Designing an Electricity Transportation Network

a game organized jointly by :

The French "Fédération Française des Jeux Mathématiques"

and the

Société de Calcul Mathématique SA

with the support of

RTE
(Réseau de Transport d'Electricité)

Total prizes amount: 2,000 Euros

Description of the game

One has to design a transportation network for electricity, very high voltage and high voltage, taking into account the usual requirements:

- each city must be connected to the network ;
- the network provides enough redundancy, so that a break of some component does not prevent any user from receiving electricity ;
- the network respects protected zones.

There are 2,000 Euros for prizes: 1,000 for individual answers and 1,000 for collective answers (schools) ; see below.

Opening date for the game: April 1st, 2010.

Closing date for the game: June 30th, 2010. All answers must be received by that date.

All answers must be sent by email, in .pdf format, to the French "Fédération Française des Jeux Mathématiques". Email address : ffjm@wanadoo.fr

Languages for the answers: English or French.

The principle of the game is simple: you are given six electricity plants, characterized by their position and power, and fifteen cities, characterized by their position and consumption. You have to build a distribution network, connecting the plants to the cities. The winner is the one who builds the best network, that is the network with smallest installation cost.

All constructions and presentations must be explicit, and their quality will be an important factor in the selection of candidates.

I. The game

1. The country

It will be represented schematically by a square of 1,000 km for each side. The origin of axes will be the point down left, and the two axes will be the corresponding sides of the square. The unity is the km.

2. General data

Here are the six power plants, with their coordinates and production:

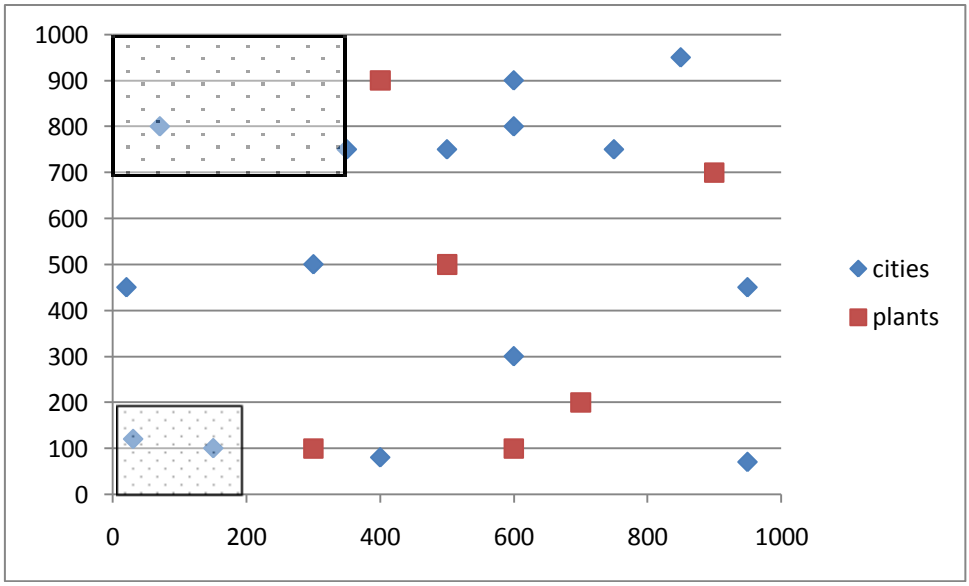
Plants	x	y	production (MW)
C1	300	100	900
C2	600	100	500
C3	700	200	1 200
C4	900	700	450
C5	500	500	750
C6	400	900	1 200
total			5 000

Table 1: the plants

Here are the cities, with their coordinates and consumption:

City	x	y	consumption (MW)
V1	150	100	200
V2	400	80	300
V3	950	70	200
V4	30	120	250
V5	600	300	300
V6	20	450	250
V7	300	500	300
V8	950	450	300
V9	70	800	250
V10	350	750	150
V11	500	750	250
V12	600	800	300
V13	600	900	100
V14	750	750	250
V15	850	950	250
total			3 650

Table 2: the cities



Map of the country, with the cities, the plants and the protected zones

3. Objective

The objective is as follows: each city must receive High Tension electricity. A city is considered as a point: the alimentation of houses inside the city is made with low voltage, and this does not concern the present problem, which deals with high tension only.

4. Electrical Lines

Two kinds of lines exist: Very High Tension (VHT), namely 400,000 Volts, and High Tension (HT), namely 90,000 Volts. The plants always produce VHT. The amount of electricity which is lost during transportation, due to Joule effect, is lower when tension is higher, so one always has to use VHT lines whenever possible, even though the installation cost is higher.

The cities must receive HT current; so a conversion from VHT to HT is necessary. It is done by transformers. The number and position of these transformers is part of the problem. The only constraints about them are:

- They cannot be installed within 1 km from each city ;
- They cannot be installed in a protected zone, defined below.

The objective of the game is to install the VHT and HT lines and the transformers, in order to bring electricity to all cities, at minimal cost.

5. Data

We give:

- Cost for each km, VHT line : 1 million Euros
- Cost for each km, HT line : 300 000 Euros
- Cost for each transformer : 500 000 Euros

6. Protected zones

Two zones are considered as protected, because the habitants do not want to see electricity lines. They are:

$0 \le x \le 200,\ 0 \le y \le 200$ (left bottom corner)

$0 \le x \le 350,\ 700 \le y \le 1000$ (top left corner).

In these zones, one cannot put VHT lines; one must use underground HT lines, and their cost per km is 1 million Euros.

7. Constraints

They are as follows:

- Each city must receive its electricity ;
- Any VHT or HT line cannot carry more than 1 GW ;
- Any underground HT line cannot carry more than 0.3 GW ;
- The network must work even if one of its components is subject to failure. This means that all cities must be served, even if one VHT line breaks down, or one HT line, or one transformer.

Important: we do not ask that the network brings electricity to everyone in case of two components breaking down at the same time.

II. Comments

Electricity production and consumption are supposed constant over time; we do not take into account daily or monthly changes (this, of course, does not reflect reality).

The distance we consider is the Euclidean direct distance.

We do not take into account the losses in electricity due to transportation, or due to the transformers.

The objective of the game is to minimize the installation cost; we do not care about the exploitation cost. This cost has been taken into account, when we said that all lines must be VHT, whenever possible.

Each line may be divided, as often as one wants; the same line may connect several plants and/or several cities.

There may be crossings between lines, with or without connection.

Several lines may be put close to each other, in parallel, but this does not reduce the costs.

III. Prizes to be given by FFJM and SCM, with support from RTE

There are two categories:

Individual Prizes:

For the winner : 500 Euros
For the second : 200 Euros
For each of the next three : 100 Euros each.

Collective Prizes (schools or academic institutions):

For the winner : 500 Euros
For the second : 200 Euros
For each of the next three : 100 Euros each.

The best solutions will be published on the web sites of FFJM, SCM and RTE.

The official announcement of the results, and prize ceremony, will happen on Thursday August 26th, 2010, in Paris, for the final of the Championship of Mathematical and Logical Games, "Maison Internationale de la Cité Internationale Universitaire de Paris", 17 Boulevard Jourdan, 75014 Paris, France.

The general rules of the game are available on the web site of FFJM. Participating in the game implies that you accept these conditions.