Título del trabajo

"Achieving 100% GT's Start-up Reliability in Genelba's CCGT plant"

- A case study-

Autores

Jorge Vugdelija, Julio Aguirre, Horacio Babino, Horacio Pérez, Héctor Frare.

Empresa

Petrobras Energía S.A.
Central Termoeléctrica Genelba

Temario:

Herramientas de Calidad

INDEX

1. - SUMMARY

Genelba is a combined cycle power plant which started its business operations in 1999. Historically, until early 2005, Genelba's statistics indicated that 1 out of 5 GT start-ups failed (20% probability of failure). In late 2004, Genelba initiated a study whereby it has significantly reduced its failure ratio to practically 0%. The study was carried out by a multidisciplinary team comprising engineers from Genelba and Siemens (GTs OEM) who used statistical tools to analyse historical data and design tests.

This paper will discuss the approach and tools used in the study, the data gathered, the conclusions reached and the actions implemented that have helped to eliminate Genelba's problem of failures at GTs start-ups. That experience has left many lessons learned to apply.

2. - THE FAILED GT START-UP PROBLEM

First and foremost, we will define the expression "Failed GT Start-up". For the purposes of this study, Failed GT Start-up occurs when a GT start-up process is interrupted by a Flame –Off signal before the turbine synchronizes with the electrical grid.

There are basically two ways in which this event can happen. In one case, the Flame-Off signal appears immediately after the Fuel Gas Emergency Stop Valve is opened, that is, the Flame-On condition is never reached. In the second case, once the Flame-On condition is reached, the flame-Off signal appears before the synchronization with the electrical grid.

Taking into account both situations mentioned above, the former condition is less harmful since it only causes a delay in the plant start-up (which should not be underestimated!). On the other hand, in the latter situation, the hot parts useful life of the turbine is affected after having undergone the Flame-On situation. Then this is worse than the first situation because parts of the hot path are unproductively worn out.

In general, gas turbine manufacturers increase the status of their Equivalent Operating Hours (EOH) counters when finding the Fuel Gas Emergency Stop Valve Open and Flame-On conditions – sometimes the outlet temperature value is also taken into consideration.

3. - PROBLEM BACKGROUND AT GENELBA

Since the plant started its operation, frequent problems in the gas turbines start-ups were observed. However, other major problems typical of a plant that was being commissioned displaced Failed GT Start-ups out of the focus of attention. Not long after that and thanks to the implementation of robust process optimization programmes, the main problems in the plant were being solved one by one. Nevertheless, problems with Failed GT Start-ups still remained part of the unavailability pie chart.

There were some other aspects that made the problem remain unsolved for some time:

- Relatively a few number of gas turbine start-ups a year (base-load operation)
- Lack of a clear pattern of failure occurrence
- Successive repetition of several failed start-ups

As regards the first aspect mentioned above, during 2004 the rate of GTs start-up was about 10 per turbine. With a 20% failed start-up rate, there were only a total of 4 failed start-ups during the year and then a few chances to study them.

As for the lack of a clear pattern of behaviour, failed start-ups occurred in all kind of situations:

- Start-ups at any GT temperature -Cold, Warm or Hot
- Start-ups after trips and normal shutdowns
- Start-ups after long and short shutdowns
- Start-ups with or without previous off-line compressor washing
- etc.

With respect to successive repetition, several failed start-ups were often necessary to achieve a successful start-up. In the meantime, it was common to take a desperate decision (e.g. exchange the flame detectors) and once the plant had been successfully started up, the conclusion that the problem had finally been solved was usually reached. On the contrary, after some time and several successful start-ups the problem used to arise again.

Hence, in the early 2005, a team was made up to analyze the failure in a systematized way. This Improvement Team, a very useful tool for the plant, comprised people from Operations, Maintenance, Processes as well as engineers from the turbine manufacturer (Siemens). As a considerable amount of time had passed since the beginning of the plant operation, a great deal of relevant historical data about the turbines start-ups was available. This data could provide valuable information for a statistical analysis.

Perhaps the last element which triggered the making up of this work team was the words uttered by a company senior manager while talking to the Genelba team one morning after his visit to the plant:

"… lads, I'm really happy with the results you have reached; thanks to them, our company has improved a lot. However, there's something I'd like to tell you. I cannot understand how it is possible that I've never had any problems with my car every morning when I start it to go to the office and these gas turbines, which are far more expensive than my car and have much more advanced technology, can cause us so many problems during their start-up…?

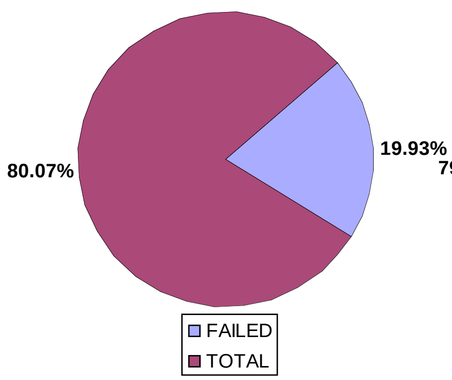
4. - FIRST APPROACH TO STATISTICAL ANALYSIS

When the team started its job, it had historical data from 301 start-ups, considering both gas turbines. It was particularly important to make all possible efforts to interpret and learn from the available information since the plant base load operation did not give us many opportunities to design and carry out lots of trials

The purpose was then to analyse this information from different perspectives trying to find a pattern of behaviour leading to the root cause of the problem. The different approaches applied are described below and in the order in which they were analysed. Some of them turned up to be irrelevant in view of the final results but this paper reproduces the whole analysis as it was carried out.

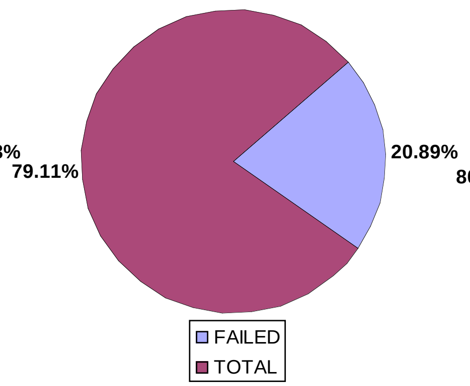
4.a- Firstly, the total rates of Failed Start-ups, as illustrated in Figure 1, and then the particular ones of GT11 and GT12, as shown in Figure 2 and 3, were analyzed. It was observed that both turbines behaved similarly so the idea that a specific problem could be directly associated with one of the GTs was ruled out.

FIGURE 1. TOTAL Start-ups -both GTs-



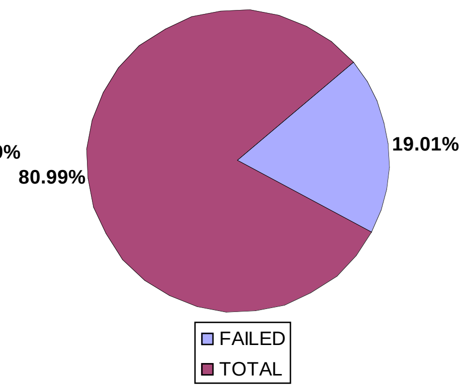
FAILED	TOTAL
61	301

FIGURE 2. GT11 Start-Ups



FAILED	TOTAL
33	158

FIGURE 3. GT12 Start-Ups



FAILED	TOTAL
28	143

4. b- Secondly, the problem development over time was analysed. For this purpose, it was not relevant to consider calendar years as time intervals but periods representing the machine life cycle. Then the GT's major inspections corresponding to 25000 and 50000 operation hours were used as milestone to determine relevant time periods. Figure 4 illustrates the failure development over time for GT11 and GT12.

FIGURE 4. FAILED Start-Ups TIME EVOLUTION

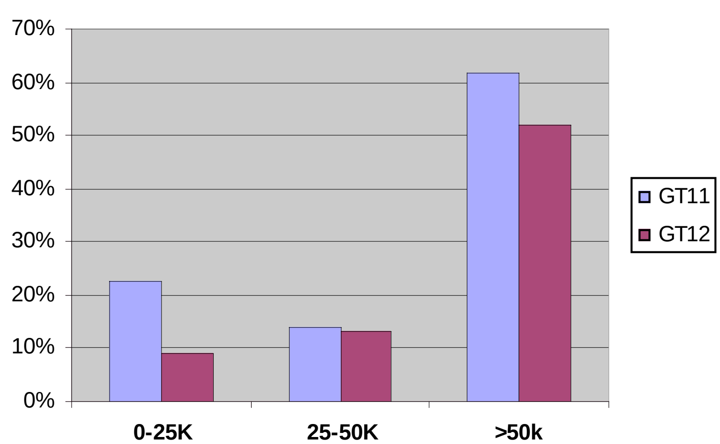
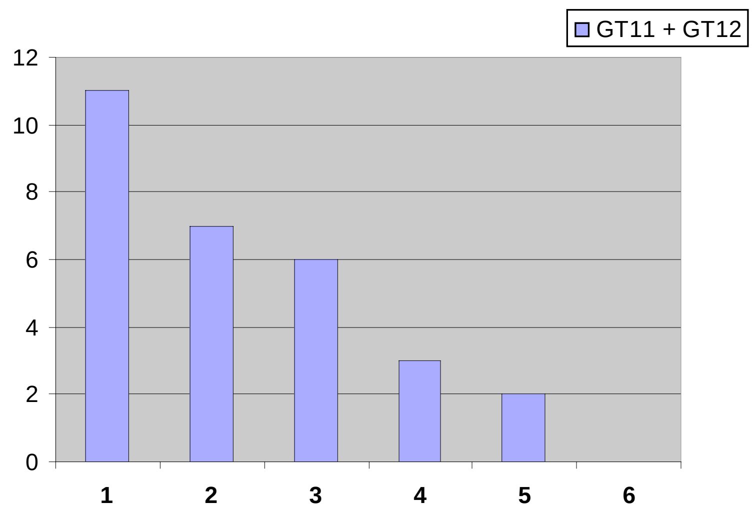


Figure 4 shows an increase in the rate percentage of the GT Failed Start-ups after 50000 EOH Major Inspection. This degradation can be seen in both gas turbines. However, there are a few start-ups during this period and precisely the last failed start-ups were the ones which motivated this study. Thus the proportional increase in failures in this last period was not considered relevant.

4. c- Other important aspects to study were the successive repetitive events of GT Failed Start-us. Figure 5 illustrates a frequency diagram whose x-axis represents the number of failed Start-ups successive repetitions while y-axis shows the amount of events in which the repetitions occurred. Note that only 11 out of 61 historical Failed Start-ups did not have failure successive repetition. The other 50 Failed Start-ups (2x7+ 3x6 + 4x2 + 5x2) were repetitions. That is, there were 17 independent Failed Start-up events (7 + 6 + 2 + 2) in which at least one additional repetition to achieve a successful start-up was necessary.

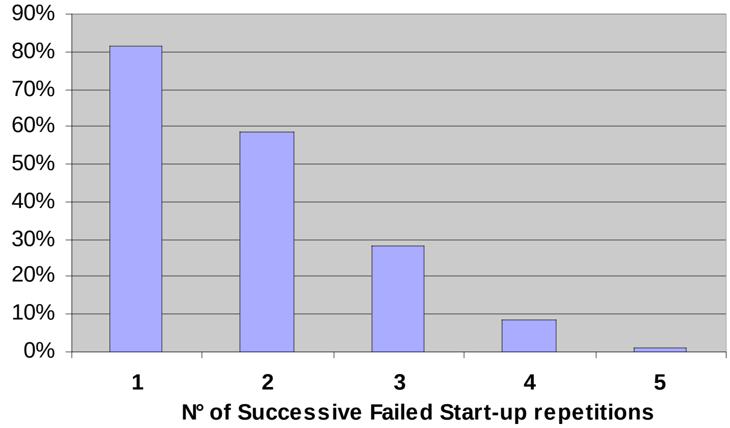
This situation made the team study the existing relationship between a Failed Start-up and

FIGURE 5. REPETITIVE FAILED START UPs



its immediate successive repetitions. Figure 6 shows Bayes's probability for the occurrence of a Failed Start-up when a Failed Start-up has just occurred. We can see that this probability exceeds 80%. The failure probability of any start-up was 20% according to Figures 1, 2 and 3. But once a start-up fails, the failure probability increases to 80% and decreases again below 20% only after 3 attempts, as illustrated in Figure 6. Based on this information, the team concluded that most of the time Failed Start-ups required several start-ups to succeed and that these successive events should not be considered independent. These conclusions helped the team to narrow down the scope of possible root causes for the problem.

FIGURE 6. Probability of Failure when a failed start-up has just occured.



4.d- Another approach applied studied the relationship between Failed Start-ups and the start-ups after a GT trip and also with the start-ups occurring after a GT had been shutdown for some days (>2 days) as illustrated in Figures 7 and 8. Relevant patterns of behaviour were not observed. There were a few Failed Start-ups not only after trips but also after prolonged shutdowns.

FIGURE 7. Failed Start-Ups after GT Trip

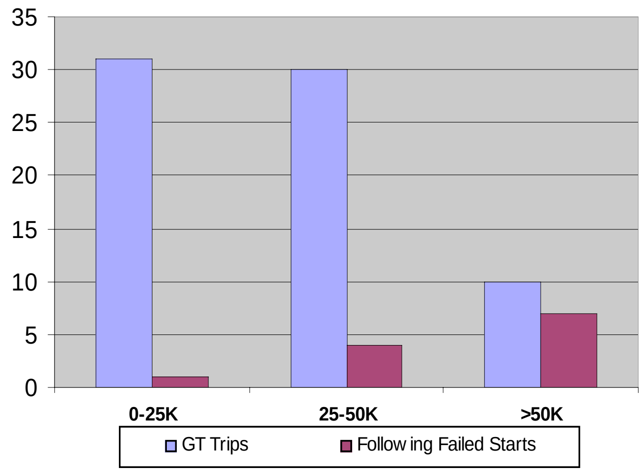
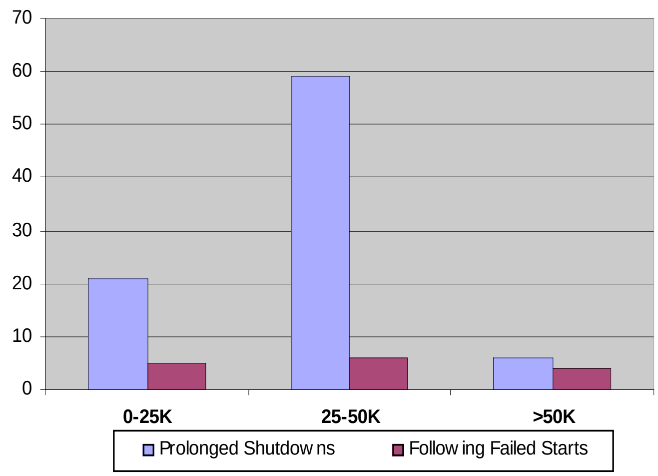
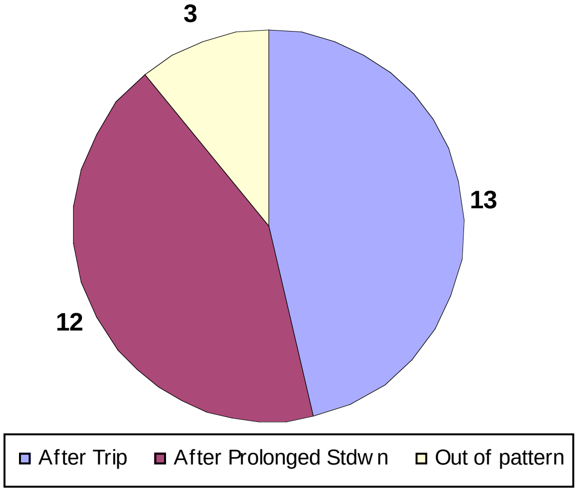


FIGURE 8. Failed Start-Ups after prolonged shutdowns.



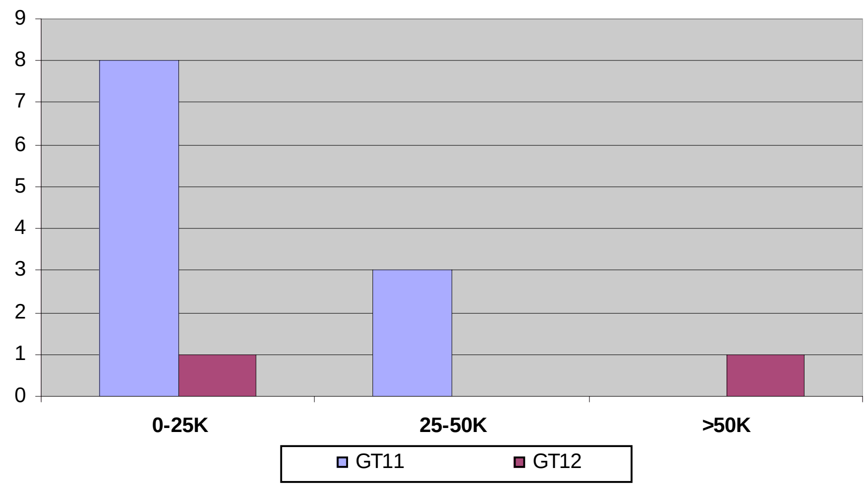
4. e- With the results from 4.-d, the same study was carried out although this time inverting the relationship. That is, answer the question: taking into account all the independent events of Failed Start-ups, how many occurred after GT trips? How many occurred after long shutdowns? Figure 9 shows this relationship. The results were relevant. Except 3 start-ups out of pattern, the rest of the Failed Start-ups occurred after a turbine trip (13) or after a prolonged shutdown (12). It is worth mentioning that the 27 failed start-ups in Figure 9 are independent Failed Start-ups according to the conclusions in Figure 6. These 27 independent Failed Start-ups, with its successive repetitions, generated the 61 Failed Start-ups of the history as indicated in Figures 1, 2 and 3.

FIGURE 9. Relationship among Failed Start-ups, Trips and Prolonged Shutdowns.



4. f- In the last statistical analysis, the team studied which of the 61 Failed Start-ups caused an accumulation of EOH according to what is mentioned in 2 above. Figure 10 shows this information.

FIGURE 10. Failed Start-Ups with EOH accumulation.



13 out of 61 total Failed Start-ups reached the Flame-On condition and then the flame blew out. After a detailed analysis of the 13 cases, the team concluded that all of them occurred after a prolonged GT shutdown.

5. - USING THE AFFINITY DIAGRAM

As a next step, the team proceeded to work with the Affinity Diagram. This technique allows you to creatively generate a great number of ideas which are organized and summarized in natural groups. This method, in view of the results of the statistical analysis above, assists in finding possible causes of the events of failure.

The natural groups containing the ideas generated turned out to be the four basic systems involved in the flame ignition in the GT combustion chamber: Fuel Gas System, Combustion Air System, Flame Ignition System, and Flame Detection System.

By means of the Affinity Diagram, the team applied the brainstorming technique, classifying the ideas in these four natural groups. Figure 11 illustrates the resulting Affinity Diagram.

FIGURE 11. Failed Start-Ups Affinity Diagram.

Fuel Gas System.

- Air input in the piping when emptied for maintenance
- Deficiencies in the Natural Gas Pressure regulation control.
- Excess of natural gas during the start-up (recent replacement of Fuel Gas Control Valve)
- No pilot used during ignition. Using premix pilot during the ignition.
- No minimum flow system for the start-up
- Combustion condensate and/or compressor washing condensate in the diffusion piping

Flame Detection System.

- Possible causes associated to this system were not identified.

Combustion Air System.

- Different flows for different ambient temperatures.
- Different flows for different GT temperatures.
- With off-line compressor washing, possible water in the air.

Flame Ignition System.

- Problems of ground shortcuts in the system.
- Low power igniters with difficulties to ignite the main burner

6. - IMPLEMENTED ACTIONS.

With the results obtained from the statistical analysis and the affinity diagram, the team determined a great deal of actions to implement which involved gathering information from the worldwide fleet, possible ignition with fuel gas pilots, etc. But among them, there were three outstanding actions that led to the problem solution and they all focused the attention on the Fuel Gas System:

- a. - f(x) function adjustment which adjust the fuel gas control valve lift at the Start-up depending on the GT temperature. This function present in the controller since the original design had not been adjusted correctly during the plant commissioning.

- b- Implementation of a new filling procedure for the fuel gas piping. Due to internal safety measures, every time an inspection of Genelba combustion chambers is carried out a 15m piping section between the fuel gas ESV and a shut-off valve in the upstream is emptied. Once the work is completed, the piping must be filled with natural gas again. The new venting procedure comprises a repetitive operation with the following sequence: opening of the shut-off valve, piping pressurization with Natural Gas, closing of the shut-off valve, opening of the piping vent valve until a minimum 2Bar pressure is reached and then vent valve is closed again. This sequence is repeated three times to ensure that no air is left in the piping.

- c- Study of systems to implement for extracting remaining water in the gas lines in the diffusion combustion mode, while the gas turbine is operating on premix combustion mode.

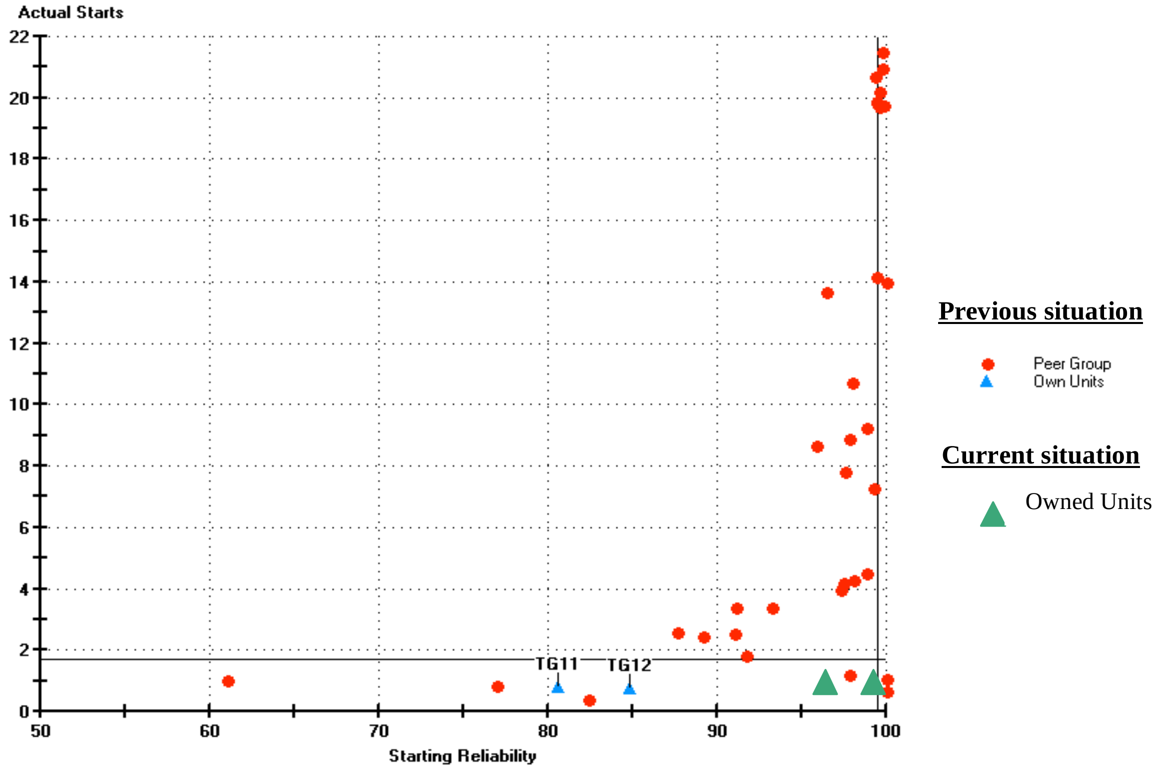
Actions “a” and “b” were immediately implemented. Action “c” is more complex. Siemens has designed a specific system to face this problem and, at the moment this paper was being written, we were waiting for the next GT Minor Inspection to install it.

7. - RESULTS.

The results obtained were outstanding. GT Failed Start-ups statistics decreased to nearly 0%. Since the implementation of actions “a” and “b” above -almost 20 months ago- all start-ups have been successful with the exception of 1 event with one repetition. This event was related to the lack of implementation of action “c”. The start-up occurred after a GT trip; this GT had been running for more than 4 months. Although this part of the problem still remains unsolved, its root cause is now well-known, and the action to solve it is already projected.

The results of a benchmarking programme developed by NCI and in which Genelba participates are illustrated in Figure 12. It shows the reliability comparative data of the start-up process. Note Genelba’s situation compared with other similar power plants before and after the study described in this paper.

FIGURE 12. Benchmarking position, before and after the case study



8. - LESSONS LEARNED

It was finally concluded that there were three main root causes to the problem of failed GT Start-ups in Genelba. These causes could occur or not depending on the specific conditions of each start-up. The causes were: presence of air in the natural gas piping, excess/defect of natural gas depending on the type of start-up –cold, warm or hot; presence of water in the natural gas piping. This accounts for the lack of a clear pattern of behaviour, what, in turn, delayed the finding of a final solution to the problem.

The use of statistical analysis tools applied to historical data, is an invaluable source of learning over past experiences. This type of analysis should always be implemented before beginning a test/error process guided by intuition. The results of these analyses usually provide information that is contrary to the specialists' a priori conclusions.

Multidisciplinary teamwork provides good results when it comes to solving complex problems. It is also of outmost importance to have the suppliers support in these study teams in a collaborative working environment.

Complex problems begin to untangle in view of a systematized analysis.

The method used in this case study for solving the Failed Start-up problem can be applied to other problematic situations occurring every day at power plants.

Authors

Jorge Vugdelija,
Gerente de Planta de la Central Termoeléctrica Genelba.
Ingeniero Electrónico. Veinte años de experiencia en la explotación de Centrales Termoeléctricas.
jorge.vugdelija@petrobras.com

Julio Aguirre,
Especialista de Procesos Sr. Central Termoeléctrica Genelba.
Ingeniero Eléctrico. Diez años de experiencia en la explotación de Centrales Termoeléctricas.
julio.aguirre@petrobras.com

Horacio Babino,
Jefe de Operaciones de la Central Termoeléctrica Genelba.
Ingeniero Mecánico. Veinte años de experiencia en la explotación de Centrales Termoeléctricas.
horacio.g.babino@petrobras.com

Horacio Pérez,
Jefe de Mantenimiento de la Central Termoeléctrica Genelba.
Ingeniero Mecánico. Treinta años de experiencia en la explotación de Centrales Termoeléctricas.
horacio.perez@petrobras.com

Héctor Frare,
Jefe de Procesos de la Central Termoeléctrica Genelba.
Ingeniero Mecánico. Quince años de experiencia en la explotación de Centrales Termoeléctricas..
hector.frare@petrobras.com