Article

# Thermodynamic analysis of nuclear plants: A virtual perspective

# Análisis termodinámico de plantas nucleares: Una perspectiva virtual

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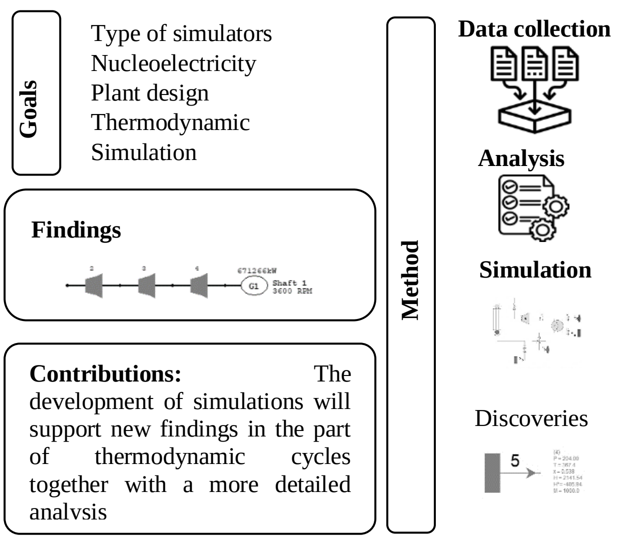
## Abstract

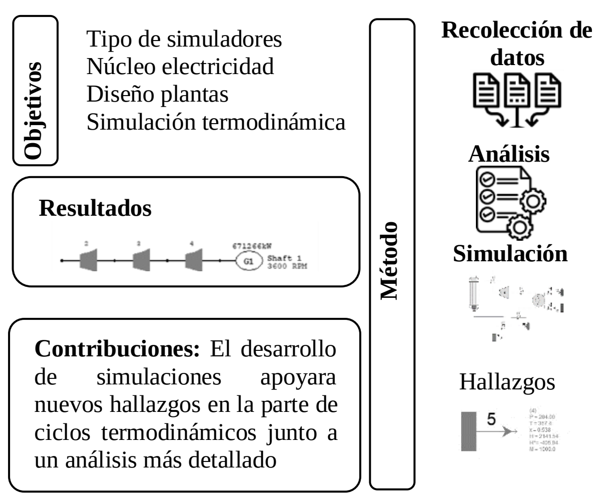
This article aims to study the generation of electricity through nuclear energy, to do so, it goes through the other ways to obtaining energy, until reaching nuclear energy, where the research is deepened, emphasizing nuclear reactions and operation. of nuclear power plants. Once the theory was understood, simulation projects were carried out in software, previously explained, the simulations were matched and complemented for a greater understanding of the theory. This article allows the understanding for a particular case, applicable to different projects promoted by Thermoflex, since there are no guides or tutorials in Spanish and those that exist in other languages, they are not very varied.




**Thermodynamics, Simulation, Thermoflex**

## Resumen

Este artículo tiene como objetivo estudiar la generación de electricidad mediante la energía nuclear, para ello, se pasa por las otras formas de obtención de energía, hasta llegar a la nuclear, en donde se profundiza la investigación, haciendo énfasis en las reacciones nucleares y la operación de las centrales nucleares. Una vez comprendida la teoría, se realizaron proyectos de simulación en software, previamente explicados, las simulaciones se empatan y se complementan para un mayor entendimiento de la teoría. Este artículo permite el entendimiento para un caso particular, aplicable a diferentes proyectos impulsados por Thermoflex, pues como ya se mencionó, no existe guías o tutoriales en español y los que existen en otros idiomas, no son muy variados.




**Termodinámica, Simulación, Thermoflex**

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## Introduction

The aim of this research is to uncover the underlying factors that contribute to the operation and functioning of power plants. To this end, emphasis had placed on the origins of electricity generation.

In modern life, it is undeniable that electrical energy is essential to satisfy all the needs that today's society requires, to address this, the various methods of generating electrical energy were addressed, taking the time to analyze and focus on them.

The focus of this project is on nuclear energy, it is important to understand the fundamental aspects, such as the atomic nucleus, conceptually, as well as its behavior during the physicochemical processes of obtaining energy.

For research purposes, a fundamental point is the nuclear power plant, which involves studying the various aspects that allow its correct operation, Safety conditions, the fuel cycle, and even social controversies are among the topics discussed.

The importance of virtual tools, specifically simulation software, which are fundamental parts of this project, has been made known. There is no doubt that virtual tools are becoming more common and can assist in multiple areas, especially in this scenario, the usefulness in favor of facilitating understanding and helping the study of different topics stands out, virtually exemplifying them is beneficial for some.

The main project of this work is to present the results of a simulation of a nuclear plant. In two different software, a related project, the proposed solution illustrates the technical possibilities and leads to a thermodynamic design that is supported by theoretical models.

The creation of both projects aims to culminate in the same results, thus complementing the projects with each other, because where one has limitations, the other corrects them, also complementing the research and analysis of what the theory comments, applying it in the simulation.

## 1. Electrical energy

To begin with, the definition of electric energy will enunciate from a focus in electricity generation plants. "The electrical energy produced by power generation plants is defined as the capacity of an electrical system to perform work. In generation plants, this energy has produced by converting another form of energy, such as mechanical power, hydropower, thermal power, nuclear power, solar power, wind power, or tidal energy.

Electrical energy is transmitted and distributed to consumers through electrical transmission and distribution systems." (Chapman, "Fundamentos de sistemas eléctricos de potencia", cuarta edición, p. 2)

With the growth of society, the demand for electricity increased and it was necessary to build new power plants and distribution networks. During these years, technological advances meant that coal combustion was not the only way to obtain electrical energy, for those years, in distinct parts of the world, the first hydroelectric and wind power plants were developed by the 1920s, electrical energy was already widely used worldwide, thus promoting the development of new sources of energy, these being solar, geothermal, biomass, among others. The first nuclear plant was officially inaugurated in Russia in 1956.

Talking about electricity being a "necessity" today is based on the endless daily activities that would be impossible to perform without electric power. Starting with the most essential such as: cooking, having a shelter, clothing, communication, transportation, medicine.

Nowadays it is unthinkable to live without the comforts that electricity provides us. It is inconceivable to preserve food without the aid of a refrigerator, to build a house without the aid of machinery, and to live in a house without electrical installation.

### Nuclear energy

The process of obtaining nuclear energy comes from two processes: fusion and nuclear fission.

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During the fusion process, two light atoms, usually hydrogen and its isotopes (deuterium and tritium). They bind or fuse, as the name implies, resulting in a heavier atom in their nucleus and simultaneously releasing energy upon bonding.

The most practical example of a nuclear fusion is in the sun. In our star, hydrogen nuclei that form helium fuse and release such enormous amounts of energy that they can reach the surface of the earth, and we feel like heat and light.

Two theories have proposed to fuse light nuclei, as it is necessary to have an extremely high amount of energy, to bring the nuclei closer to such small distances that the nucleus's force of attraction is greater than the force of electromagnetic repulsion. One method is to accelerate an "A" particle.

At a speed sufficient for the resulting force to be greater than the repulsion force, Once the desired speed is achieved, the particles 'B' are released and collide with each other, leading to nuclear fusion and, consequently, the release of desired energy.

The other method consists of heating the atoms to gigantic temperatures, to the point of obtaining plasma, in this state of matter, the electrons are free, and the atoms ionized. The problem with this method for fusion lies in the confinement of the plasma to those temperatures. Currently, reactors and vessels capable of withstanding the conditions required by the processes are still under development.

The process of nuclear fission involves supplying an incident neutron to a heavy atom, splitting it into two lighter atoms, resulting in the release of neutrons, gamma rays, and significant amounts of energy.

When the heavy atom receives the neutron, it becomes unstable in its nucleus, which produces a division of the nucleus, resulting in lighter and more stable atoms, in addition, in the reaction neutrons are released that impact other heavy atoms, causing a series of fissions, releasing an effect called chain reaction.

The thermal energy produced by the fission reaction in the vessel of a nuclear reactor is used to generate electricity in a nuclear power plant.

The main part of a nuclear power plant is the reactor, as it houses the nuclear fuel and the systems that conduct fission reactions in a controlled manner, releasing the thermal energy necessary to heat the water and convert it into high-pressure steam. Steam propels a turbine that is connected to a generator. The mechanical power is transformed into electrical energy, which is then transported for commercial use.

## 2. Software for simulation of thermodynamic processes

In this section a small demonstration of the basic capabilities of two software will be made, the main idea is to show the possibility of designing thermodynamic cycles in these simulators, maintaining a nuclear power plant approach, thanks to these programs, it was possible to simulate this type of generation plant, for easy study and understanding of this type of thermodynamic cycles.

### 2.1 Importance of simulation software.

Today, the use of technology has increased in countless areas. Simulation is a technique that enables the analysis of any desired system.

The simulation models were created to simulate the behavior of these systems. They are mathematical representations of real systems that use programming tools, taking the form of software running on a computer.

The industry relies on simulation software for several reasons. A fundamental point is the optimization of the design, in engineering the use of simulation software allows you to explore various configurations of a single system, looking for the optimal one.

Following this logic, it is also possible to evaluate the performance of the systems prior to their construction, this has a direct impact on the quality of the result, since it is known in greater detail how the product or process will behave in its different operational stages, all thanks to the prediction made by the software.

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It is impossible to talk about benefits without mentioning the savings that a simulation can provide. That is, costs and time. By allowing a virtual test of ideas and prototypes, choosing in the most suitable simulation for the project, it is possible to reduce development and construction time. By identifying and correcting potential design errors, one can also choose a more suitable material during the simulation.

Another valuable point is safety, because as already said, Simulations can assist in identifying potential failures, possible safety failures, which allows these errors to be addressed before they happen and become potential risks for production, operators or even society.

In summary, simulation software is an essential tool throughout the engineering industry, as it provides an efficient and cost-effective way to design, analyze and optimize a wide range of systems and processes. These constitute an effective instrument within the training and technical certification of personnel who will operate thermoelectric plants. The operating personnel are trained using a simulator, who will acquire the skills and abilities required to solve problems and situations that compromise the operation of a plant in real life, without putting the systems of said plant at risk.

Two thermodynamic cycle simulators were chosen because they were the most suitable for the type of project studied: the Thermoflex for which you have an educational license and the "BWR" or boiling water reactor nuclear plant simulator (BWR NPS).

## 3. Thermoflex

The main purpose of this software is the design and simulation of thermal systems, it allows analyzing a wide number of variables, from heat transfer, fluids (ranging from coolant of a system to water used as a supply for systems that run on steam), fuel flows, air, among many other analysis tools

Figure 1 shows the main screen of the program, it seeks to generate a friendly and intuitive interface for the user; to be able to simulate anything, it is first required to design a system. Given the wide variety of software libraries, many configurations can be created.

**Box 1**

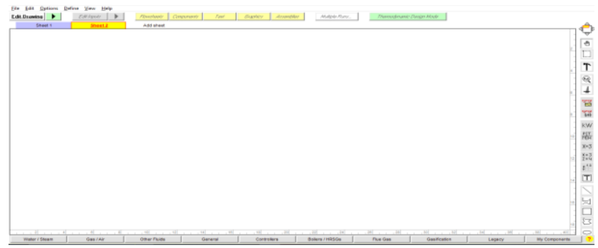

**Figure 1**

Thermoflex main display

*Source: own elaboration*

Here are the three most used source types in software (Figure 2) in most systems, water, air/gas, and fuel, respectively.

**Box 2**

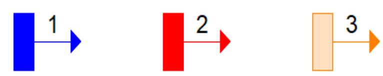


**Figure 2**

Thermoflex Sources

*Source: own elaboration*

Simple systems like a water source, a turbine, and a receiver can be created to close the circuit., by doing this, the software allows you to edit the characteristics of each element placed in the design (Figure 3).

**Box 3**

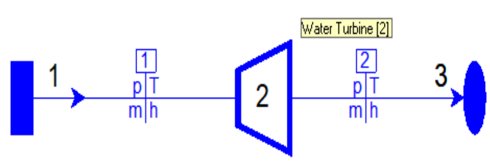


**Figure 3**

Thermoflex Water turbine

*Source: own elaboration*

The first suggested input is the environmental conditions, altitude, temperature, humidity, etc. (Figure 4).

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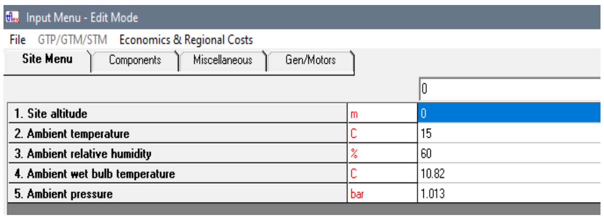
## Box 4



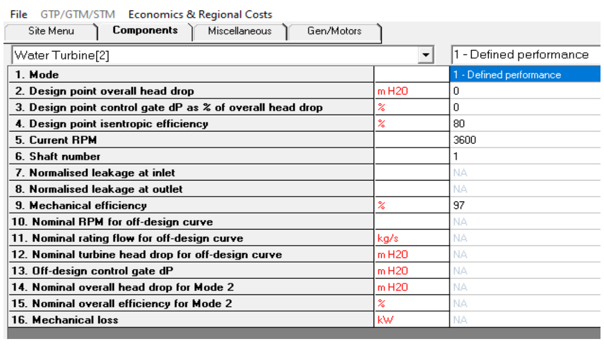
Input Menu - Edit Mode
File GTP/GTM/STM Economics & Regional Costs
Site Menu | Components | Miscellaneous | Gen/Motors

| | | 0 |
|---|---|---|
| 1. Site altitude | m | 0 |
| 2. Ambient temperature | C | 15 |
| 3. Ambient relative humidity | % | 60 |
| 4. Ambient wet bulb temperature | C | 10.82 |
| 5. Ambient pressure | bar | 1.013 |

**Figure 4**
Thermoflex menu
*Source: own elaboration*

It is also possible to edit the values presented, in this case for the water turbine, as well as for the water supply. (Figures 5 and 6).

## Box 5

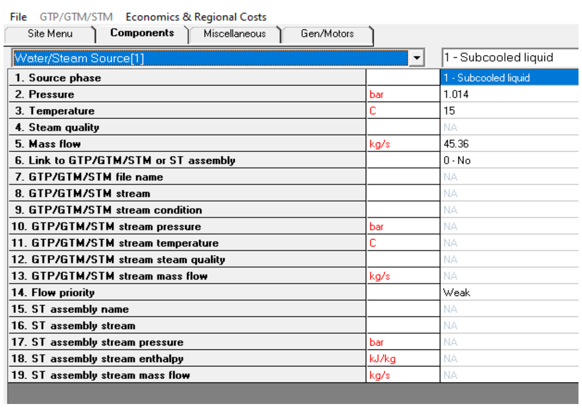


File GTP/GTM/STM Economics & Regional Costs
Site Menu | Components | Miscellaneous | Gen/Motors

| Water Turbine[2] | | 1 - Defined performance |
|---|---|---|
| 1. Mode | | 1 - Defined performance |
| 2. Design point overall head drop | m H20 | 0 |
| 3. Design point control gate dP as % of overall head drop | % | 0 |
| 4. Design point isentropic efficiency | % | 80 |
| 5. Current RPM | | 3600 |
| 6. Shaft number | | 1 |
| 7. Normalised leakage at inlet | | NA |
| 8. Normalised leakage at outlet | | NA |
| 9. Mechanical efficiency | % | 97 |
| 10. Nominal RPM for off-design curve | | NA |
| 11. Nominal rating flow for off-design curve | kg/s | NA |
| 12. Nominal turbine head drop for off-design curve | m H20 | NA |
| 13. Off-design control gate dP | m H20 | NA |
| 14. Nominal overall head drop for Mode 2 | m H20 | NA |
| 15. Nominal overall efficiency for Mode 2 | % | NA |
| 16. Mechanical loss | kW | NA |

**Figure 5**
Thermoflex Component Edition (Turbine)
*Source: own elaboration*

## Box 6



File GTP/GTM/STM Economics & Regional Costs
Site Menu | Components | Miscellaneous | Gen/Motors

| Water/Steam Source[1] | | 1 - Subcooled liquid |
|---|---|---|
| 1. Source phase | | 1 - Subcooled liquid |
| 2. Pressure | bar | 1.014 |
| 3. Temperature | C | 15 |
| 4. Steam quality | | NA |
| 5. Mass flow | kg/s | 45.36 |
| 6. Link to GTP/GTM/STM or ST assembly | | 0 - No |
| 7. GTP/GTM/STM file name | | NA |
| 8. GTP/GTM/STM stream | | NA |
| 9. GTP/GTM/STM stream condition | | NA |
| 10. GTP/GTM/STM stream pressure | bar | NA |
| 11. GTP/GTM/STM stream temperature | C | NA |
| 12. GTP/GTM/STM stream steam quality | | NA |
| 13. GTP/GTM/STM stream mass flow | kg/s | NA |
| 14. Flow priority | | Weak |
| 15. ST assembly name | | NA |
| 16. ST assembly stream | | NA |
| 17. ST assembly stream pressure | bar | NA |
| 18. ST assembly stream enthalpy | kJ/kg | NA |
| 19. ST assembly stream mass flow | kg/s | NA |

**Figure 6**
Thermoflex Component Editing (suply)
*Source: own elaboration*

In this scenario, we have a fuel-fed heater that has air inlets and outlets, as well as a water supply. From this heater, steam is obtained. Figure 7.

## Box 7

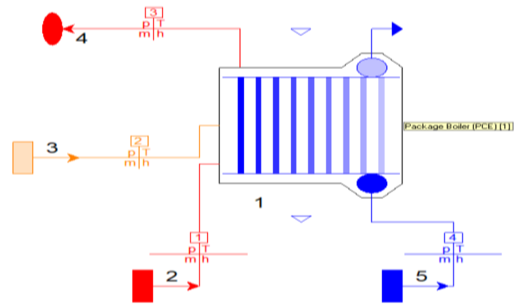



**Figure 7**
Thermoflex Package boiler
*Source: own elaboration*

To the heater shown above, components were added to complete the system, to the outlet of the heater, (steam) we have connected with the identifier no. 6 is the turbine, later, with no. 7, is the condenser, to this arrives the steam outlet of the turbine and as a refrigerant, the software offers a source called "brine", which can be translated as brine, or saline water, simulates a system that is fed with seawater.

At the outlet of the condenser water is obtained which will be directed to a drain, it could well be reintegrated into the system to be used in the entrance to the heater, however, it requires more components that would make the system more complex and therefore the introduction to it.

## Box 8

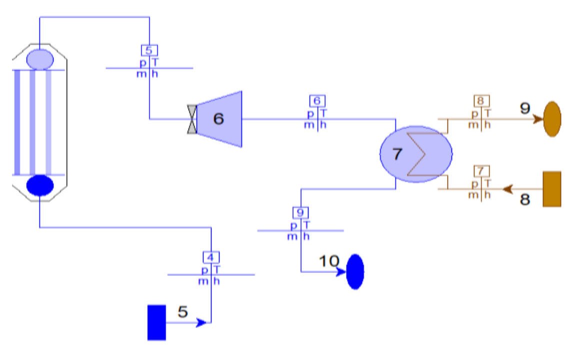



**Figure 8**
Thermoflex Steam System
*Source: own elaboration*

With a simple and demonstration design, you have the option to edit the entries to your liking, on this occasion, The decision was made to operate with the values suggested by the software, it should be noted that these values are exceedingly small.

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This image (figure 9) shows the system operating without failures and continuously, that is, the simulation is running. Due to the values chosen, the generator (placed in the upper right corner) tells us that there is no power generation.

**Box 9**

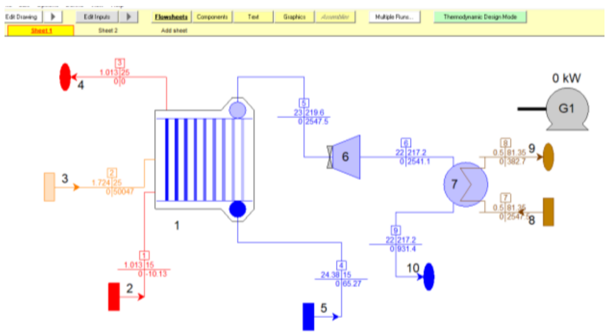


**Figure 9**
Thermoflex Rankine cycle
*Source: own elaboration*

However, when we analyze the generator further (figure 10), we can see that, it there is an exceedingly small power generation, as a result of the values that were entered into the components.

**Box 10**

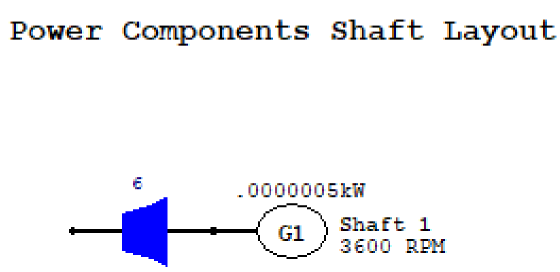


**Figure 10**
Thermoflex Generator
*Source: own elaboration*

### 3.1. Nuclear plant simulation

This section presents the simulation of a nuclear plant operating with an approximate capacity of six hundred megawatts.

It had simulated, and the result was presented in the following diagram supported by theoretical designs and with the possibilities that the software provides, then it will be broken down component by component, talking a little about its function in the system (Figure 11).

**Box 11**

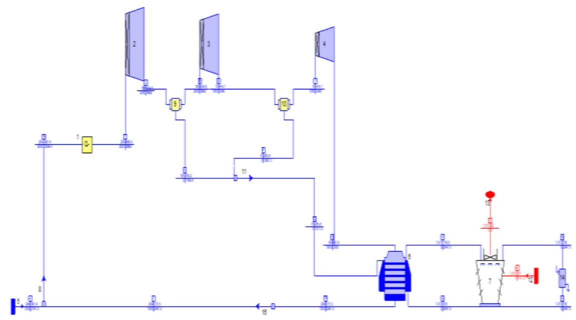

**Figure 11**
Thermoflex Simulation overview
*Source: own elaboration*

The software does not have the capacity to implement a nuclear reactor, the way to solve this problem is to use a "heat adder" or heater (figure 12), this component does what its name indicates, and basically it was placed there to simulate the process that takes place inside the reactor vessel, because in the end, the temperature of the steam at the outlet is higher than the one that enters.

**Box 12**

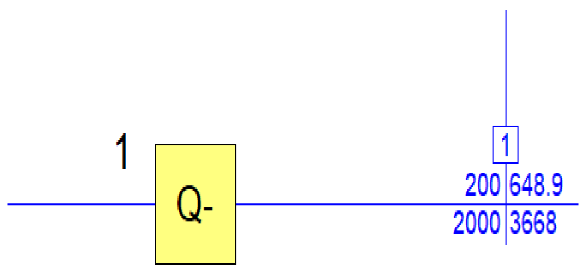


**Figure 12**
Thermoflex heat adder
*Source: own elaboration*

Now it is time to design two turbines 2 and 3. This design employed a configuration of three turbines that utilize the same steam line.

**Box 13**

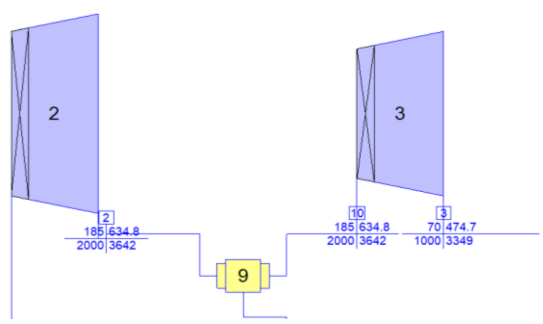


**Figure 13**
Thermoflex Turbine 2 & 3
*Source own elaboration*

The configuration of the first turbine or "turbine 2"(figure 14), the pressure point was created to be comparable to the one that is directly from the heater. this being two hundred bars.

## Box 14

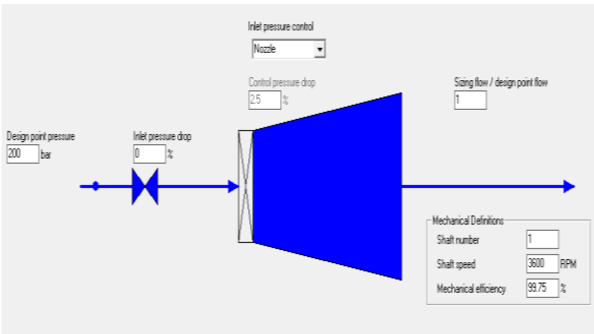


**Figure 14**
Thermoflex turbine 2
*Source own elaboration*

The same idea was used to design 'turbine 3' with a lower pressure point than the previous turbine. following a logical sequence of a real process with pressure losses. Figure 15.

## Box 15

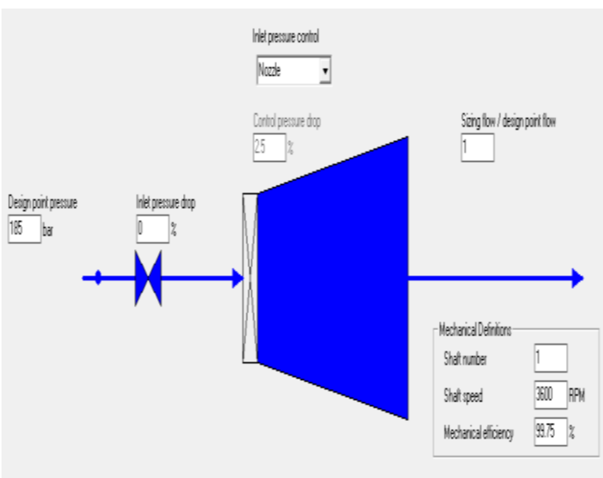


**Figure 15**
Thermoflex turbine 3
*Source own elaboration*

In figure 13, component nine appears among the turbines, this is a "moisture separator" or moisture separator, it complies with what its name suggests, It was placed to be a 'filter' and maintain the highest possible quality of the steam that enters the turbine.

Between "turbine 3" and "turbine 4" another moisture separator was placed that fulfills the same function as the previous one. Figure 16.

## Box 16

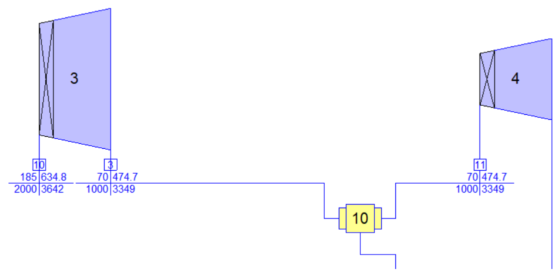


**Figure 16**
Thermoflex Turbine 3 and 4
*Source own elaboration*

The design of this turbine (figure 17) is established for a lower pressure than the previous ones, having a design point for 70 bar, thus completing a set of 2 high pressure turbines and one low pressure turbine.

## Box 17

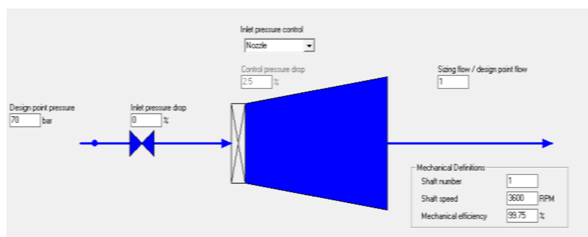


**Figure 17**
Thermoflex turbine 4
*Source own elaboration*

Figure 18 shows the configuration chosen to send the water and steam outputs expelled by the turbines, combining them to deliver them to the condenser.

## Box 18

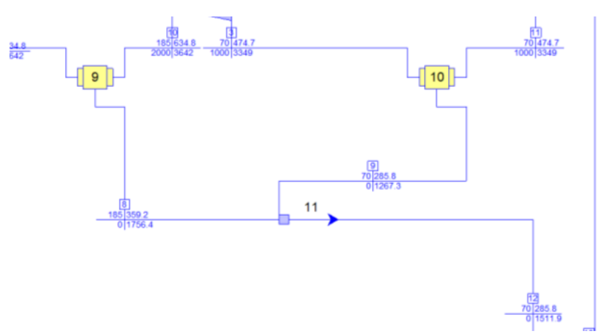


**Figure 18**
Thermoflex Lines routed to the condenser
*Source: own elaboration*




Cortes-García, Alicia, Valencia-García Alejandro Cesar, Rodríguez-Miranda, Gregorio and Mendoza-Hernández, Guillermo. [2024]. Virtual reality forklift simulator - VRFS. ECORFAN-Journal Democratic Republic of Congo. 10[18]1-7: e11018107.
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Figure 19 shows how the steam lines coming from the turbines converge in the condenser to be processed by it.

**Box 19**

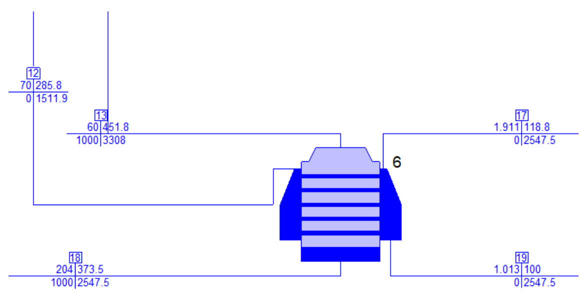

**Figure 19**
Thermoflex Condenser
*Source own elaboration*

Figure 20 shows the standard configuration that the software provides, it should be noted that this component has the capacity to receive two different lines of steam, (the one that comes from "turbine 4" and those resulting from the humidity separators) as well as the hot water output and its return with cold water, to later release the condensed liquid back into the system.

**Box 20**

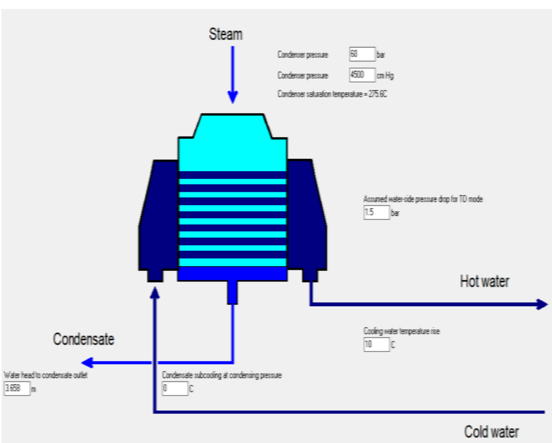


**Figure 20**
Thermoflex Condenser Design
*Source own elaboration*

The hot water outlet from the condenser is directed directly to an air-supported cooling tower, represented by inlets and outlets 13 and 14. Figure 21.

**Box 21**

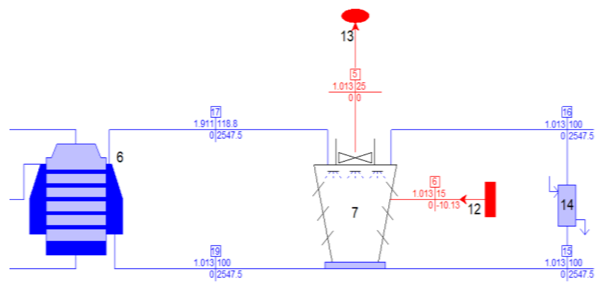

**Figure 21**
Thermoflex Cooling tower
*Source own elaboration*

A standard configuration was chosen for the wet cooling tower, and the chilly water resulting from this is redirected to the condenser.

The selected cooling tower requires an external water source as shown in the figure below.

**Box 22**

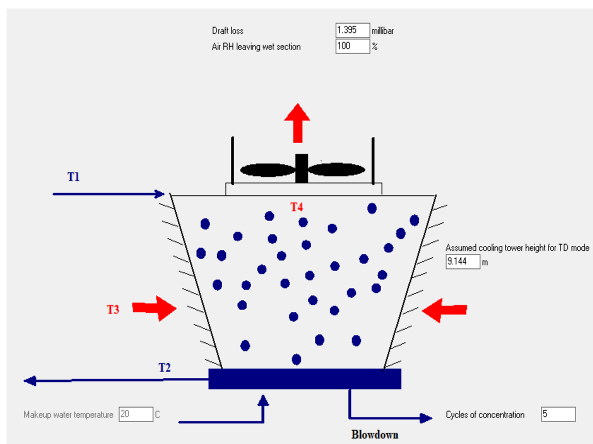


**Figure 22**
Thermoflex Cooling tower configuration
*Source own elaboration*

"Makeup water" and "blowdown" can translate as "make-up water" and "drain" respectively. These functions are fulfilled by component 14, shown in Figure 21.

Once the condensed liquid has been obtained, it is directed to what we initially consider to be the substitute of the reactor, before placing a new source of steam, supporting the temperature and pressure of the system to promote greater efficiency in the turbines, and therefore a greater amount of electrical energy generated. The values given to the steam source are listed below.

**Box 23**

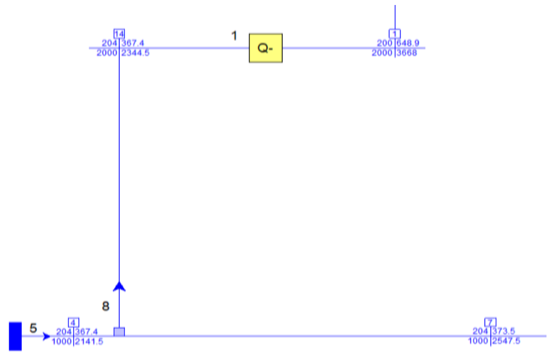

**Figure 23**
Thermoflex Back to heat adder
*Source own elaboration*

**Box 24**

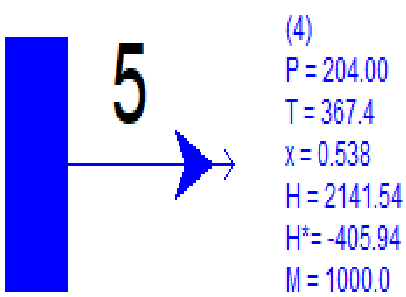


**Figure 24**
Thermoflex Steam source
*Source own elaboration*

Once the system design is completed, the software allows a simulation to be run and within the tools of this, it finds the possibility of implementing an electrical generator to the system, which analyzes the values chosen in the design of the components, Allowing us to obtain a result for statistical or processing purposes.

**Box 25**

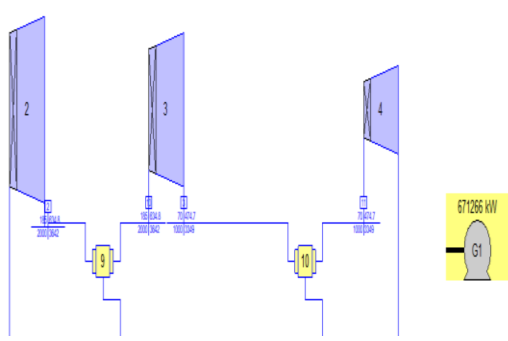


**Figure 25**
Thermoflex Generator
*Source own elaboration*

As already mentioned, in this exercise, we seek to exemplify a nuclear plant, in this simulation a generation of 671,266KW was obtained (figure 26), this would be within the average of a conventional nuclear plant, which shows us that the design is optimal to be executed in the proposed simulation.

**Box 26**

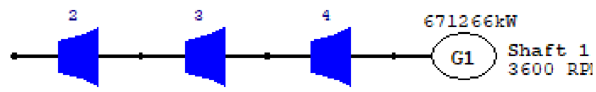


**Figure 26**
Thermoflex Turbine shaft and generator
*Source own elaboration*

### 4. BWR NPS

The "BWR" or boiling water reactor. Nuclear Plant Simulator (NPS). In short, the control panel of a nuclear power plant, in which we are allowed to manipulate the nuclear power plant at will, the area where the greatest emphasis is placed for the program is on the reactor vessel, because when manipulating the control rods, the chain reaction increases or decreases, depending on the case.

Here is the main panel with which the software allows us to interact, for the demonstration of one of the functions of the program the reactor will be heated in a controlled manner, gradually increasing the desired values Figure 27.

**Box 27**

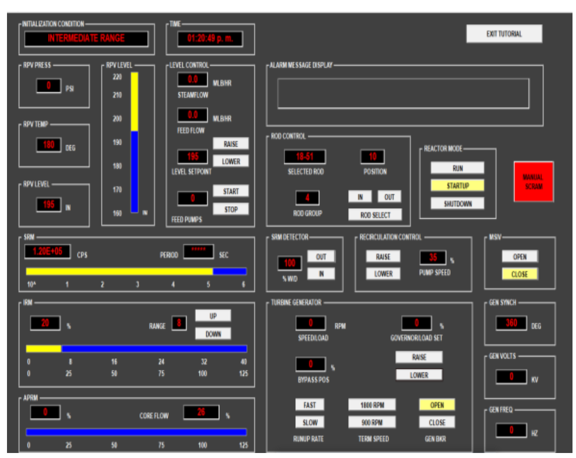

**Figure 27**
NPS Control Panel
*Source own elaboration*

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RENIECYT-CONAHCYT: 1702902

For this demonstration we will focus on these areas of the panel, the values that interest us on this occasion are the following:

**Box 28**

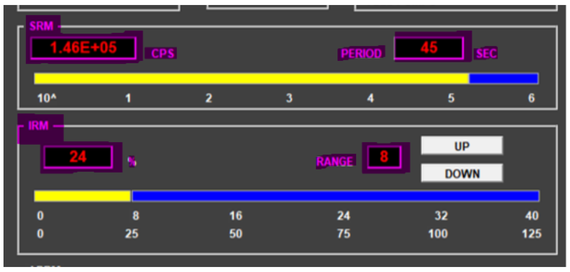


**Figure 28**

NPS Units of reaction

*Source own elaboration*

The "SRM" sourse range monitor. This indicator shows the neutron population, the unit expressed is counts per second "CPS", this system indicates ranges from 1 to 1 million, in this order, 100,000 CPS are expressed as 1.0E+05.

The "PERIOD" refers to how fast the power in the reactor is changing. A period of 100 seconds means that the power is increasing in a range of approximately 2.72% every 100 seconds, in the same way if the indicator shows -100 seconds, it means that the power is decreasing in the same range.

The "MRI" intermediate range monitor. This indicator shows the relative neutron population, that is, the percentage of the neutron capacity that the reactor can accommodate, this is It shows in two scales, from 0 to 40% and from 0 to 125%, depending on the scale that best suits you. The "RANGE" is expressed from 1 to 10 and is used to increase or decrease the range of the MRI, understood as the speeds to a car.

To increase power in the plant, the "ROD CONTROL" panel is interacted with.

**Box 29**

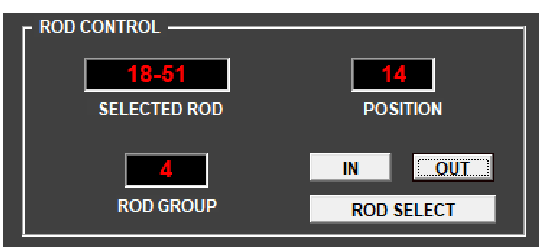


**Figure 29**

NPS Bar Controller

*Source own elaboration*

Each group of bars has positioning limits, in this case, for group 4, the effective limit is position 16, when you click on the "out" button, the bar is removed, thus generating an increase in the fission reaction. Figure 30

To select the correct bar to remove or enter, it helps to visit the map. Figure 31.

**Box 30**

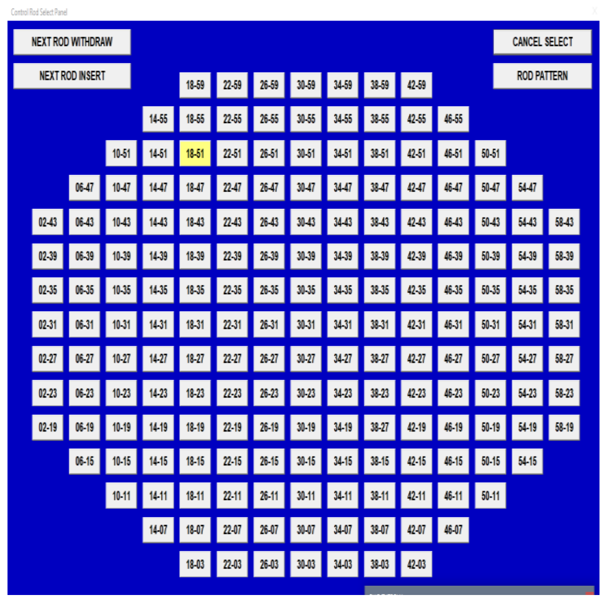


**Figure 30**

NPS Control bar selection

*Source own elaboration*

On this screen, it is possible to select the bar and then manipulate it. In this scenario, we are on bar 18-51, because they belong to group 4, they have as an effective limit to enter up to position 6, but to not be at the limit, they are usually in position 8. And they have as an effective limit, the possibility of folding to position 16.

The software provides us with this map, as we saw previously, we were at bar 18-51, which, when reaching its limit, but not the desired power levels, it is required to remove the next bar, in this case, bar 34-51 and then those highlighted in green, as they are in the standard position of their group.

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## Box 31

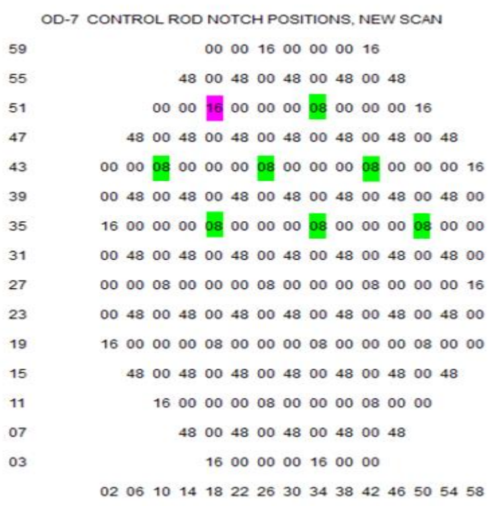


**Figure 31**
NPS Control bar map
*Source own elaboration*

By making the correct movements with the control rods (the correct rods at the ideal speed and times) we can increase the period, by reducing the time, we increase the neutron reaction rate, once the rods were removed, the period was reduced to 29 seconds and the SRM went from 1.46E+05 to 8.75E+05. The IRM also increases during the process, thus the range increased from 8 to 9 (this process is done manually when the IRM bar approaches its limit). Figure 32.

## Box 32

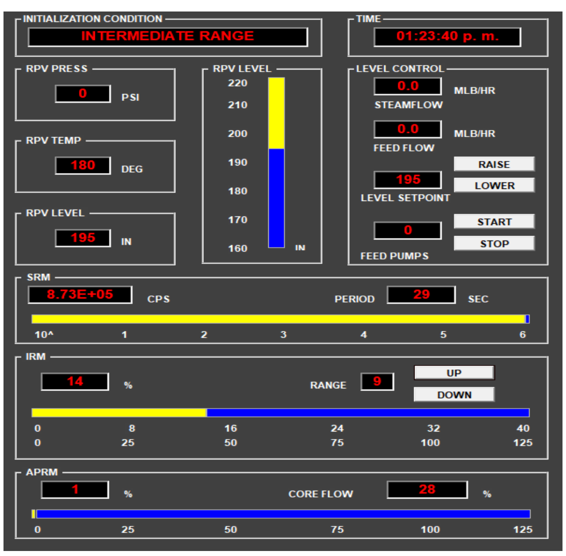


**Figure 32**
NPS Result of the reactor heating
*Source own elaboration*

### 5. Simulation with BWR NPS

In the previous section we talked a little about this software, with which we can represent the dashboard of a nuclear plant, it has a wide range of simulation tools, from a critical condition of the reactor to the start-up, which would give birth from the heating of the rector to the start-up of the turbine.

The system's turbine will be put into operation during this simulation exercise, seeking to match the power generation with the simulation proposed in Thermoflex.

At the beginning of the simulation, we find that the simulator finds an MRI (relative percentage of the neutron population inside the vessel) of 10%, which leads to the heating of the system. Figure 33.

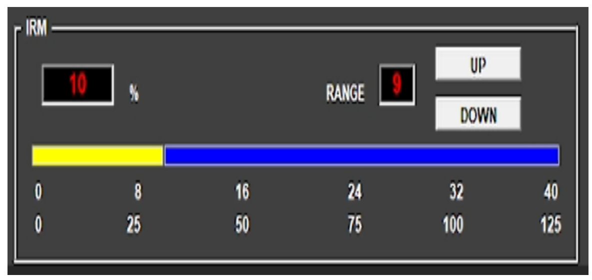


**Figure 33**
NPS Initial MRI
*Source own elaboration*

As shown in the previous chapter, the control rods must be removed to increase the chain reaction.

The neutron population needs to be increased enough for the "pos bypass" (representing the position of the main turbine's shut-off valve) to open. Figure 34.

## Box 34

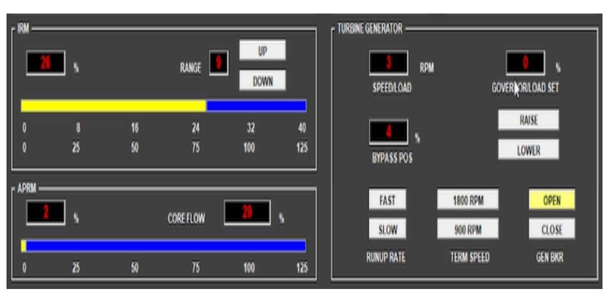


**Figure 34**
NPS Bypass open
*Source own elaboration*

After increasing the MRI to approximately 26%, the valve is opened to 4%, then bars should continue to be removed until the POS bypass is in a range of 30% to 35%.

## Box 35

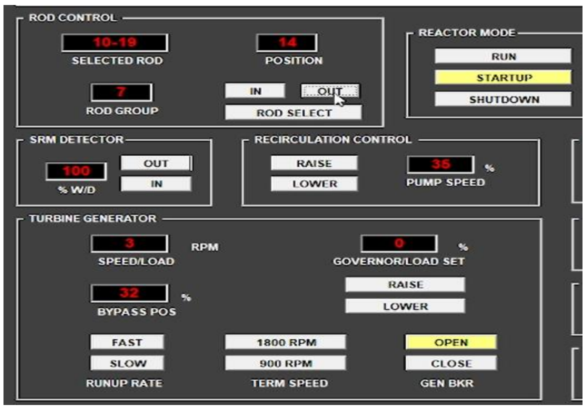


**Figure 35**
NPS Bypass 32%

*Source own elaboration*

After the valve opening has been reached, the reactor mode must be set to 'RUN'.

Once the generator mode is changed, it is time to start the turbine, this starts slow and at low revs.

That is, after putting the reactor in "RUN" mode, the acceleration is selected at "SLOW" and the speed at "900 RPM" (Figure 36).

## Box 36

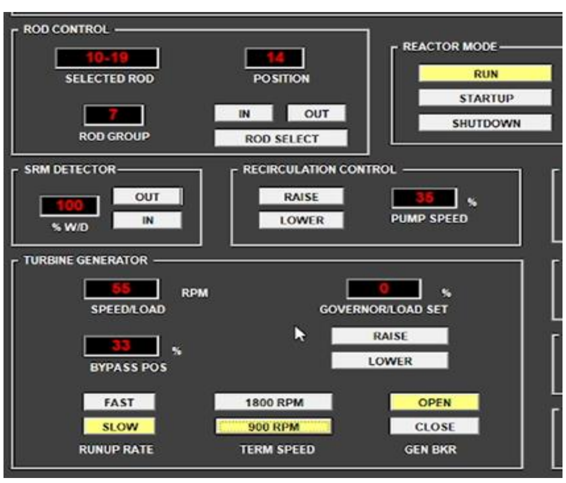


**Figure 36**
NPS 900RPM turbina

*Source own elaboration*

Once these steps are done, the "speed/load" marker starts to increase.

## Box 37

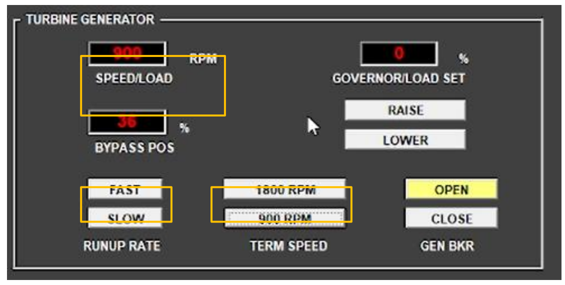


**Figure 37**
NPS 900RPM turbine

*Source own elaboration*

Again, after these steps, the revolutions continue to increase, and once 1800 RPM is reached, the "GEN SYNCH" (shows the angle of rotation between the generator and the electrical distribution system and the synchronization between them) begins to rotate in a negative direction figure 38,

## Box 38

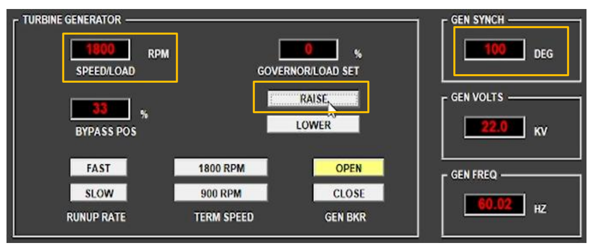


**Figure 38**
NPS GEN SYNCH

*Source own elaboration*

After clicking on the "RAISE" button, the rotation speed of the SYNCH gene begins to decrease, the rotation must be reversed before you can continue with this.

Once the rotation has been reversed, the generator switch must be closed when the marker is 360°. Figure 39.

## Box 39

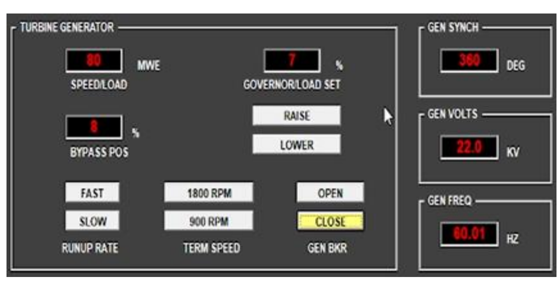


**Figure 39**
NPS GEN BKR

*Source own elaboration*

Once the generator is synchronized, all that remains is to increase the power of the plant, increase the "governor/load set", allow to increase the capacity of the generator and in turn, close the "BYPASS POS" valve which at the same time gives rise to continue extracting the control rods.

The process of increasing electricity generation consists of removing the control rods in the order dictated by the map of the rods, each time the steam generated exceeds the capacity of the turbine, the capacity of the generator has to be increased, which closes the valve and allows the process to continue.

To maintain the increase in power in a controlled manner, it is necessary to remove the bars one by one and point by point.

As mentioned at the beginning of this project, the idea is to generate the same amount of energy as in the Thermoflex project.

Here it is shown as the final generation of the project 671MWE (figure 40), exact value to which the project shown in Thermoflex yields, as shown, the capacity of the generator is at 60%, taking this into account, we can understand that this software has the capacity to produce more electrical energy, however, given the limitations that are dealt with in Thermoflex.

The energy it generates can be considered as a maximum value given the possible values and the proposed design, however, 60% of the plant's capacity helps to maintain better control of it.

**Box 40**

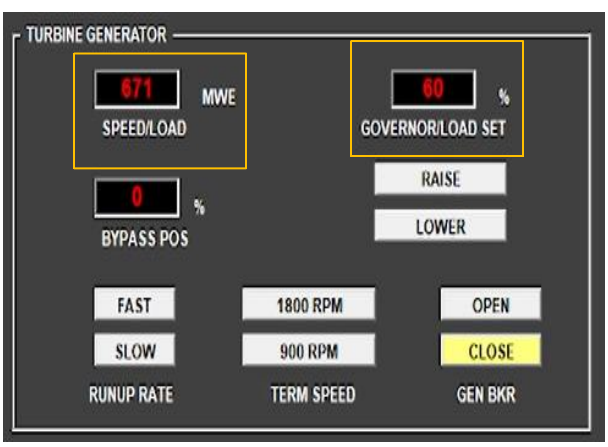


**Figure 40**
NPS Final generation

*Source own elaboration*

**Conclusions**

The study has analyzed and explored the various methods of power generation in great detail, it was enriching to study at least superficially the way in which electricity generation plants operate.

Thanks to the fact that the main focus of this project is based on nuclear energy, an entire chapter was dedicated to the analysis of this topic, seeking understanding from the most basic topic, starting with the physicochemical structure of the atom and its reactions, it was nourishing for the research and personally to understand the fundamental concepts to understand the later topics, that is, the operation of a nuclear power plant.

Arriving at the study of the nuclear power plant led to various branches, since delving into the study of nuclear reactions, approached the domain of quantum mechanics, this becomes interesting and perhaps studying future projects., but it was beyond the scope of this project.

As a result of studying the theoretical concepts that encompass a nuclear power plant, it was possible to design a project with the intention of complementing the research., the intention was to complement the research, giving it a virtual view, promoting the understanding of the subject.

Coming to the software, specifically Thermoflex, it was complicated to understand the program, since the existence of guides or manuals is almost nil, even more so for this specific project, since the software itself is not designed to house a nuclear power plant, due to these limitations and added to the fact that an academic version of the program was used. pure simulation, only in Thermoflex, was incomplete.

Due to this scenario, BWR NPS was reached, this simulator helped to nourish the general project, since a panel in which to control all the elements that control the plant was what the project needed to complete the empty space generated by Thermoflex.

This article allows the understanding for a particular case, applicable to different projects promoted by Thermoflex, because as already mentioned, there are no guides or tutorials in Spanish and those that exist in other languages are not very varied.

For future research, the field of quantum mechanics was remarkably interesting and, above all, broad for exploration, in addition to the specialization in the proposed software, or one that has a greater scope in terms of the elements that they can host.

**Declarations**

**Conflict of interest**

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

**Author contribution**

Each researcher developed the article together.

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**Abbreviations**

| | |
|---|---|
| BWR | Boiling Water Reactor |
| GEN BKR | Generator switch |
| NPS | Nuclear Plant Simulator |
| RPM | Revolution per minute |
| SRM | sourse range monitor |

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