.7 Reduction of power losses with real restrictions.

- For the calculation of the overall power losses, it is considered that the conductor carrying the power flow has a resistance of 0.2 Ω/km. The voltage to which the smart grids and customers will join is 22 kV and if a customer connects to the substation it will do so at a voltage of 50 kV.
- The average losses when customers have decided to buy energy from the substation is 0.3639 MW, while coalitions are carried out, the average loss is reduced to 0.2531 MW, that is, there is a reduction in losses of 30.46% when Customers choose to form coalitions with the Smart Grids in an extensive game.
- In the analysis of the average 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.

MOTIVATION OF THE WORK

Model of the electrical system for an extensive game.

Each substation k∈S contains a number M of macro networks and the network macro j∈M contains a set N of initial coalitions in the micro distribution network. Each Smart Grid is considered as a coalition. The incidence area of the i-th coalition is called a_i, and the total incidence area of the j-th macro station is [1]:

$$\alpha_j = \sum a_i \quad (1)$$

Then the incidence area of the k-th macro station will be [1]:

$$A_k = \sum \alpha_j \quad (2)$$

Within the i-th Smart Grid is a set Φ of customers to which it is desired to satisfy their demand for electric power, then in the Smart Grid N_i there is a certain amount of generated energy G_i and a certain number of customers belonging to Φ each of which requests a certain amount of energy from the network x_n [1].

It is also considered that there is a fixed price p for the purchase of energy within the grid given in \$/kWh, this price will be appropriate to optimize energy sales revenue. It is considered that the demand for energy in the Smart Grid can change over time and depends on several factors such as the system's energy storage capacity, the price of energy, the uses that are given to the energy being Are reflected in the needs of the electric load. For a given time interval, the generated power G_i is given by a fixed value for the Smart Grid, so the power demanded by all clients must comply with the following constraint [1]:

$$\left(\sum x_n\right)_i \leq G_i \quad \forall i \in N \quad y \quad \forall n \in \Phi \quad (3)$$

X_n is the individual power demand of each client in the electricity grid. Equation (3) expresses that the total demand of the customers to much must be better or equal to the power generated by a Smart Grid so that it can satisfy the demand of the customers. The value of x_n does not contain the power losses that are present in the energy exchange.

Model of the electrical system for a cooperative game.

The main network macro is considered to be linked to the Smart Grid set through the substation (square). The link between the substation and the Micro Grids can be made at a higher voltage level U_0 than the link that might present between Smart Grid at a voltage level U_1, ie $U_0 > U_1$.

A given electrical network can be constituted by a set of Smart Grid N, where for the i-th Smart Grid in a given time it can be considered that that Micro Network has a total Power generated called G_i and at the same time a power demand of a group of consumers denoted by D_i, then the energy surplus for the Smart Grid i∈N, is given by [2]:

$$Q_i = P_i - D_i \quad (4)$$

Depending on the generation and demand values present in the Smart Grid, the surplus energy can define three cases to be analyzed:

- Case 1: $Q_i > 0$

This means that the Smart Grid has a surplus of energy which makes it able to sell that power (seller) forming coalitions with other Smart Grid or to the Substation.

- Case 2: $Q_i = 0$

In this case the Smart Grid satisfies its own consumption

- Case 3: $Qi < 0$

In this case corresponds to that the Smart Grid is able to buy energy (buyer) from another Smart Grid or from the Substation

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

NEXT YEAR PLANNING

1. Real data gathering
2. Simulation of electrical systems
3. Publish results in conferences and journals
4. Implementation of a real-time simulation laboratory applied to game theory.

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DISSEMINATION OF RESULTS (in the last year)

- **Publication in journals:**

[1] **Cabrera, J.**; Araujo, G.; "Eficiencia Energética en el sector industrial en media y alta tensión.", YACHANA, Noviembre, 2016, ISSN: 1390-7778

- **Conference:**

[1] Vimos, C.; Morales, D.; **Cabrera, J.**; "Implementation of a network sensor using Arduino devices and multiplataforma applications though OPC UA", 2016 IEEE ANDESCON, 2016. ISBN: 978-1-5090-2531-2