Modelling and analysis of the cooling system energy consumption from thermal power plants powered by internal combustion engine: case study or the thermal power plant Luiz Oscar Rodrigues de Melo

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Abstract. A Due to the world's growing energy demand, more efficient power generation processes are crucial for global energy security in the future. A valid strategy to increase the total balance of available energy supply, without increasing the consumption of natural resources unrestrainedly, is to reduce the internal consumption of generating power plants, increasing the final amount of energy generated. In the Brazilian electricity matrix, there is a large portion of thermoelectric power plants which were initially designed and installed as standby electric power plants, which were to be dispatched only on special occasions. However, as these facilities have an efficiency below the desired and their dispatches have constantly been more frequent than originally planned to supply the national electrical system, they present a great energy savings opportunity. This research developed a case study of the Luiz Oscar Rodrigues Melo Thermoelectric Power Plant (UTE LORM), in which data were collected from the supervisory system and alongside the equipment data, made it possible to develop a simplified computational model that evaluated the electric energy consumption of the existing three-phase induction motors in the radiators of the cooling system, when subjected to different speed controls based on the power supply voltage/frequency ratio. The superiority of keeping the V/f ratio in a quadratic behaviour, rather than a linear one, for fan-type loads was attested, by simulating the computational system model for both controls and assessing that the electric energy consumption was about 1,4% lower, resulting on an average efficiency nearly 2,1% higher during the operation of one of UTE LORM's generating units on a day with typical weather conditions.

Keywords. Energy Efficiency, Thermoelectric Power Plants, Cooling System, Computational Modelling.

1. Introduction

Due to the finite characteristics of natural resources, energy efficiency must lead discussions in managing such resources, as well as measures that can be taken to ensure that power generating plants operate in their optimal range.

Thermal power plants make up for almost a quarter of the Brazilian electrical matrix, as reported in [1]. Therefore, it becomes relevant to access whether these plants can improve in any manner.

International rankings have continuously place Brazilian efficiency efforts in the lower tier of the biggest global economies, as shown in [2]. Despite recent improvement efforts, measures can be taken and evaluated to further enhance the energy landscape. Especially considering the role that electricity plays in modern activities.

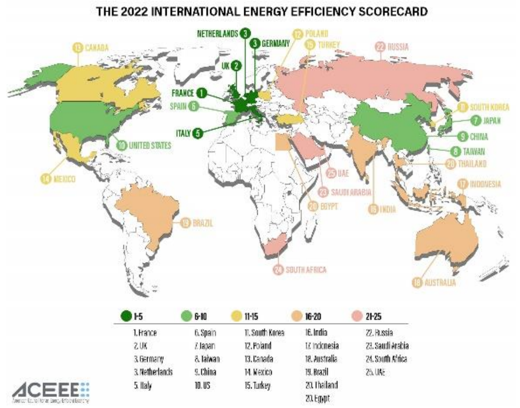


Fig. 1 – The 2022 International Energy Efficiency Scorecard

2. Goal

In this paper, a case study was performed in a 204MW thermal power plant (UTE LORM) that included internal combustion engines powered by natural gas, in which the cooling system included radiator that exchanged heat using fans that where driven by three-phase induction motors and controlled by frequency inverters.

Fig. 2 – UTE LORM

The presence of such electrical devices represents an internal energy consumption, that affects the overall net energy generated. Therefore, an accurate model can provide a valuable analysis of improvement strategies that can be achieved.

3. Methodology

In MATLAB/Simulink a computational model that represented the devices in the UTE LORM was developed to accurately emulate the responses the electrical devices in the radiators would provide under certain circumstances.

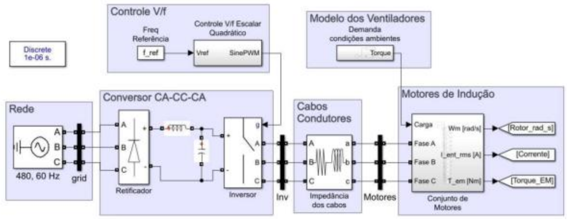


Fig. 3 – Complete Simulink Model

The three-phase induction motors were modeled through the Simulink asynchronous machine block, that implements a d-q model of the motor. The motor design sheet specs provided the equivalent single-phase parameters.

As for the frequency inverters, it had to be adopted a no-loss model due to the lack of parameters provided by the manufacturer. When it came to the switching control signal, a V/f control was applied in both linear and quadratic manner, according to the nameplate motor parameters, as well as to which speed the motor should develop.

The radiator should perform according to the cooling demand of the power plant operations, that were directly influenced by the atmospheric whether conditions. A python script was implemented that performed the calculations described in [3].

4. Development

The response of the simulated system was compared to what was expected, in relation to the power plant supervisory system, which displayed: frequency, voltage, current, torque, speed and power measurements.

Data from two typical operation days were extracted, to access whether the model was performing correctly. The speed demanded of the motors were calculated to the operation status every six seconds. Based on these results, the appropriate operating points were evaluated and loaded to the Simulink model.

Due to inadequate interference in the thermal plant control parameters, a fraction of the collected measured data couldn't be considered in the final analysis. Therefore, only the first half of the July 27th, 2021, was accounted, as shown in [4].

The expected results deviated in small percentages in the evaluated parameters. The only one that didn't perform as well, was the torque, which was a major uncertainty point in this study. The measurement devices were physically distant from the induction motors, so there no information feedback from the motor shaft performance. After contacting the manufacturer, no explanation was provided as to how this information was provided to the user.

Tab. 1 – Deviation between the expected and simulated results.

	Lowest	Average	Highest
Frequency	0,04%	0,69%	3,59%
Speed	0,20%	0,40%	0,80%
RMS Voltage	0,00%	0,70%	1,67%
RMS Current	0,56%	2,14%	3,90%
Mechanical power	0,00%	1,01%	3,23%
Torque	0,12%	14,50%	22,17%

As expected, both responses are presented as having the same nature, while the quadratic achieves lower levels of power demands, that result in lower energy consumption.

Fig. 4 – Active power demand, in kW, adopting the quadratic V/f parameterization.

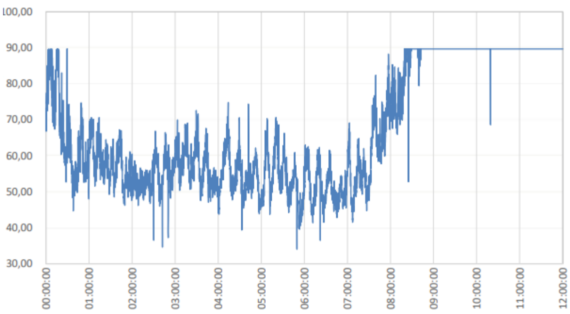
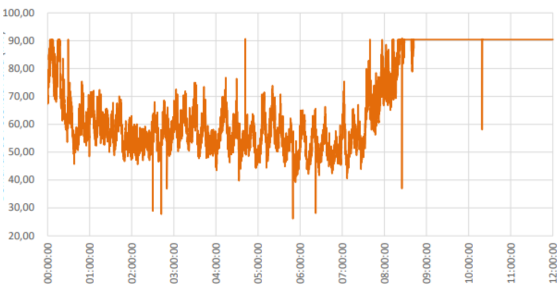


Fig. 5 – Active power demand, in kW, adopting the quadratic V/f parameterization.



Evaluating the responses in applying each of the V/f parameterization, it becomes clear that in this context, where the fan-type load has a quadratic characteristic to its torque-speed curve, a quadratic curve should also be followed by the V/f curve.

Tab. 2 – Computational simulation results to a quadratic V/f curve parameterization.

	Minimum	Average	Maximum
Speed	552,27 rpm	790,51 rpm	882,96 rpm
Mechanical power	1,40kW	4,06kW	5,50kW
Efficiency	81,85%	84,35%	86,76%

Tab. 3 – Computational simulation results to a linear V/f curve parameterization.

	Minimum	Average	Maximum
Speed	574,62 rpm	797,02 rpm	882,91 rpm
Mechanical power	1,46kW	4,05kW	5,39kW
Efficiency	78,07%	83,25%	84,64%

The final evaluation performed was intended to check the energy consumption level and access which of the two parameterizations presented itself as a more interesting approach to energy savings.

Tab. 4 – Electrical Energy Consumption.

	V/f quadratic	V/f linear	Deviation
Electrical energy consumption	808,23 kWh	819,54 rpm	882,91 rpm

5. Conclusion

This study reached its goal of creating a computational model of the radiators present cooling system of the thermal power plant in this case study. The results indicated the better performance of the quadratic V/f parameter curve, when it comes to power fan-type loads. It is hoped that in future papers, different induction motor controls and operating point can be evaluated, to access energy saving solutions.

6. References

[1] Empresa de Pesquisa Energética. *Balanço Energético Nacional – Ano Base 2020*. Rio de Janeiro, Brazil; 2021.

[2] American Council for an Energy Efficient

Economy. *The 2022 International Energy Efficiency Scorecard*. Washington, DC, United States of America; 2022.

[3] Miotto, B. M. F. *Dimensionamento e Análise de um Sistema Experimental para Recuperação de Calor Residual e Condicionamento de Ar para um Motor de Combustão Interna de Grande Porte*. Master Thesis. Vitória; 2021.

[4] Nascimento, D. F. *Modelagem e Análise do Consumo Energético do Sistema De Resfriamento de Termelétricas a Motores de Combustão Interna: Estudo de Caso da Usina Termelétrica Luiz Oscar Rodrigues de Melo*. 2021. Bachelor thesis. Vitória; 2021.