Methodolgy and optimization of the electrical energy in a gas turbine power station

Méthodologie et optimisation de l'énergie électrique dans une centrale turbine à gaz

Ayoub Oubourhim[1], Khalil El-Hami[1], Aziz Soufi[2]

[1] Laboratory of Nanosciences and Modeling, University of Hassan 1st, Faculty of Khouribga, Morocco, oubourhim.ayoub@gmail.com, Khalil.elhami@uhp.ac.ma
[2] Laboratory of Nanosciences and Modeling, University of Hassan 1st, National school of Applied Sciences of Khouribga, Morocco, az_sfi@yahoo.fr

ABSTRACT. Energy Dependence in Morocco is about 93.3%, which makes the price of kWh tightly linked to fluctuations in oil prices. This paper focuses on improving the energy efficiency of an auxiliary gas turbine 315 MW station of Kenitra city in Morocco as example. The main goal of this study is to calculate the cost of kWh and try to reduce it by developing proposals and solutions to optimize energy, operational conditions and performance of the station. In this regard, a functionally planned cutting of the station to calculate the cost per kWh based on the cost of consumption of each station. Then, we mathematically modeled the equations that result .This will allow to analyze consumption auxiliary energy of the station and consequently to identify the most energy installations consumption.

RÉSUMÉ. La dépendance énergétique au Maroc est d'environ 93,3%, ce qui rend le prix du kWh étroitement lié aux fluctuations des prix du pétrole. Cette étude se concentre sur l'amélioration de l'efficacité énergétique d'une turbine à gaz auxiliaire de 315 MW à la ville de Kenitra au Maroc par exemple. L'objectif principal de cette étude est de calculer le coût du kWh et d'essayer de le réduire en développant des propositions et des solutions pour optimiser l'énergie, les conditions d'exploitation et les performances de la station. À cet égard, une coupe de la station fonctionnellement planifiée pour calculer le coût par kWh basé sur le coût de consommation de chaque station. Ensuite, nous avons modélisé mathématiquement les équations qui en résultent. Cela permettra d'analyser l'énergie auxiliaire de consommation de la station et par conséquent d'identifier la consommation d'installations la plus énergétique.

KEYWORDS. Gas turbine, Optimization, Electrical Energy.

MOTS-CLÉS. Turbine à gaz, Optimisation, Energie Electrique.

1. Introduction

The rationalization and optimization of energy consumption is a unique solution for sustainable development to preserve energy wealth for future generations. Howard Geller 2006 [GEL 06] estimates that OCED countries (France Germany Italy Japan Norway Sweden United Kingdom Australia Denmark Finland) have reduced the need of energy to fuel economic growth 49% from 1998, especially through adopting efficiency energy policies in industry.

ISO 50001[ECC 12], Energy Management Systems - requirements and recommendations for implementation, offers organizations a recognized framework for the implementation of a management system effective energy. Like other standards systems management, this standard follows the improvement loop continues called PDCA (Plan-Do-Check-Act).

The Moroccan law 47 09 3 about efficiency energy provides a regulatory framework for executing a mandatory energy audit each year for inefficient organizations such as Gas turbine stations, which constitutes a huge potential of saving energy. This paper provides a guide for applying energy audit on gas turbine station basing on a case study of gas turbine 315 Mw in Kenitra city, Morocco.

1.1. *Study of the existing and Calculation of the cost of KWh*

This step involves collecting energy data. The basic data of the analysis must be available in order to define reasonable objectives for saving energy. These data include the characteristics on the nameplates, the monthly quantities of energy consumed spread over a period of at least one year (March 2014 - February 2015). Based on these data, an assessment of the energy situation can be made. This calculation will be based primarily on static data (water consumption rates, monthly statement, and technical data (flowmeter, dosage ...).

The calculation steps are:

– The functional division of the station into stations.

– The modeling of each position.

– The calculation of expenses in a period of time of each position.

– Deduct the unit cost.

– The projection of the cost over the duration of study.

1.2. *Analysis and quantification of losses*

This step involves developing an approach for calculating and choosing the performance and energy balance indicators. Since there are various efficiency energy indicators [QIN 14], we use, in our study, Yield ASME PTC 4.1 [WAN 10], which lead into two methods for yield calculations: in the first one, as direct method, consists of determining the consumption input and output of the facility to determine the performance. The second, indirect method is more precise which can determine in detail the losses (L) and the credits (B) at the level of the installation to finally deduce the yield. The reliability of the results obtained by this method is conditioned by the accuracy of the measurements. We notice that the thermal balance energy is an important indicator to find thermal and electrical losses.

1.3. *Identification of energy improvement projects*

The objective of this step is to evaluate the energy saving measures based on three criteria: The economic (additional investment or value current net), the energy (total consumption of primary energy or energy economized and ecological (emissions harmful to the environment).

2. Experimental Set up

2.1. *Modeling and calculation of the cost of KWh*

The station has two main categories of auxiliaries: common auxiliaries No.1 to ensure the operation of the whole station including three turbines and clean auxiliaries (close) that ensure the operation of each turbine independently of the others (The three turbines are identical).

Since clean auxiliaries ensure the transfer and conditioning of fuel and diesel to the turbines simultaneously with the operation of the turbine, we can consider the clean auxiliaries and the turbine as a single system. In this perspective we build a model for each position. Therefore, it will consist of a column matrix, which represents the entries of each item in their international units, and in a row matrix α_m which represents the degree of presence of the inputs to form a unit quantity of the output as follow:

$$E = (\alpha_{i.1}\ \alpha_{i.2}\ \alpha_{i.3}\ \alpha_{i.4}\ \alpha_{i.5}\ \alpha_{i.6}) \begin{pmatrix} e_{1.1} \\ e_{1.2} \\ e_{1.3} \\ e_{1.4} \\ e_{1.5} \\ e_{1.6} \end{pmatrix}$$

We proceed the same modeling in the water treatment station, fuel treatment station boilers station and unloading diesel fuel stations until we get the final used energy:

$$KWh = (\alpha_{6.1} * G + \alpha_{6.2} * e_{1.4} + \alpha_{6.3} * e_{1.6} + \alpha_{6.4} * F + \alpha_{6.5} * Va)$$

We used the invoice archives to determine the price of entries of degrees of presence that ends based on the flow meters, the injection sliders, the transmitters, and the manufacturer's documentation. Therefore, taking into consideration the price of maintenance, finally, 1 KWH = 1,96 MAD.

2.2. *Optimization of the cost of KWh*

2.2.1. *Diagnosis of losses and corrective actions*

The two pumps supplied the boiler room with fuel oil and diesel fuel continue to operate, even if the boilers are off, which is the seat of the fuel pump runs 7 527 hours/annum with a power of 2.2 kW, so the loss is about 16 MWh/annum. For the diesel, pump operates 8 425 hours/annum with a power of 1.5 kW, so the losses are about 29 MWh/annum. The solution in this case is to start the pumps (fuel/diesel) when the start order of the boiler is active according to the nature of the selection. This action avoids 45 Mwh/annum with TRI of 20 days. In lighting, the first action in the search procedure solutions allowing saving energy consumption of lighting, which can make changes at the level of lamp technologies installed in Kenitra's TAG power station in order to reduce the power dissipated by these lamps. However, by keeping the even light, it will provide adequate lighting and satisfies the working conditions. The most effective solution for managing lighting inside the station is the use of crepuscular switches and presence detectors.

Results and discussion

For increasing efficiency of boilers we can use ASME PTC 4.1. This American standard provides tow methods for calculating the yield of boilers to find where we have to make some improvement decisions. We use the indirect method which actually serves to identify energy losses and gives solution to increase the efficiency of boilers. Therefore, according to our study we obtain the following results summarized in tables 1 and 2.

Lost type		Value (Kcal/kg.Comb)	Lost %
Lost by thermal sensitive to dry gases	Lg	1 472.88	90.73
Lost by humidity formed by combustion of H	Lh	0.51	0.03
Lost by humidity inside combustible	Lmf	0.02	0.001
Lost due to the humidity of the air	Lma	16.03	098
Lost due to the formation of carbon oxid	Lco	0	0
Lost of temperature due to convection and radiation	L	134	8.25
Sum of losses	L	1 623.26	100

Table 1. *Identification of lost types and their corresponding values*

Credit type	designation	boiler value (kcal/kg.comb
Heat credit supplied to the combustion air	BA	142.49
Heat credit supplied to the combustion air humidity	BmA	1.29
Heat credit provided by fuel warming up	Bf	28
Heat credit provided by the boiler control auxiliaries	Bx	263.8
PCI	PCI	9738
Sum of credits	B	10173.58

Table 2. *Identification of credit types and their corresponding values*

As result of this diagnostic we suggest to recover the heat of the smoke and the regulation of the combustion. The ultimate goal of this idea is the recovery of the heat released by the smoke and transfer to the combustion air. The present operation will allow us a double gain, the first is the decrease in the temperature of the exhaust while the second it is the gain in credits brought by heat to the air of oxidize.

The heat exchanger installation project has increased the efficiency of the boiler of + 9.22% which has reduced the average fuel flow of -16.49 kg/h considering hours of operation of the boiler is 7 600h / annum. As a result, the annual fuel gain is 125.5 kg of comb /annum have also been able to reduce the energy consumed by boilers.

The yield of water treatment station is about 63% and recovering the rejections is necessary to maintain the flow between input and output of sand filter. The design of this post is made to admit a certain flow, thus if we pass the range elaborated by the constructor the driving will explode. To solve this problem we suggested the installation of a variable speed drive for the pump. The loss is due to the heat given by the whole heat, as shown in table.1, exchanger heat to the outside air. This loss can be determined by means of special measures and this is the method that has been adapted for this part. But the more often that it reads on a chart endorsed by A.B.M.A (American Boiler Manufactures Association) depending on the nature of the walls, the nominal capacity of the boiler, and the actual load of the test. The emission of an electromagnetic radiation by the surface at the temperature Tp, although partially compensated by the reception of a radiation coming from the surrounding environment at temperature Ta, also participates in the exchanges thermal surface. Without going into the complex equations describing these two phenomena, we operated with a "phenomenological" approach and by analogy with the conduction equations, which has the thermal equilibrium, the power exchanged at the surface is:

$$P = P_{conv} + P_{ray} = h_{conv}(Tp\ \ Ta)S + h_{ray}(Tp\ \ Ta)S$$

Where we were using infrared thermal camera, as shown in figure 1 as free convection diagram [DUE 54].

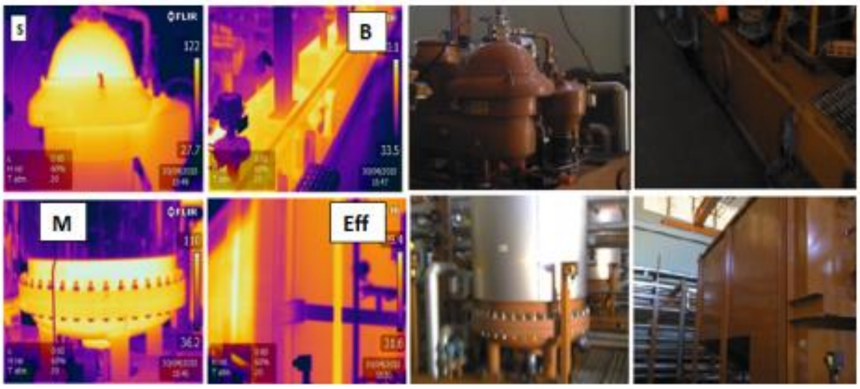

Figure 1. *Images of real and infrared thermal camera*

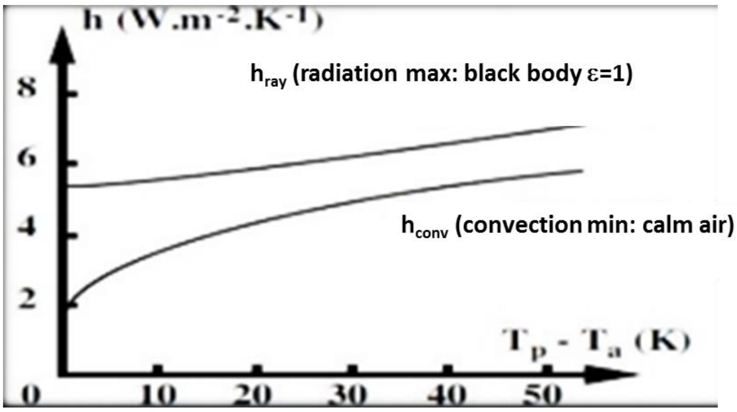

Figure 2. *The dependence of h_{rad} and h_{conv} with temperature*

The thermal losses are about 31 MAD/hour, the most effective solution to recover this energy is implementing insulation. The choice of insulation is based on professionals requirements, security, corrosion protection and the cost NBN D 30-0412 [ARM 02] Standard.

The objective of this part has been to reduce the cost of fuel treatment and as a consequence of the reduction in the cost of fuel treated. We have proposed optimization scenarios that we studied them economically and technically by choosing the most adaptable and optimal solution.

Optimization project	Gain per year MAD/annum
Pump regulation fuel injection in boilers	48 618
Insulation	271 560
Recovery of water from the sand filter	595 548
Lighting	216 904
The heat exchanger	808 590
Total	1 941 220

Table 3. *Variable's optimization*

According to the calculations made previously, we have the net production of the power station of 279192920 kWh saving adequately cost of KWh.

Conclusion

We studied the theory of modeling and the audit, then, we proceeded to a linear modeling of the power station for the exact calculation the cost of KWh and the analysis of energy consumptions. This allowed us to develop an application for calculating the cost of KWh and to evaluate the losses.

Then we engaged in a critical study of the different methods calculation of the performance of auxiliaries of the TAG control unit; so we have carry out a measurement campaign which made it possible to calculate the performances of auxiliary boilers, heat exchangers, and electrical auxiliaries. To the light of the results obtained we were able to determine the coefficients on which we will play in our modeling to optimize the cost of KWh.

We started an analysis of the sources of ineffectiveness, in which we have determined the main causes of deterioration in the performance of the auxiliaries, and propose corrective procedures to improve their efficiency. Allowed us to improve the cost of KWh through the projection of the actions corrective on the modeling.

Finally we carried out a technical-economic study which shows that the improvement of the considerable sum of 1 941 220 MAD can be benefit and can quickly amortized in short time by the National Office of Electricity of Kenitra city, Morocco.

WE ALSO PERFORMED A COST CALCULATION OF KWH AND OPTIMIZED IT BY PERFORMING AN AUDIT ENERGETICS OF THE STATION'S AUXILIARIES GAS TURBINES KENITRA 3 105 MW. WE

CONSIDERED THE EVALUATION OF THE PERFORMANCE OF THE EQUIPMENT AND DETERMINATION THE CONSUMERS POTENTIAL ENERGY.

Acknowledgment

This study has been done with collaboration with National Office of Electricity of Kenitra city, Morocco, and the Laboratory of Nanosciences and Modeling, University of Hassan 1st Morocco.

Bibliography

[GEL 06] Howard Geller, Policies for increasing Energy efficiency, Thirty years of experience in oecd countries, 2006.

[ECC 12] C. H. Eccleston, F. March, T. Cohen, Developping and managine ISO 50001, CRC Press, Taylor and Francis Group, 2012.

[QIN 14] J. Li, Na Qin, Zhipeng Hao,The on-line calculation of coal-fired boiler thermal efficiency and the analysis of energy saving[J],In Chinese,GAS & HEAT, 2014.

[WAN 10] J. Wang, C. Jiao, Comparison to Thermal Efficiency Calculation of CFB Boiler based on ASME PTC—1998 Criteria and DL/T 964—2005, Inner Mongolia Electric Power, 2010.

[DUE 54] J. A.Due, William A.Beckman Mc Adams, Heat transfert relations for internal flow, 1954.

[ARM 02] ARMACELL GMBH, L'isolation pour la réfrigération et climatisation, Info service*technique NR. 6.1 Edition: Février 2002.