TOTAL ENERGY BY GAS ENGINES OR TURBINES IN PROCESSING INDUSTRY AND TERTIARY SECTOR MECATHER SOFTWARE: A USEFUL TOOL FOR PROJECT STUDY AND INSTALLATION MANAGEMENT

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ABSTRACT

After a presentation of the French energetics context describing the electricity tariffs and the problems different partners are confronted with, we will show the advantages of cogeneration for each of them. Simultaneously, the interesting types of units and their running schedules will be deduced.

The technical and economical conditions which are of primary importance in the study of any installation, will then be developed through the MECATHER approach. The MECATHER software makes an hourly energy balance by an hourly description of the factory using standard days and standard months.

This method will be further developed through a case study.

NOMENCLATURE

B.I.E.	:	Bureau d'Informatique Energétique
CETIM	:	Centre Technique des Industries Mécaniques
EDF	:	Electricité de France (French Electricity Distributor)

FRENCH ENERGETICS CONTEXT

Electricity demand

Fig. 1 shows variations of electricity demand in France of corresponding winter and summer days.

ELECTRICITY LOADS OF CHARACTERISTICS DAYS –

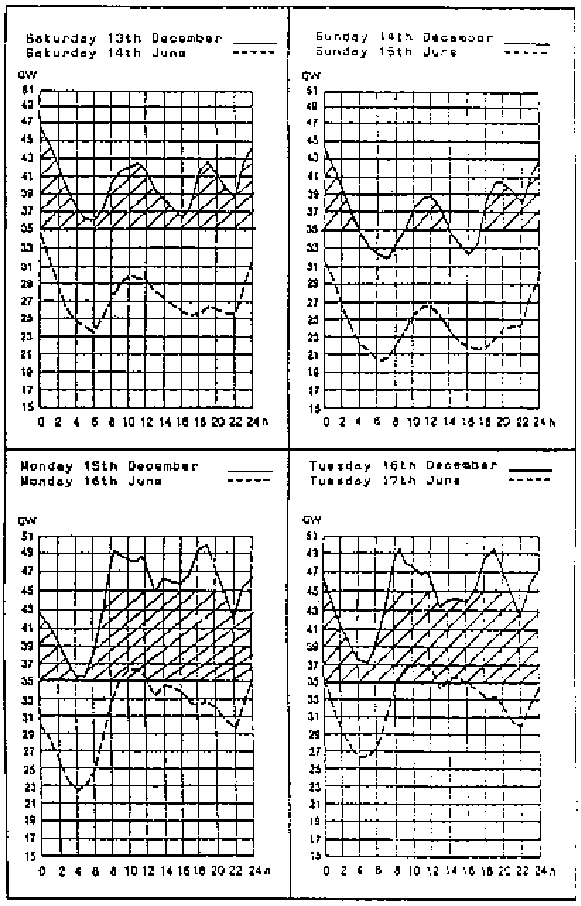

Fig. 1

The following observations can be made :

(a) a great difference between the winter and summer demands. This can be explained by :

* Electrical heating. This type of heating will be further developed and will thus accentuate the winter/summer differences and increase the peak levels.

* The longer use of certain electrical apparatus such as light, heating auxiliaries, etc.

* Increase of the energy consumption of certain processes such as water heating, etc.

(b) Peak periods (9-11 am) and (6-8 pm). This is due to the working schedules and to the use of domestic appliances at certain fixed periods.

Production of electricity

In order to cope with these great variations of demand, EDF has several types of production units. Hydroelectric and nuclear power stations produce the base load, thermal power stations using coal or oil are used for cold winter days. Gas turbines provide the daily peaks in winter.

Problems encountered by EDF

Saturated network. Last years investments mainly concerned production units. The electricity distribution network did not benefit of an equivalent effort and is now very heavily loaded. EDF has to make heavy investments to improve its network.

Nuclear overproduction. Because of important differences between consumption forecasts and reality, the important French nuclear programs has led to the overcapacity of nuclear production with regards to French demand.

Costly gas and coal thermal station. To cope with daily peaks and hard winters, EDF must maintain an important park of gas and coal stations which are very rarely used and are thus very expensive.

Electricity tariffs

The price of electricity in France is based on a complex marginal cost theory. Our purpose here, is not to explain this theory but only to show how the price of electricity varies with time.

The year is divided into two main parts : winter (November-March) and summer (April-October).

Winter is subdivided into two : winter with peaks (December to February) and without peaks (November and March).

3 periods are used to describe a day : winter peak time (9-11 am and 6-8 pm), full time (6 am-10 pm) and slack time (10 pm-6 am).

TABLE 1 : Energy prices and susbscription fee

TARIF VERT « A5 » moins de 10 000 kW
OPTION BASE

VERSIONS	PRIME FIXE ANNUELLE (francs par kW)	PRIX DE L'ÉNERGIE (centimes par kWh)				
		HIVER			ÉTÉ	
		Pointe	Heures Pleines	Heures Creuses	Heures Pleines	Heures Creuses
TRÈS LONGUES UTILISATIONS	831,57	41,30	32,32	22,93	13,12	9,26
LONGUES UTILISATIONS	542,87	60,36	44,20	25,69	14,60	9,39
MOYENNES UTILISATIONS	342,57	104,29	54,21	25,26	15,53	9,53
COURTES UTILISATIONS	110,51	148,60	74,88	33,67	20,72	9,3[illegible]

ÉNERGIE RÉACTIVE (c/kvarh) (1)	11,88

TABLE 2 : Reduction coefficients

Coefficients de la puissance réduite

VERSIONS	Pointe	Heures Pleines	Heures Creuses	Heures Pleines
TRÈS LONGUES UTILISATIONS	1	0,70	0,19	0,05
LONGUES UTILISATIONS	1	0,60	0,24	0,06
MOYENNES UTILISATIONS	1	0,54	0,20	0,09
COURTES UTILISATIONS	1	0,60	0,35	0,24

NOTA : Ne s'applique pas en Corse et dans les départements et territoires d'outre-mer

(1) A compter du 1er novembre 1987, la proportion d'énergie réactive gratuite est ramenée à 40% de l'énergie active consommée en dehors des heures creuses pendant l'hiver.

TABLES 1 and 2 represent the different types of contracts that a French industry can strike with EDF. The most suitable contract depends on the peak power demand and the equivalent time during which this peak power is effectively used.

Annual electricity cost

p : period
SF : total subscription fee
SPp : subscribed power in period p
RCp : reduction coefficient in period p
sf : subscription fee per unit kW
CC : consumption cost
Ep : energy consumed in period p expressed in kWh
Cp : cost of a kWh

SF = ((SPp - SPp+1) * RCp) * sf
p

CC = Ep * Cp
p

TOTAL COST = subscription fee (SF) + consumption cost (CC)

Variations of electricity costs with periods

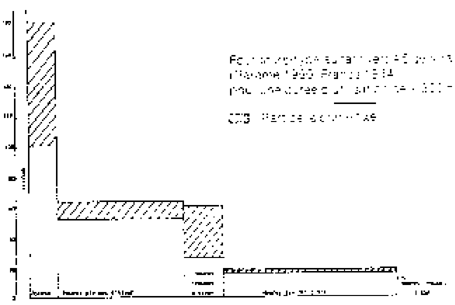

Fig. 2

Fig. 2 shows the evolution of electricity prices with the different EDF periods for a particular contract. The shaded part represents the subscription influence on the total price.

We can note the high cost of electricity in winter and the great difference between winter and summer prices.

ADVANTAGES OF COGENERATION

Cogeneration is of economical and energy savings interest only in winter (November to March) for a unit having simultaneous electricity and heat needs.

Depending on the type of industry, we can differentiate two types of running schedules :

(a) Permanent operation (24 hours a day for 7 days a week) that is an annual running period of 3,000 to 3,600 hours,

(b) Full and peak periods operation (16 hours a day - 5 or 6 days a week) that is approximately from 1,600 to 2,200 hours anually.

Each of these two schedules may interest these types of installations.

(1) Permanent running : Industrial activities like contineous processes, 6 or 7 days a week and having continuous energy needs,

Hospitals, commercial centers.

(2) Full and peak periods operation : 2 shifts industrial activities (2 * 8 hours a day, 5 days a week),

Services, banks, commercial firms, etc.

Consumers interests

Financial interest : the lower cost of self-generated electricity compared to EDF tariffs.

Self-generated electricity's cost must take into account the energy consumption but also the exploitation and maintenance costs and the economy due to the heat recovered from the motor.

The cost of electricity bought from EDF must include the subscription fee.

Calculations show that the mean price of a kWh (3.6 MJ) from the EDF tariff (Tarif vert A5) including the subscription fee for the periods concerned is of :

0.50 to 0.65 F for permanent running,
0.65 to 0.90 F for peak and full periods operation.

The self-generated kWh cost's varies from 0.10 to 0.25 F. Cash-flow coming out from each self produced kWh ranges from 0.40 to 0.70 F.

Remarks : The price of one kWh obtained after accounting for the depreciation of the installation is approximately of the same order as summer EDF prices, thus giving a price which is almost constant throughout the year.

The study of several cogeneration units shows that the investment needed for a cogeneration unit varies from 3,000 F to 6,000 F per installed kW. Pay back varies in general from 3 to 5 years.

Cogeneration also has other side interests such as : a greater choice of energy sources and increased negociation power towards the suppliers, increased supply reliability.

EDF's interests

Main interests. The interests come essentially from the complementarities that cogeneration presents towards the nuclear power stations.

These complementarities are :

(a) in situ, energy production :

- no transportation losses,
- decrease of network overloads,
- less investment for improvement and maintenance of distribution network,

(b) rapid installation (a few months are necessary to implant a cogeneration unit),

(c) flexibility :

- instantaneous and if necessary automatic starting ups and shut downs,

- easy power regulation.

If we consider the national loads' curves in Fig. 1, we find a zone (between 35 GW and 45 GW) where this type of installation allows to peakshave the power demand in good conditions.

We can imagine the situation when the lower parts of this zone will be produced by "permanent installation" and the upper one by "peak and full" units.

This flexibility will be reinforced if EDF negociates with its customer having a cogeneration unit in order to make network disconnection agreements when necessary (incidents, particular situations, ...) and inversely, stopping these units when the demand decreases (mild winters, ...) for a better use of the nuclear plants.

Other interests for EDF. The presence of an important cogeneration network will :

(a) allow EDF to cope with the rapid development of actual and future electrical heating which will considerably increase the peaks,

(b) favourise electricity sales to neighbour countries having peak demands they can't satisfy,

(c) help EDF answer to the strong pressure coming from its partners aiming to reduce the mean cost of electricity for industrial purposes by a less important difference between winter and summer prices.

National collectivity

The main interest for the nation is a more efficient use of imported fuels.

The efficiency of cogeneration being between 70 and 80 % whereas that of thermal power stations are only of 30 %.

The economy generated by cogeneration is estimated to be around 0,4 tOE per MWh of electricity produced.

If we suppose that half of the 35-45 kW range (see Fig. 1) is supplied by cogeneration during the 2,000 winter hours, producing around 12,500 GWh of electricity, 5 million tOE/year mostly imported will be saved that is 3 to 4 billion francs.

The other interest being the opportunity to export French products developed for the national market.

Utilization effeciency

Theoretically, a cogeneration unit has a relatively high efficiency (80 %). This efficiency does not take into consideration the use of the waste heat. If the heat demand is greater than what is produced, all the heat produced may be considered as energy savings (not produced by auxiliaries). On the contrary, excess heat is vented to the atmosphere or may be stored.

The utilization efficiency may then be defined as :

$$\eta_{Utilization} = \text{(Electricity produced + heat recovered) / Energy consumption}$$

This utilization efficiency may have instantaneous high values. The mean utilization efficiency varies considerably from one plant to the other.

Partial or complete disconnection from the EDF network

A cogeneration unit may

firstly : allow the factory to disconnect completely from the EDF network by the use of a sufficiently powerful system in order to absorb the peaks,

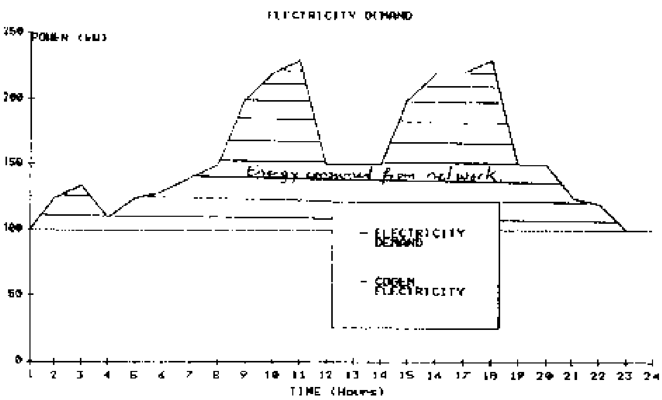

Fig. 3

secondly : reduce the power demand from EDF by the use of a cogeneration unit designed to satisfy the base power demands. EDF power being used to absorb the peaks (see Fig. 3).

The second type of installation allows :

(a) the installation of a smaller unit and thereby less investment,

(b) the running of the motor near the optimum conditions,

(c) a better utilization efficiency.

Type of motor : reciprocating engine or turbine

To choose between a motor or a turbine, we must take the following criteria into condensation :

(a) the ratio between the electricity and heat demands,

(b) the temperature at which the heat is used,

(c) the variation of (a) and (b) with time,

(d) investment level and pay back

Running schedules

The price of EDF bought electricity varies with the seasons but also with the hour of the day. A close study of the evolution of the difference between the cost of self-produced and that of EDF electricity must be made in order to choose between producing or buying electricity.

This can only be done if the power demands are known with sufficient details and certainly not by the use of mean values.

In order to optimise the cogeneration unit, detailed technical and economical calculations must be made. Several iterations may be necessary to reach the optimum solution.

MECATHER SOFTWARE

Objectives

(a) increase the reliability of a project study,

(b) minimise the costs of a project study,

(c) give significant results for the management of the existing or future unit.

Method

MECATHER takes into account the variations of the utilization efficiency and variations of energy prices by an hourly description of every significant energy consumer and producer. Hourly energy balances are made to reconstruct the power demand curves and thereby calculate the utilization efficiencies and the real costs.

Comparison between real consumptions and calculated ones are used to verify the validity of the computer model. Once a reliable model of the existing installation is obtained, we may proceed further with modifications of the plant in order to make energy savings and reduce costs.

Machine description

Operating conditions	Electrical power (kW)	Heat power (kW)
a - no load	50	10
b - normal load	50	100
c - peak load	75	125

A machine is defined by its different operating conditions. These conditions are used to describe standard days. A standard day fills each of the 365 days of a year.

Building description

Comfort conditions	Temperature (°C)	Relative humidity	etc.
a - night	15	60	...
b - day	20	60	...
c - week-ends	10	60	...

The same method using standard days is used to describe the building throughout the year.

Building consumption : MECATHER has a cer-tain number of numerical files corres-ponding to different regions of Franc where the outside temperature, humidity an solar radiations are given with the sam hourly precision. The files are used t calculate heating and air conditionin consumption.

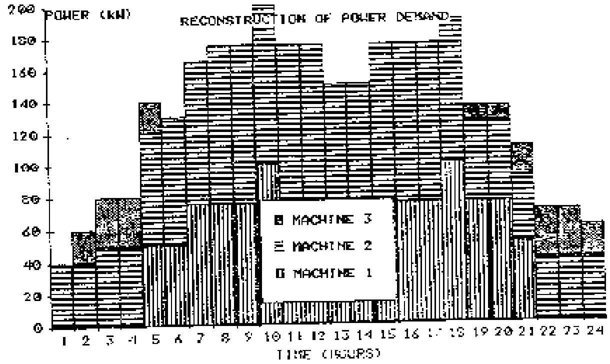

Fig. 4

The power demand of each machine is adde to reconstruct the total power demand (se fig. 4). This is done for each type c energy and for each network.

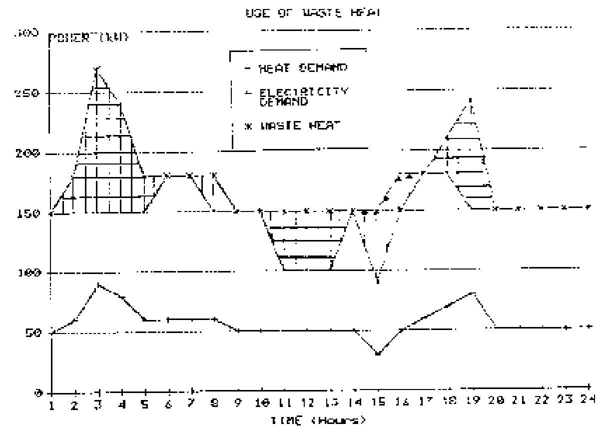

Fig. 5

Vented heat
Heat supplied by auxiliairies

By this method, we calculate the heat rec vered from the cogeneration units, t additionnal heat supplied by the aux liaries (see fig. 5). Other values such machines and buildings consumptions a costs are also calculated.

MECATHER'S POSSIBILITIES

A plant modelised with MECATHER may have up to :

4 different energy sources
30 heated or air conditionned buildings
40 machines : a machine may consume two differents types of energy at the same time
10 energy generators :
    electricity : hydroelectric generators
                  reciprocating engines
                  gas turbines
    heat : boilers
           heat pumps
           heat accumulators

Two heat networks and two electrical networks may be used to transport energy from the generators to the consuming units.

Detailed results concerning consumption, costs and peak power demands are available at every level in the description of the plant.

CASE STUDY : CONTENTS

- Brief descrition of the factory (size, production, energy consumption),
- Main energy consumers (machines),
- Energy demand curves,
- Possible solutions,
- Technical results,
- Economical results,
- Conclusions.

The case is actually being studied, the results will be presented at the conference.