Optimization in Energy Systems and Markets

Laboratory Assignment on Market Clearing Models

The effect of minimum up/down times and minimum income condition in the market equilibrium.

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The effect of minimum up/down times and minimum income condition in the market equilibrium.

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Contents

Description of the study

The goal of this study is to develop a new market clearing model, called $(TCMPA - UC - MIC)$, which consists on model $(TCMPA)$ with the following extended features:

1. It must include the minimum up/down time constraints of the (GUC) model.
2. It must include the *Minimum Income Condition* (MIC) of the complex bids of the MIBEL (see description below).

This generalized model will be the tool to analyse how minimum up/down time constraints, MIC and transmission constraints, affects the market equilibrium. To this end, the following four market clearing models must be considered:

(MPA):	the model (MPA) introduced in the course.
$(MPA - UC)$:	model (MPA) plus minimum up/down time constraints[1]
$(MPA - UC - MIC)$:	model $(MPA - UC)$ plus MIC constraints.
$(TCMPA - UC - MIC)$:	model $(MPA - UC - MIC)$ with transmission constraints.

Table 1: family of MCM to be studied.

In order to undertake this study you first have to:

1. Develop the mathematical formulation of the model $(TCMPA - UC - MIC)$.
2. Develop a heuristic procedure to solve models with MIC constraints.
3. Develop **a single script**, say `tcmpa_uc_mic.run`, that allow to solve, depending on the value of some parameters, all the models in Table 1.

Then, script `tcmpa_uc_mic.run` must be used to compare the market equilibrium of:

- **Study #1:** (MPA) vs $(MPA - UC)$.
- **Study #2**: $(MPA - UC)$ vs $(MPA - UC - MIC)$.
- **Study #3**: $(MPA - UC - MIC)$ vs $(TCMPA - UC - MIC)$.

There is not going to be strict guidelines about how to do the study: take it as an open "research" topic where you have to figure out how to analyse and interpret the results observed in the solution of the models in Table 1 to the test case that will be introduced later in this document. Therefore, your creativity and originality doing the analysis together with the comprehensibility of the report are going to be plusses while grading the task.

[1] The AMPL implementation of the (GUC) problem (files **`guc.mod`**, **`guc.dat`** and **`guc.run`**) will be included in the supporting material of this assignment.

Minimum Income Condition (*MIC*)

Complex bids in the MIBEL[2] include the following conditions:

- *Indivisibility.*
- *Load gradients.*
- *Minimum income.*
- *Scheduled stop.*

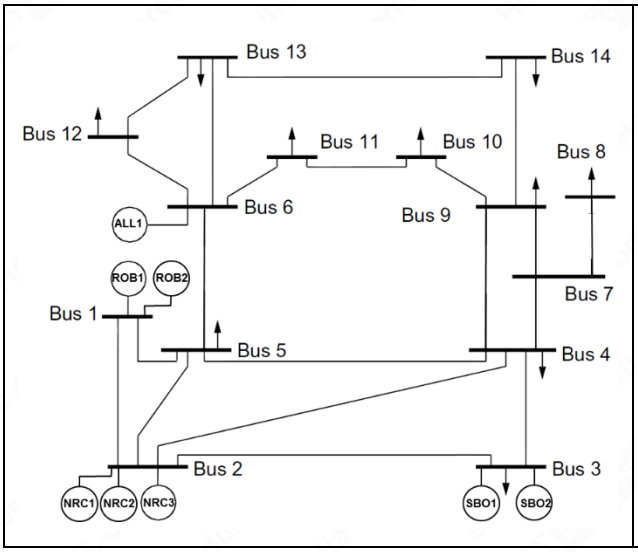
The load gradients condition is the same upwards-downwards ramp condition included in the (*MPA*) model. Among the other conditions, we will only consider the minimum income condition, MIC, defined as follows[2]:

> **The condition of minimum income** enables bids to be submitted in all hours, provided that the production unit does not participate in the daily matching result if the total production obtained by it in the day does not exceed an income level above an established amount, expressed euros, plus a variable remuneration established in euros for every matched MWh.

In addition to that definition, the MIBEL rules set that the stablished incomes cannot be greater than a 100% of the incomes resulting from the complete acceptance of the submitted bid (*producer's utility*) and nor the fix neither the variable terms can be negative[3]. To simplify the study we are going to assume that the income required in the MIC of every production unit only takes into account a constant term equal to the total producer's utility, without variable remuneration.

Case study

The electricity market study will be applied to the 14-busses IEEE transmission grid in Table 2



Hard coal and Anthracite

- Anllares grup 1 (ALL1)
- La Robla grup 1 (ROB1)
- La Robla grup 2 (ROB2)
- Nárcea grup 1 (NRC1)
- Nárcea grup 2 (NRC2)
- Nárcea grup 3 (NRC3)

Fuel-oil

- Sabón grup 1 (SBO1)
- Sabón grup 2 (SBO2)

Table 2: IEEE 14 transmission grid (source: https://www2.ee.washington.edu/research/pstca/)

[2] "*DAY-AHEAD MARKET OPERATION*", OMIE. https://www.omie.es/sites/default/files/inline-files/day_ahead_market.pdf

[3] Resolución de 6 de mayo de 2021, de la Comisión Nacional de los Mercados y la Competencia, BOE Jueves 20 de mayo de 2021. https://www.boe.es/boe/dias/2021/05/20/pdfs/BOE-A-2021-8362.pdf.

The thermal units are real generation units of the MIBEL and the load data are based on the real value and variation of the total energy traded in Spain during 18 October 2017[4]. All the numerical values for the technical data describing the generation units and the loads at demand busses are included in file **`tcmpa_I3E14_uc.dat`**. Producers and consumers bids are saved in files **`*_lbG.dat`**, **`*_pbG.dat`**, **`*_lbD.dat`**, **`*_pbD.dat`**, that can be read from AMPL with the following script:

```
# Generation bid functions ##################################
for {g in G}
{       read {t in T}: {b in bG} lbG[g,b,t] < (g&"_lbG.dat");
        read {t in T}: {b in bG} pbG[g,b,t] < (g&"_pbG.dat"); }
# Purchase bid functions ####################################
for {d in D}
{       read {t in T}: {b in bD} lbD[d,b,t] < (d&"_lbD.dat");
        read {t in T}: {b in bD} pbD[d,b,t] < (d&"_pbD.dat"); }
```

Each one of these files contains a 24×10 matrix where the rows are associated to the 24 hours and column i corresponds to the submitted quantity (files **`*_pbG.dat`** and **`*_pbD.dat`**) or price (files **`*_lbG.dat`** and **`*_lbD.dat`**). Producers' bids correspond to the *marginal bid functions* that will be studied in the last topic of this course, while consumers' bid functions are randomly generated from the expected demand used in the (GUC) assignment and the prices of the generation bid functions.

Report, submission and grading

You must upload a file **`MCM_surname1_surname2.rar`** or **`.zip`** (where **`surname1`** and **`2`** correspond to the two members of the group) with all the AMPL files used in the different sections and a **`surname1_surname2.pdf`** and the report of the assignment.

The report must follow the IEEE template published at Atenea, with the usual structure of a IEEE paper[5]:

I. Title, filiation, abstract.
II. Notation.
III. Introduction.
IV. Description of the mathematical model $(TCMPA - UC - MIC)$ and optimization algorithm (with special focus on the procedure to find a solution abiding by the MIC constraints).
V. Results: descripton of the test case, and analyse of the numerical results for studies #1 to #3.
VI. Conclusions.
VII. References.

The relative weight of the differents parts in the grading of the assignment is :

- 30% : study #1, (MPA) vs. $(MPA - UC)$.
- 30% : study #2, $(MPA - UC)$ vs. $(MPA - UC - MIC)$.
- 30% : study #3, $(MPA - UC - UC)$ vs. $(TCMPA - UC - MIC)$.
- 10% : general quality of the report.

[4] Sources:

i. Load values from the webpage of the iberian market operators OMIE (http://www.omie.es/informes_mercado/listados/lista_unidades.pdf)

ii. Thermal unit description from: "Estudi i optimització de l'oferta al Mercat Ibèric d'Electricitat (MIBEL)" PFC (http://www-eio.upc.es/~heredia/?q=node/156).

[5] An example of how to organize a IEEE paper can be found at http://hdl.handle.net/2117/20642

Supporting material

The supporting material for this assignment is:

- AMPL implementation of the (GUC) problem: files **`guc.mod`**, **`guc.dat`** and **`guc.run`**.
- The data for the IEEE14 grid system: file **`tcmpa_I3E14_uc.dat`**
- The producers and consumers bids: files **`*_lbG.dat`, `*_pbG.dat`, `*_lbD.dat`, `*_pbD.dat`**
- The AMPL and Matlab scripts for the graphical representation of the aggregated functions: files **`tcmpa2m.run`** and **`tcmpa_abf.m`** respectively.
- IEEE TPWS templates (Word and LaTeX).

This material is available at this link.