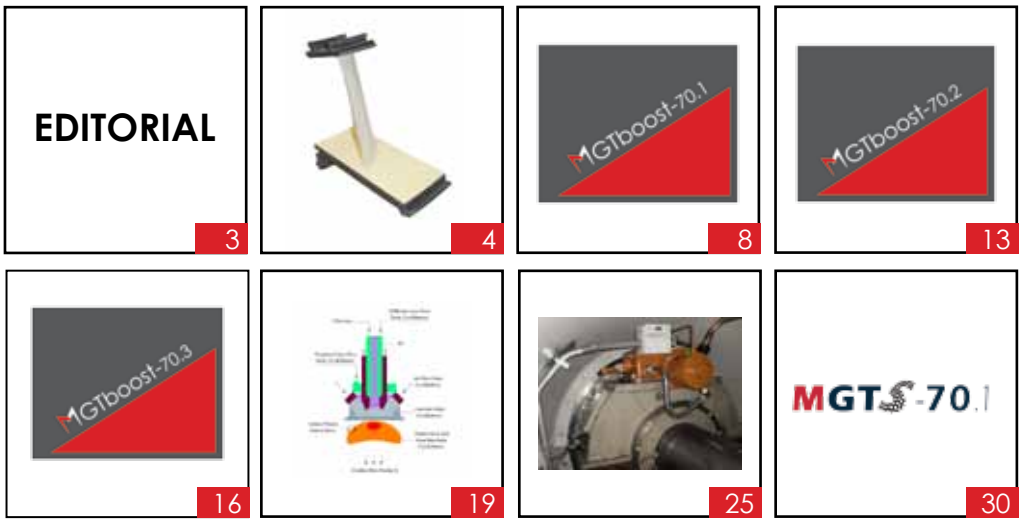
Technical Review

MAPNA TURBINE ENGINEERING & MANUFACTURING CO. (TUGA)

No.1-March 2014

Our Willpower, to Empower Generations



Contributors to this Issue:

Ali Motahar

Saeid Rashidi

Habib Habibian

Kianoosh Radfar

Ahmad Razzaghi

Afshin Koohestani

Alireza Rezaeinasab

Morteza Nezamabadi

Abbas Fakhr Tabatabaei

IN THIS ISSUE YOU WILL FIND:

EDITORIAL

Dear Customers, Partners, and Professionals,

By publishing this inaugural issue of MAPNA Turbine Technical Review in 2014, we are pleased to officially set off on our world-class journey of technology development in the field of Turbo-machinery. The Technical Review, which will be released twice a year, is to introduce the latest developments and achievements in MAPNA Group's Turbine technology and other related products.

The first issue focuses on our oldest product, the heavy-duty gas turbine MGT-70 (former V94.2). An inclusive design review of the machine in the past years along with fleet analysis conducted by MAPNA Turbine, has clearly shown that there is room to improve performance, maneuverability and availability of this well-proven, robust machine. Internal R&D and engineering, together with technical partnerships have now resulted in commercializing upgraded versions of the machine and a number of rather huge modifications to enhance its maneuverability, as well as by-products that bring value to customers.

So far, beyond the MGT-70 new versions (1) and (2), MAPNA Turbine has introduced the MGTboost-70 platform; a series of developed technologies by MAPNA Group for the installed-base units to boost operational flexibility, reliability, and energy efficiency of the machine. The innovations are based on powerful combination of experience and information coming from fleet analysis, as well as customer operational feedbacks on the MAPNA Group's remarkable running fleet of MGT-70s. As an OEM, the solutions that we introduce to our customers, unleash the full performance and value of their existing machines, and demonstrate how their information and feedbacks have been transformed into tremendous gain for them.

In this issue of the Technical Review, a few developments are reflected. Behind each, there has been an enormous amount of research and plenty of field tests. However, attempt has been made to outline major technical aspects and the value offered by each, to all stakeholders. Firstly, the machine upgrades introduced to the market have been dealt with. Secondly, a bold philosophy shift to increase the machine efficiency for operation at partial load in simple cycle has been elaborated on. In the two following essays, two well-proven significant measures to improve the machine start-up maneuverability and thereby considerably enhance the availability of the machine have been put forth. Items 5 and 6 in this issue are dedicated to address two design problems in the original machine and relevant solutions to eliminate them. Finally, a description of the MGTS-70.1 Simulator, developed to assist both engineers and operators to observe, monitor and forecast the behavior of this specific machine has been provided.

This Technical Review is in essence, a brief account of the information provided by the experts in different fields, active in technology development of MAPNA Turbine Company, whose invaluable sharing is hereby appreciated.

Sincerely

Mohammad Owliya, PhD
Vice President for Engineering and R&D
MAPNA Turbine Company (TUGA)
March 2014

1- Introducing the Machine Upgrade, MGT-70, to the Market

Introduction

At the moment, the V94.2 fleet manufactured by MAPNA Turbine Company, way outnumbers that supplied by other licensees, combined. The number also amounts to over 40 percent of those manufactured and put into operation by Siemens AG, ever since 1981 that it was first introduced to the Energy Market. This provides MAPNA Turbine with more than enough room to get to know about the weak spots of the machine and the areas which are prone to premature damage and hence good subjects of improvement.

Major upgrades Introduced

Combined with a thorough design review on this machine, the aforementioned practical record has brought about attractive modifications which enhance either its performance or its availability. The upgrading modifications encompass three categories:

a) Modifications in some materials, (the fuel gas distributer pipe, for instance) to prevent their premature corrosion and modifications in geometry to improve the thermal fatigue strength.

b) Hot Gas Path components thermal barrier coating to extend their life time far beyond that proposed by the original, without-coating design.

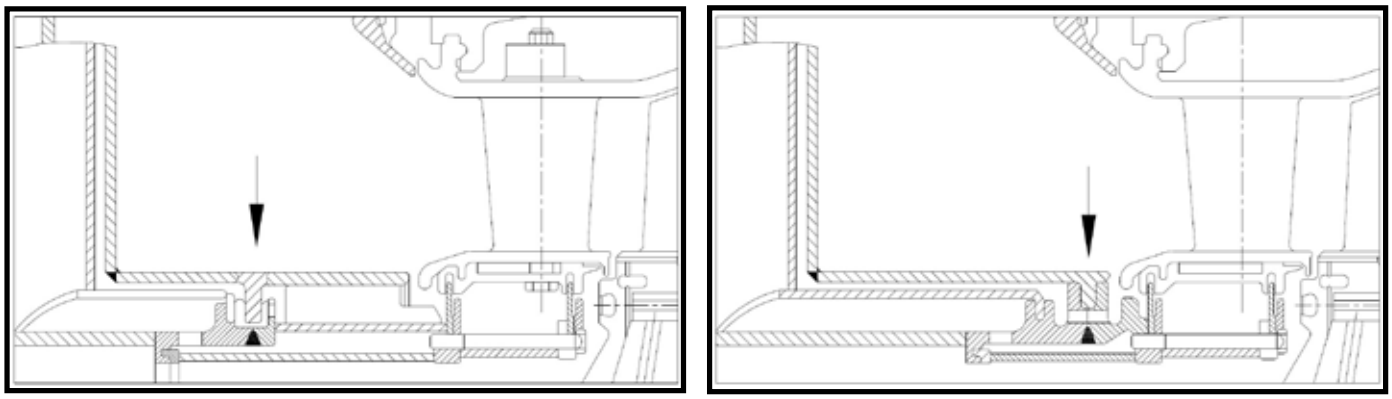


Fig.1- Relocating the Hot Gas Inner Casing's hub ring from the middle (left) to the end of the hub (right) to enhance thermal fatigue strength

Fig.2- Thermal Barrier Coating and internal Aluminizing, added to Blade and Nozzle vanes of stage 1; The same might be done for Blades and Vanes of stage 2 and Vanes of stage 3 can also be coated with a new coating system (MCrAly)

Fig.3- Hot Gas Casing hub coated for MGT-70(1)

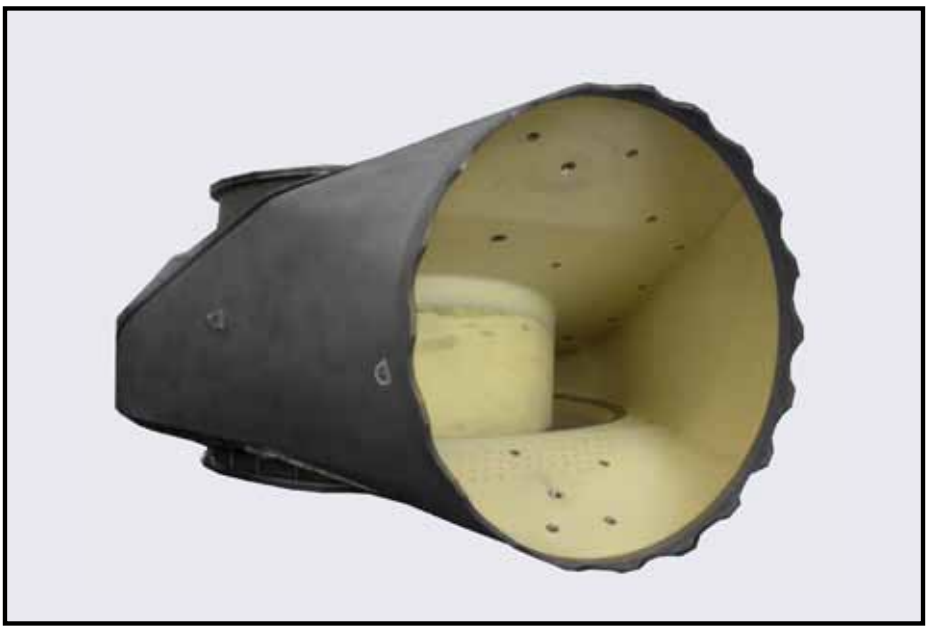


Fig.4- The inner side of the Hot Gas Casing TBC coated completely
(not only on the hub) for MGT-70(2)

c) Wear-resistant coating on the interfering edges throughout the hot gas path; burner inserts-air side plates, burner insert-flame side plates, flame tube-mixing casing and mixing casing-inner casing transition rims/edges.

The first upgrade of the machine to MGT-70(1) (known also as MAP2+) gives a standard increase in output of about 4MW and a new efficiency rate of 34,5% while the latest upgrade to MGT-70(2), offers a standard increase in output of about 8MW (total output=170MW) and a new efficiency rate of 34,6%. If the operator decides not to increase the TIT to enjoy the higher efficiency/output, they have the option to stick to the previous limits of TIT, but instead, lengthen the major hot gas path inspection duration from 33kEOH to 41kEOH. The former upgrade has been so far carried out on 14 machines in different power plants inside the country and the latter has been successfully executed on one machine, namely unit 4 of ASSALUYEH power plant.

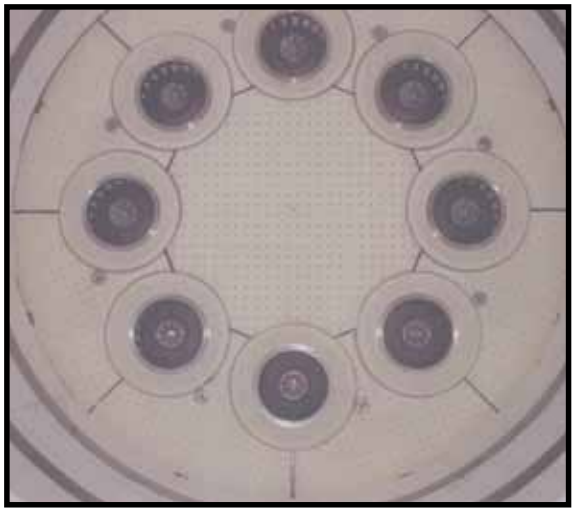


Fig.5- TBC coated burner Segments and Flame Side Plates of the combustion chamber flame tube

Fig.6- Thermal barrier coated Mixing Casing of the combustion chamber

Future Work

Developing a new upgraded machine called MGT-70(3) is in process at the moment which has aimed the extreme output of 180MW and a marvelous efficiency of 36% for this machine. Given the recent achievements in Directional Solidification and Single Crystal Growth technology at MAPNA BLADE manufacturing subsidiary of the Group, MAPNA TURBINE will be able to develop and manufacture a new generation of its own original gas turbines in the not too distant future.

Conclusion

After more than one decade of under-license manufacturing of the same gas turbine, a breakthrough in research and development at MAPNA TURBINE has emerged. This, on one hand, has led to developing a few upgrades on the existing machine to enhance its performance and uptime and on the other hand, has paved the way for MAPNA TURBINE to aim at design and manufacturing brand new machines of a new generation enjoying its huge advances in machine design and manufacturing technology.

2- Boosting the Partial Load Efficiency through Control Philosophy Shift

Introduction

MGTboost-70.1 is one the series of MGTboost-70 platform for boosting the partial load efficency through control philosophy shift. It is well established that maximum achievable performance in part-load operation depends on the control philosophy adopted in various gas turbines. In particular, IGV-constant loading control of gas turbines leads to a better simple-cycle efficiency in part loads compared with that of the TET-constant (Constant turbine exhaust temperature) and TIT-constant (Constant turbine inlet temperature) control philosophies. TET logic, best suits combined cycles where the fluctuations in HRSG temperature are slim to none.This philosophy keeps the thermal shocks in HRSG components during load change, reasonably low in order to not impair its components. TIT regime, on the other hand, brings about some fluctuations in exhaust temperature, but is normally ideal to prolong the life of the hot gas path early components. At the same time, as this regime brings about the highest achievable gas turbine exhaust temperature, which improves the thermal efficiency of HRSG, it can lead to time-dependent failures (creep) in mid/down-stream parts of the hot gas path components . In this way, toggling among TET, TIT or IGV control philosophy is in essence more of a trade off for boiler/steam turbine robustness, early hot gas path components life plus overall combined cycle efficiency, and simple cycle thermal efficiency, respectively.

For MGT-70 machines working in simple cycles, boiler design would not be a problem, because simply there is no HRSG. So, if the maximum temperature gradient could be maintained lower than a certain threshold to avoid an adverse impact on the hot gas path components, and control system could be aligned to guarantee the smooth machine operation, shifting to IGV-constant philosophy would be of considerable advantage in part load regimes in terms of efficiency. The increase in part load efficiency when shifting from TET-constant to IGV-constant philosophy might reach values as interesting as 2%.

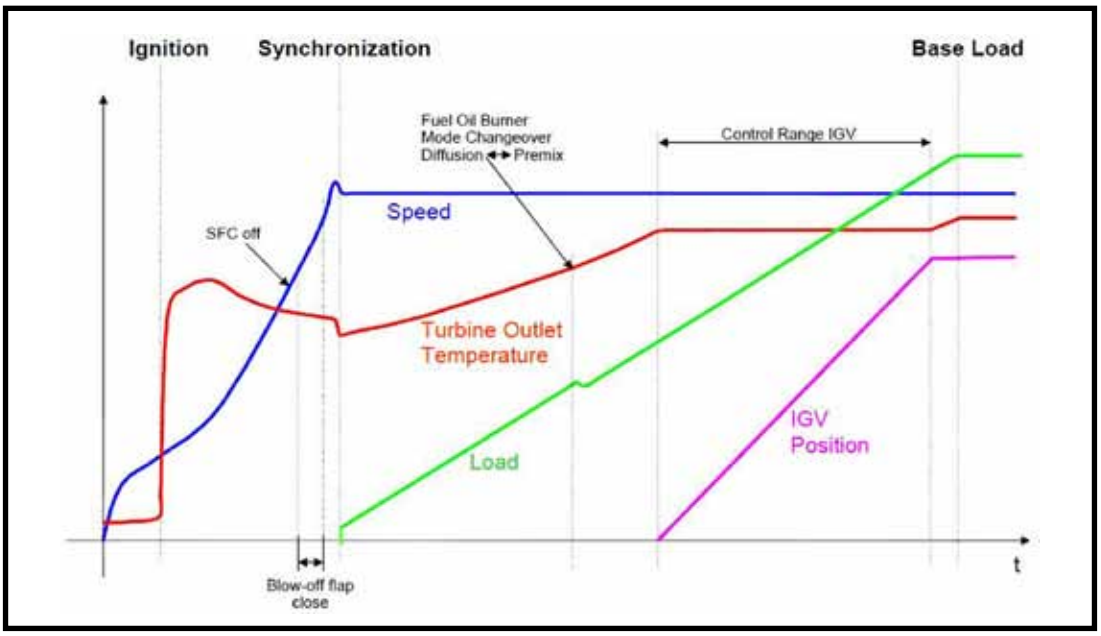


Fig. 1. Start-up and Loading Overview – TET Constant control philosophy

Major challenges of the trade-off

Fig. 2 provides a comparison among the simple cycle efficiencies in the entire load spectrum for different control philosophies for a typical gas turbine of base output of 160MW.

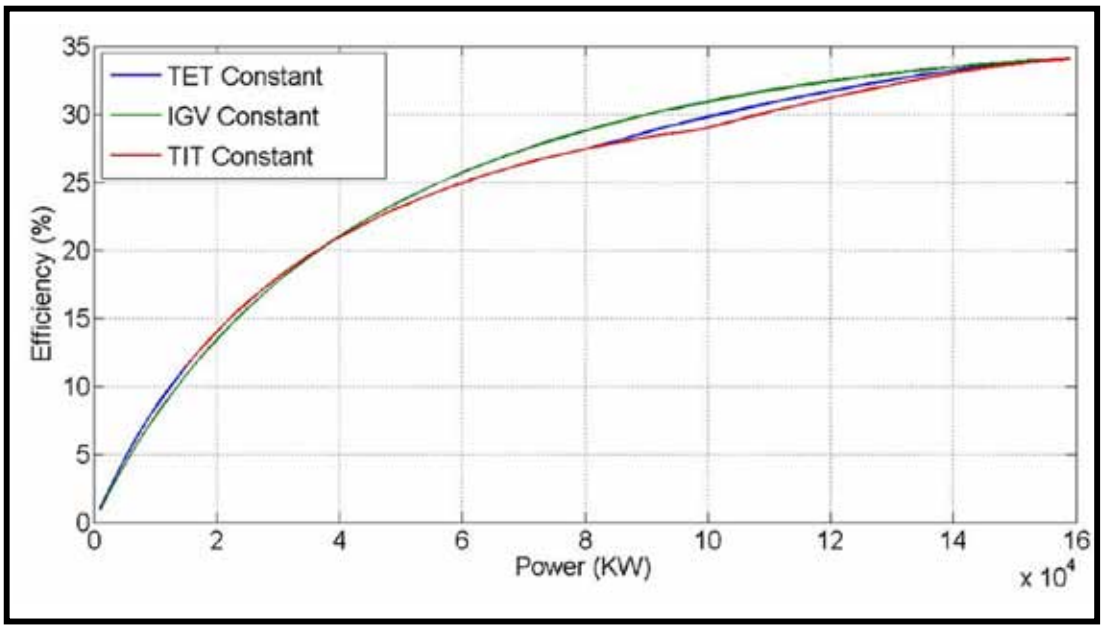


Fig. 2. GT Efficiency versus Load for different control philosophies

With only simple-cycle efficiency taken into account, shifting toward IGV-constant loading philosophy looks quite interesting, in particular, when operating the machine in the vicinity of half base-load area. There are, however, certain challenges in need of being taken care of in doing so. The challenges in question, do not rule out the philosophy shift, but yet force it to be a well-engineered and well-thought-of process.

The main points of concern are given below:

1- Observing the compressor surge margins and seeing to the required provisions needed in the control logic

2- Observing the flame stability and the smooth combustion in the new philosophy

3- Observing the TET temperature gradient as a result of the philosophy shift

4- Applying new settings in the load controller

5- Applying new settings in the IGV controller

6- Applying new settings in the compressor outlet pressure gradient controller

To guarantee the flame stability and to keep a safe distance away from surge margins, start of operation for IGV opening needed to happen at a certain load. After a long process of calculations and practical feedbacks from the conducted on-field tests, the team came up with the idea of postponing the IGV operation start to around 10% of the base load and smoothly getting to the fully-open condition at around 30% of the base-load. This well-proven milestone paved the way for the relevant team to develop the right scenario for the control philosophy shift.

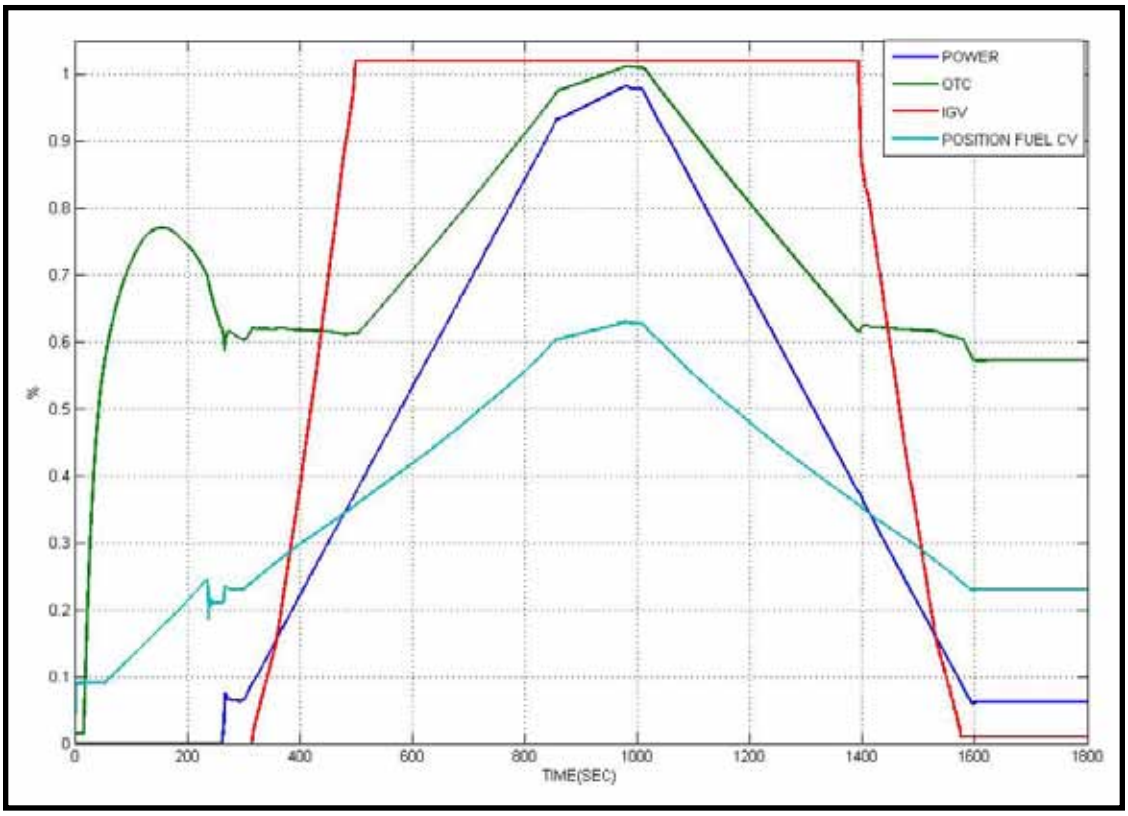


Fig. 3. Start-up and Loading Overview – IGV Constant control philosophy

To avoid high temperature gradients on the machine components, temperature gradients undergone by it during the conventional TET-constant philosophy were observed. Note that, both the turbine inlet and the exhaust temperature gradients resulted by TET-constant philosophy were calculated and taken into consideration in doing so. Then, effort was made to set the parameters in the control system so that the maximum allowable temperature gradients, were never exceeded any where in the new loading process in which IGV-constant philosophy was adopted.

Implementing the new settings in load and pressure gradient controllers and substantial modification on IGV controller were the last but not the least modifications applied to enable the new philosophy to be rolled out on the machine.

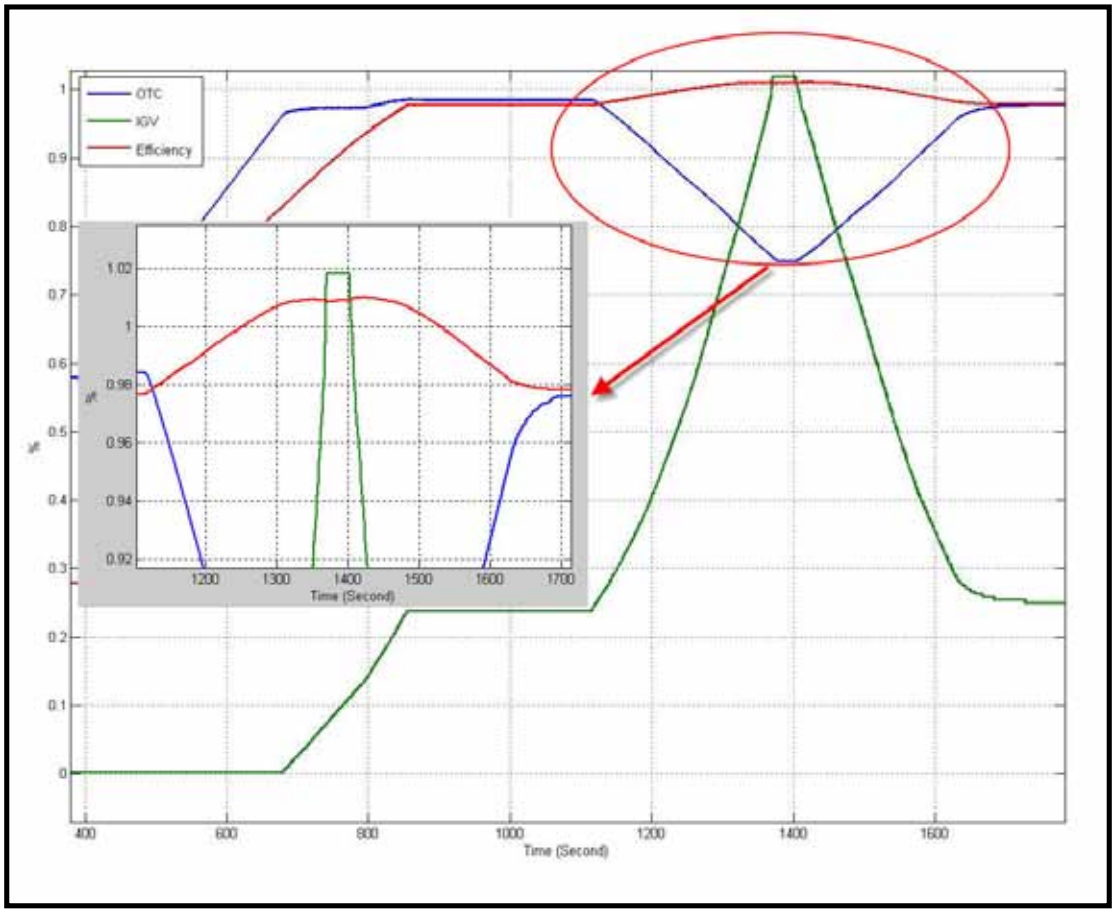


Fig. 4. Changing control philosophy from TETC to IGVC and vice versa – Turbine Efficiency increases up to 2% in IGVC

Conclusion

Enormous savings can be achieved, in particular for simple-cycle machines running at partial loads for a rather long proportion of their life when a shift is made toward IGV-constant philosophy from either TIT-constant or TET-constant regimes.

Fig. 5 shows how large the annual savings might be for a certain increase in efficiency of a typical machine running at part load of 70MW, 4 hrs a day.

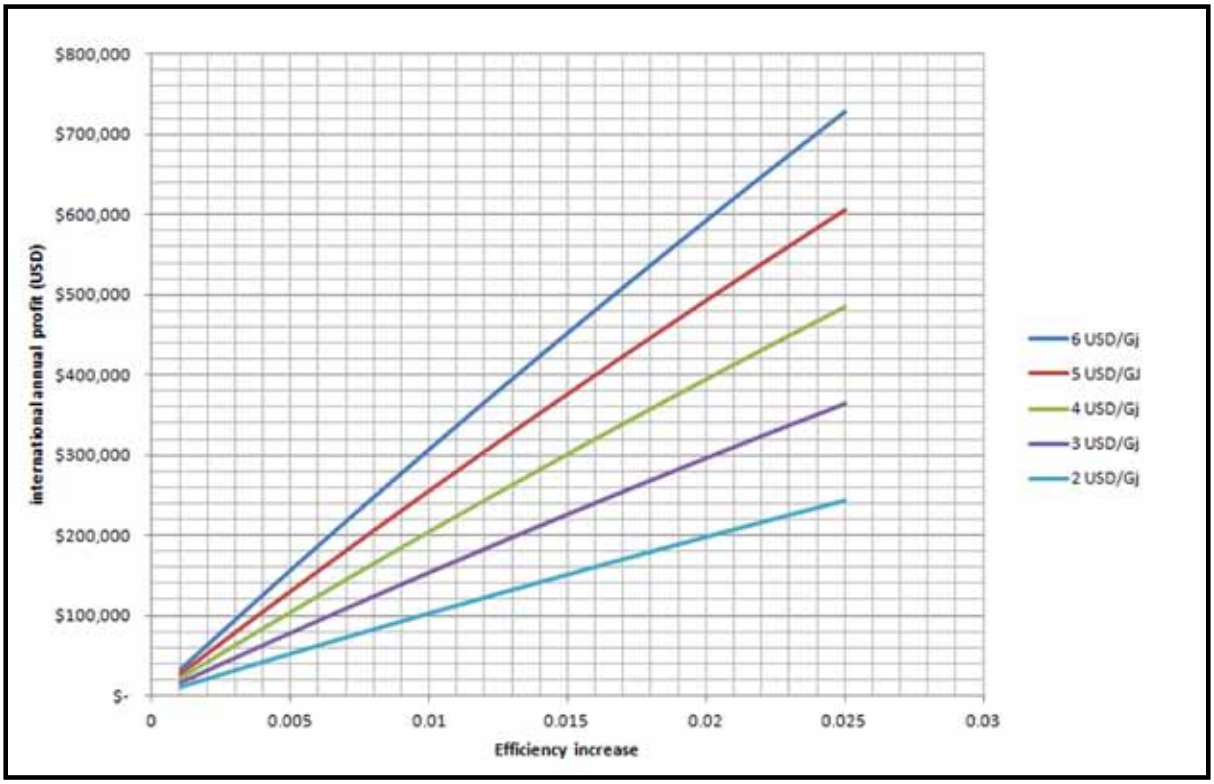


Fig. 5. Annual Savings versus Efficiency Increase, for various fuel costs, for a typical machine running at 70 MW load, 4hrs a day

To illustrate what is meant by the chart in figure 5, let's calculate savings offered by the philosophy shift for a 160-MW machine of figure 1, that works 4 hrs a day at a load of 70 MW.

The curves shown in figure 2, reflect an efficiency increase of 0,010 (one percent) for such a machine at such a load, if we shift from TET-constant to IGV-constant control philosophy (The efficiency of 26,5% improves to around 27.5%). So, referring to fig.5 above, one can see that, annual savings as huge as at least "one hundred thousand US dollars" to over "three hundred thousand US dollars" per machine (based upon the fuel price) can be achieved through such a philosophy shift.

3-Safely Start up the Fuel-Oil Operated Machine without the Ignition Gas!

Introduction

The MGTboost-70.2 is another package of MGTboost-70 platform for safe starting up the fuel-oil operated machine without the ignition gas.

The MGT-70 machine is capable to be started on both fuel gas and fuel oil. To have a stable start-up flame in fuel oil mode, should be necessarily made of an auxiliary gaseous fuel of high heat value (usually LPG) which imposes a rather considerable cost to the operator. It stands to reason to use a less costly gaseous fuel to eliminate this need. The process engineering department has come up with an adroit solution to serve this purpose using the existing structure of the standard burners without a need to set up any additional auxiliary fuel gas supply.

Technical Details

As shown below, the standard HR3 burner consists of a few paths used by natural gas, fuel oil, ignition gas and pilot gas.

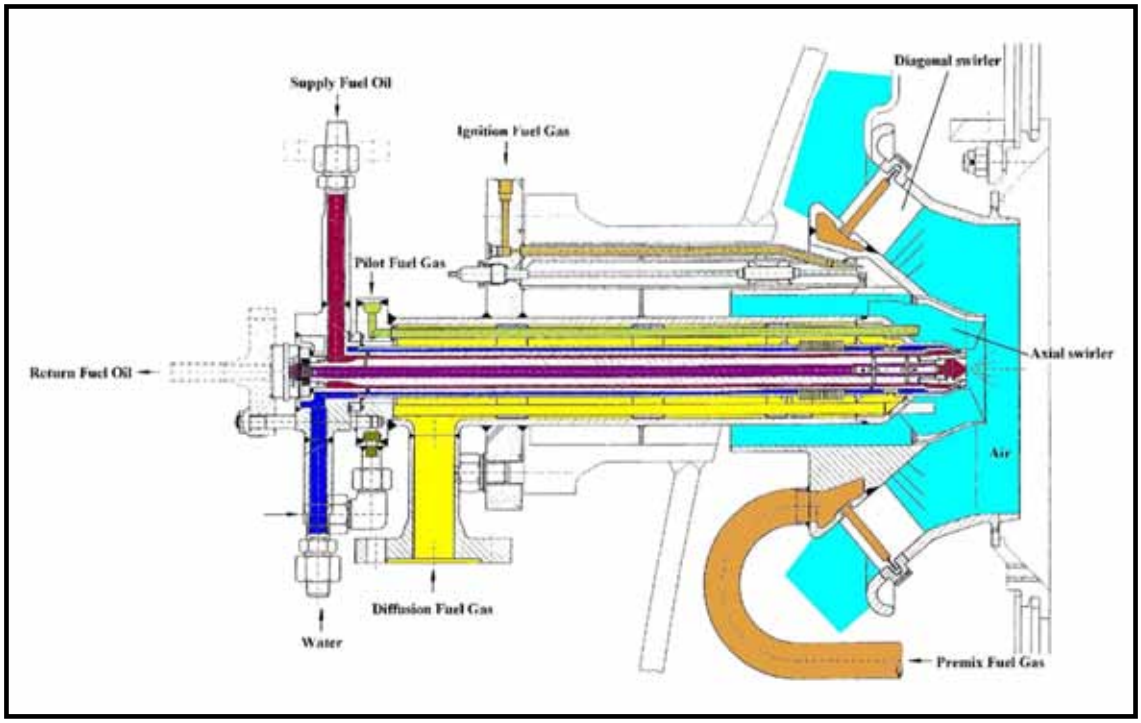


Fig. 1- Various paths for different fuel supplies to the HR3 burner

At a normal fuel oil operated start-up, auxiliary fuel gas is supplied to the ignition path and forms a stable auxiliary flame to ignite the main fuel oil. To eliminate the need for the ignition gas (LPG), it was experimentally shown that use can be made of the natural gas supplied to the pilot gas path. It is noted that pilot gas path is mainly used to stabilize the flame in fuel gas premix combustion mode.

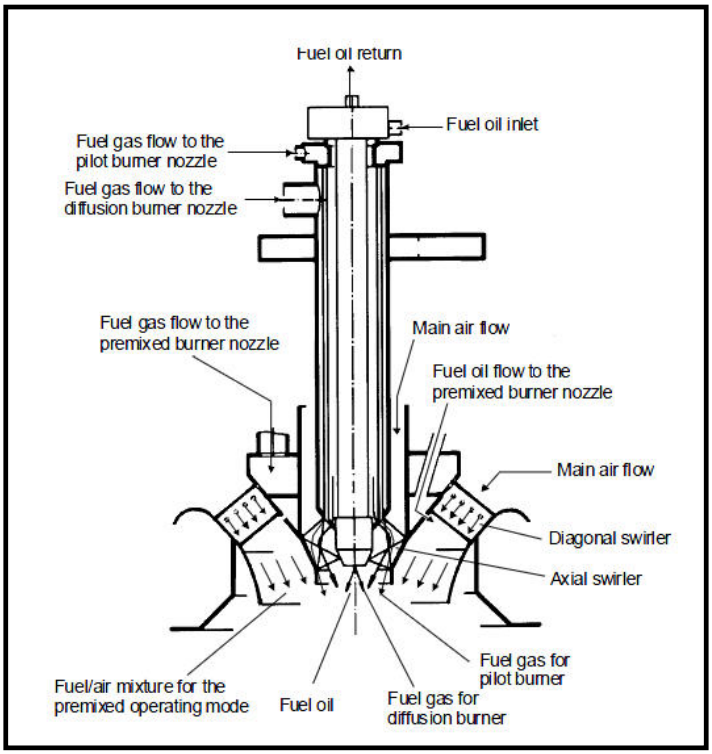


Fig.2 -HR3 Burner

In the designed scenario, natural gas is supplied to the ignition path instead of the LPG. At the same time, natural gas is supplied to the pilot gas path and the flame started by ignition extends to the pilot gas to form a powerful enough flame to ignite the main fuel oil stream. This leads to formation of a stable flame at the combustion zone of the main fuel oil.

The question that might arise is: “If fuel gas were available in the field (to be used as pilot gas in the a.m. scenario), what would be the point in switching to the fuel oil mode in the first place?” Having in mind that the machine has been working in fuel gas mode before switching to fuel oil, one can realize that there is more than enough fuel gas trapped between the upstream natural gas depressurizing station and the fuel gas skid for ignition purposes. This trapped natural gas is used to feed the pilot burner mentioned in the scenario above.

As further starts are accumulated, the pressure of the trapped natural gas drops off, and to maintain the flow rate for the pilot gas we need to adjust the pilot control valve dynamically even during the start-up process. Field tests have proven that with a pipeline already filled with the natural gas with the nominal pressure, the trapped gas is enough to provide for about 30 GT starts. Should more than 30 starts be needed, the operator might ask for a refill of the pipeline by the gas providing station which is far less costly than providing the LPG for ignition purposes. It goes without saying that such a refill does not inflict any pressure drop whatsoever in the gas station grid.

Conclusion

To eliminate the need to use the rather costly LPG for start-up at fuel oil operation mode, use has been of the combination of the natural gas flowing into the ignition and pilot paths to form a stable flame. The natural gas to serve this purpose is taken from the trapped gas downstream of the gas transmission line. The constant flow for the pilot gas is maintained through dynamically actuating the relevant pilot gas control valve, getting instantaneous feed back from the pressure drop in the pipeline. the trapped natural gas can accommodate more than 30 starts once we begin with the nominal pressure. To continue beyond 30 GT starts, the operator can ask the natural gas provider for a refill of the pipeline which normally will not cause a problem and will be readily admitted.

4-Start up your Fresh-shut-down Machine!

Introduction

The other package of MGTboost-70 series introduced in the current techincal review is MGTboost-70.3 ,which provides hot-start of the machine .

Ordinary or emergency shut-down of a typical heavy duty gas turbine from base load, normally requires a cool-down period of 3 to 5 hours before the operator can restart it. For MGT-70, it used to be the case as well. The normal start-up algorithm of the machine, requires the exhaust temperature fall below 150˚ C to successfully start the machine up and practically, to remove the probability of premature trips, one might need to let the machine cool down to even lower than 100˚ C. The change in the start-up algorithm and logic tested and successfully implemented by MAPNA TURBINE, however, enables the operator to restart the machine in technically no time after normal or emergency shut-down while the outlet temperature is even as high as 300˚ C, which has substantially improved the availability of the machine.

Modification in the Start-up Logic

Conventionally, During the start-up of the machine, the fuel control valve is minimally open at first and at a certain rotor speed, it starts to get more open at a constant rate (first linear increase or ramp function). At some other machine speed, the fuel valve gets more open at a higher but yet constant rate (second linear increase or ramp function). In this way, opening position of the fuel control valve during start-up takes place in three stages as shown in fig. 1: Minimally open and constant in position, first ramp of opening at a moderate constant rate and finally the second ramp at a rather higher constant rate. This is to maintain the fuel-air ratio during the entire start-up process and subsequently maintain a constant corrected exhaust temperature.

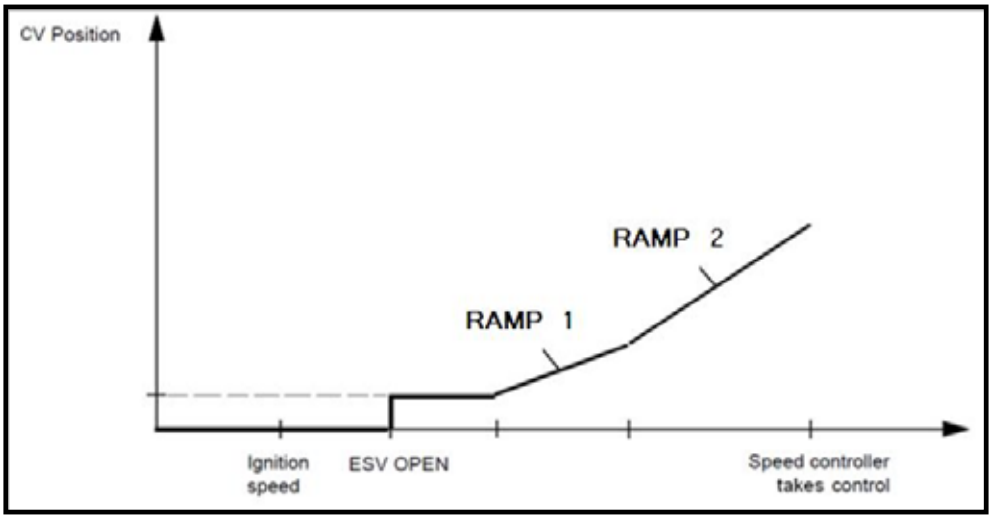


Fig. 1- Fuel Control Valve positioning regime

This algorithm is once fed into the control system in its commissioning phase and made use of, allover the machine life. If the exhaust temperature is upper than 150˚ C, the aforementioned conventional fuel valve opening regime will automatically lead to an exhaust temperature gradient that might impair the machine components or in a nightmare scenario bring about temperatures as high as that of the protection limit which renders the start-up process unsuccessful with the subsequent trip.

If one were able to teach the control system to follow different “fuel valve opening regimes” based upon the different exhaust temperatures, they could successfully hot-start the machine accordingly without exceeding the protection limit. To get that materialized, an inclusive team composed of process and control people at MAPNA Group, conducted the relevant study.

The study showed that the opening rates offered by the bilinear ramps should remain untouched, because they approximate the relation between heat input of the machine and rotor speed which is all about the nature of the machine. On the other hand, to undermine the heating of the machine in excess, the whole curve (fuel control valve openness position versus time) could be shifted downwards based upon the exhaust temperature to avoid the subsequent temperature limit trip or component damage.

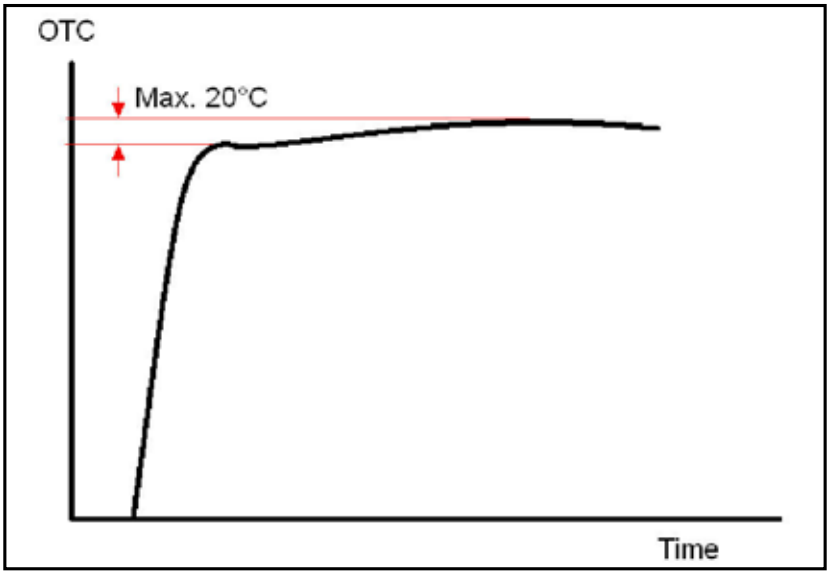


Fig. 2- Ideal gas turbine start up

A number of smartly planned tests were conducted afterwards to determine the reduction of fuel control valve openness position required to safely restart the machine for each corrected exhaust temperature. Such characteristic curves were produced for gas and oil fuels separately and the reduction in openness (downward shift of the openness position) for each exhaust temperature ranging from ambient temperature to 300˚ C was then available. By adding another correcting function to the control logic, the start-up curve is first produced according to the corrected exhaust temperature and then it is followed to start up the machine to minimize the heating effects on the machine components and avoid hitting the protection limit at the same time. In effect, the hot start conducted in this way results in a temperature gradient as smooth as a normal start at temperatures lower than 100˚ C.

Conclusion

To eliminate the cool-down period of the machine and enable its hot-start, a new upstream correction was added to the control logic. Prior to any hot-start, this correction produces the appropriate fuel control valve position curve versus time and machine speed. This curve is produced by a downward shift of the conventional one. The amount of this reduction in openness per corrected exhaust temperature was practically extracted out of quite a few adroitly designed tests on the machine for both gas and oil fuels separately. The results show that by a minimal shift-down of the openness position of the fuel control valve in the entire curve (the exact amount depending on the type of fuel, type of the valves and most importantly, the corrected exhaust temperature), a safe and smooth start-up can be guaranteed. This new logic well enables the hot-start of the machine with corrected outlet temperatures as high as 300˚ C and thereby considerably enhances the availability of the machine by literally eliminating the otherwise required cool-down.

5- Getting the Combustion Chamber Humming Hushed!

Introduction

Combustion instabilities have always been a point of concern in gas turbines. Flow and mixture perturbations can lead to oscillations in heat release which in turn can result in acoustic oscillations. Finally, the acoustic oscillations generate the disturbance in flow and mixture, closing the feedback loop.

Depending on the phase between the pressure and heat release, the flame may add or remove energy from the acoustic field during each cycle. If the energy supplied to the acoustic field exceeds the energy losses of the mode, the acoustic amplitude will grow and the vicious circle keeps moving around.

Side effects of the aforementioned instabilities, so-called humming, are numerous and may adversely impair the integrity of components and put the whole operation at stake. It can lead to:

- Unscheduled outage to repair the damaged components

- An increase in loading time to base-load

- Expenses claimed by the operator, if efforts to eliminate humming happen to fail, before the official final delivery of the machine at the end of the guarantee period

Taking the above into account, any effort to detect and subsequently eliminate the root causes for humming, can well pay off both technically and financially.

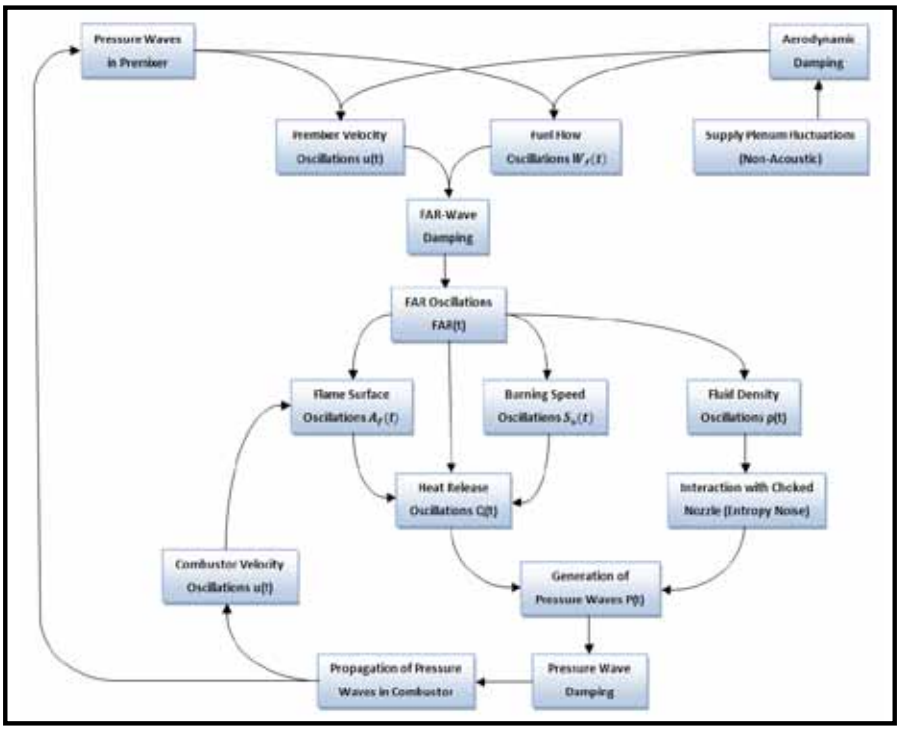


Fig.1- Combustion Instability Driving Mechanisms and Means to Suppress it

Problem Description

In MGT-70 (V94.2) machines, humming typically happen at a specific frequency region during start-up of the machine and more severely at a certain load, while loading the unit running in the fuel gas diffusion mode. DLN burners in paticular are more susceptible to inflict humming on combustion chambers, because they are supposed to provide a tradeoff among low NOx, low CO, flame stability and combustion dynamics at the same time.

The diffusion mode in MGT-70 machines is designed to cover a wide range of combustion regimes from start-up to base load.However, there might be regions that the diffusion mode of operation is not efficient to keep up with all the limitations. On the other hand, the manufacturer can not and should not limit the operator to run the machine in premix combustion mode in an as wide as possible range of the loading spectrum; this is the operator's call according to its own utilities and requirements.

Observations showed that high levels of humming are present in MGT-70 combustor, when loading the unit. The critical load in this regard was somewhere between 40MW to 70MW output. For some units, the differential pressure reached values as high as 40 mbar at the time of humming occurrence, compared with the allowable and critical values of 20 and 30 mbar respectively. Furthermore, MGT-70 combustion chamber suffered from another humming mode during start-up, at around 2100 rpm. The differential pressure level at the latter (start-up) humming mode was not as critical as that in loading, though.

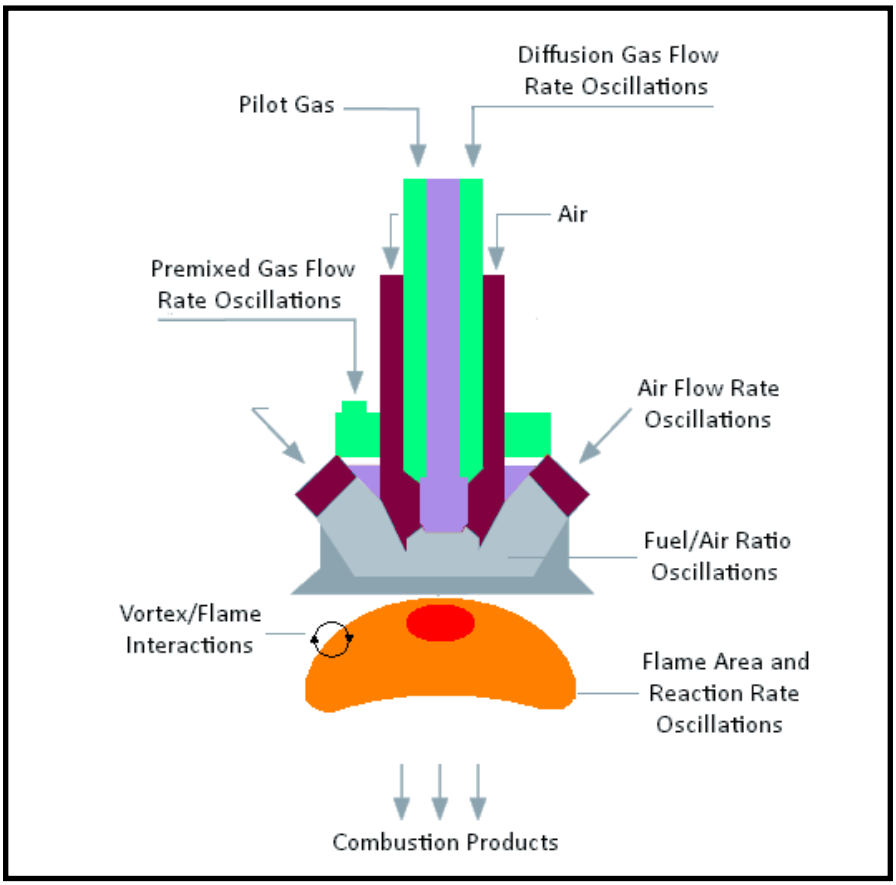


Fig.2- Flow and flame processes that can cause instability in MGT-70 combustor

Technical Measures: Identification, Analysis and Remedial Action

A study needed to be conducted to detect the roots of the phenomenon. Numerical 3D modeling were set up to analyze the combustion system with focus on gas diffusion mode. It was followed by developing a more simplified 1D code to analyze the combustion instabilities. Finally, a number of adroitly designed tests were run on-field to practically verify the findings out of the aforementioned analysis.

The studies showed that the major part of the problem arises from the wrong fuel-air mixture ratio and subsequent out of position flame and interactions between them. It all ended in an adverse combustion dynamics around the critical load, in which, longitudinal waves in the humming area, invariably occurred at a specific frequency associated with the natural acoustic mode of combustor.

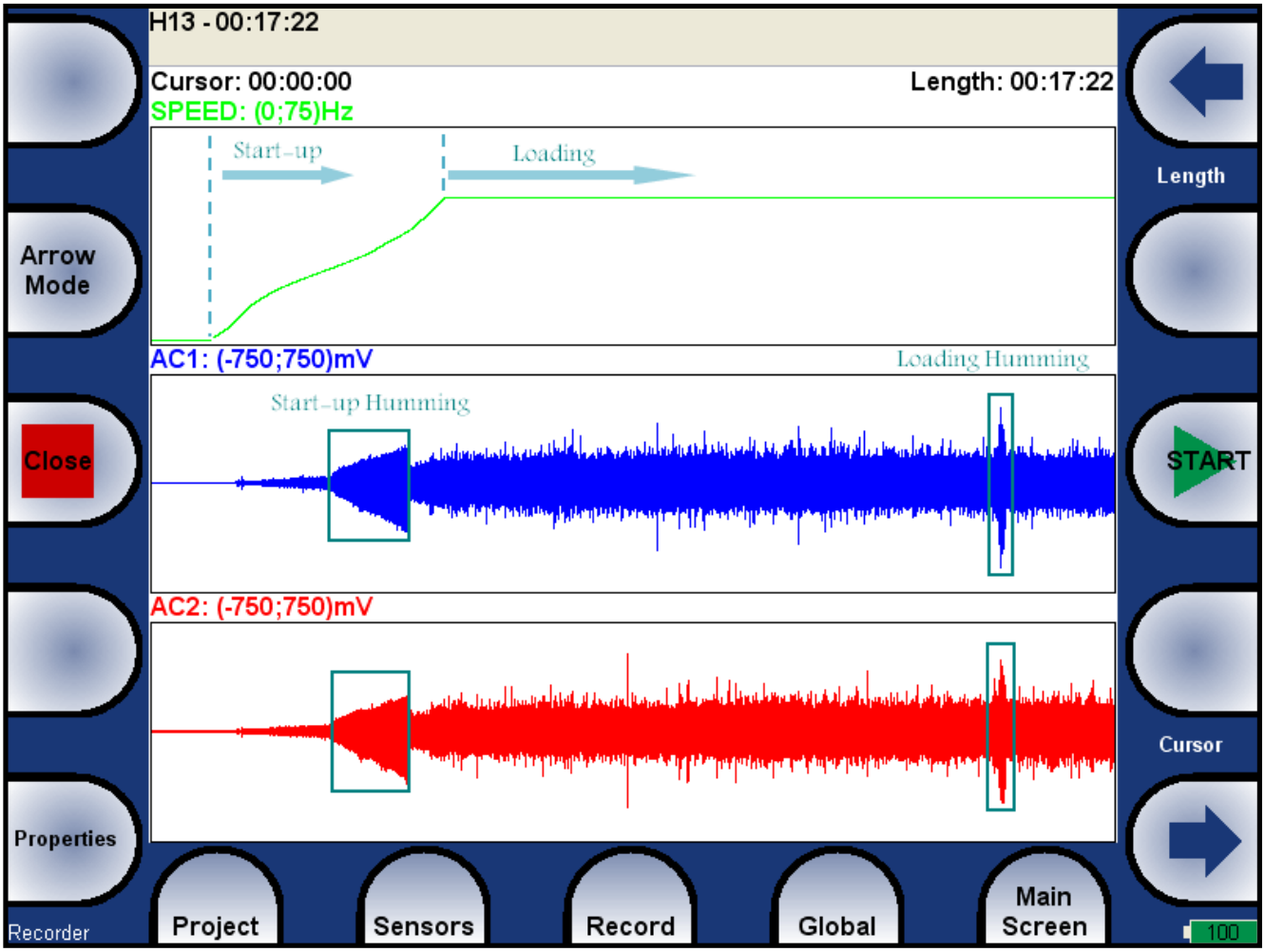


Fig.3- Dynamic Pressure Signal from Start-up and Humming Occurance Zones - Signal Recorded by Adash VA4 Vibration Analyzer

On-field observations showed that the adverse humming occurred during start-up and loading, regardless of the ambient tempera

ture for both cold and hot conditions. Based upon the data gathered from the humming differential pressure sensors, it was then deduced that the humming mechanism is the same for all units independent of ambient temperature and running conditions.

To modify the fuel-air ratio in the vicinity of the critical load for humming, there are two imaginable approaches: Manipulating the fuel flow or controlling the air flow through IGV positioning. The former, is hard-to-implement, mostly because of its close interconnection with other control logics and the narrow range between maximum and minimum openness position of the fuel valve. The latter is considered feasible, but yet needs to be done, following well-planned tests and a demanding practical validation process. To bypass the critical point, IGV was manually switched to a more open position, sufficiently below the critical load and kept that way until the critical load was well passed.

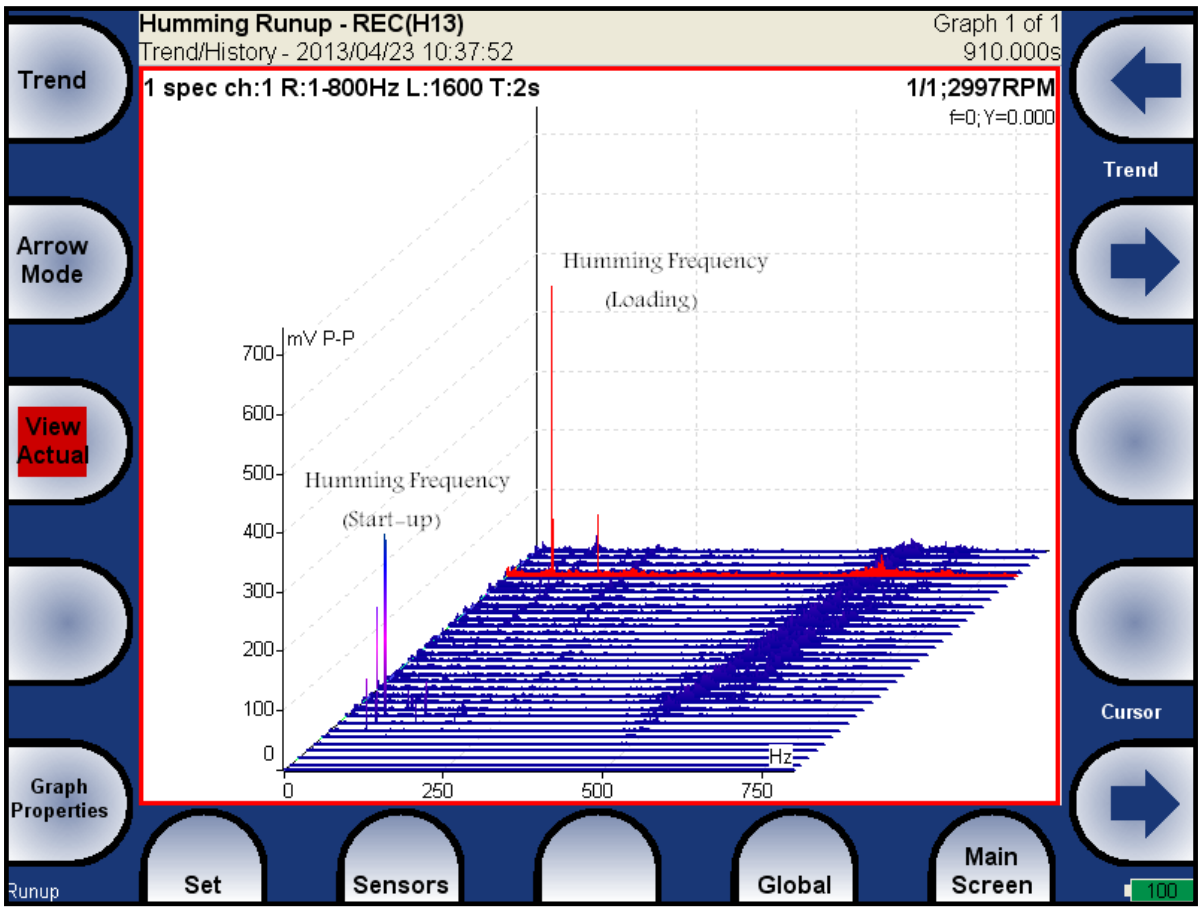


Fig.4- FFT Transform of Dynamic Pressure Signal

After getting sufficiently away from the critical load, IGV was made to restore the normal position and continue normally. After implementation of designed tests, the appropriate loads to start and stop this manual process and the effective IGV openness rate to successfully bypass the critical load for humming were determined. Humming level successfully returned to normal (differential pressures as low as 15 mbar) and to undermine the humming in all the units, the manual process is supposed to be fed into the automatic control system.

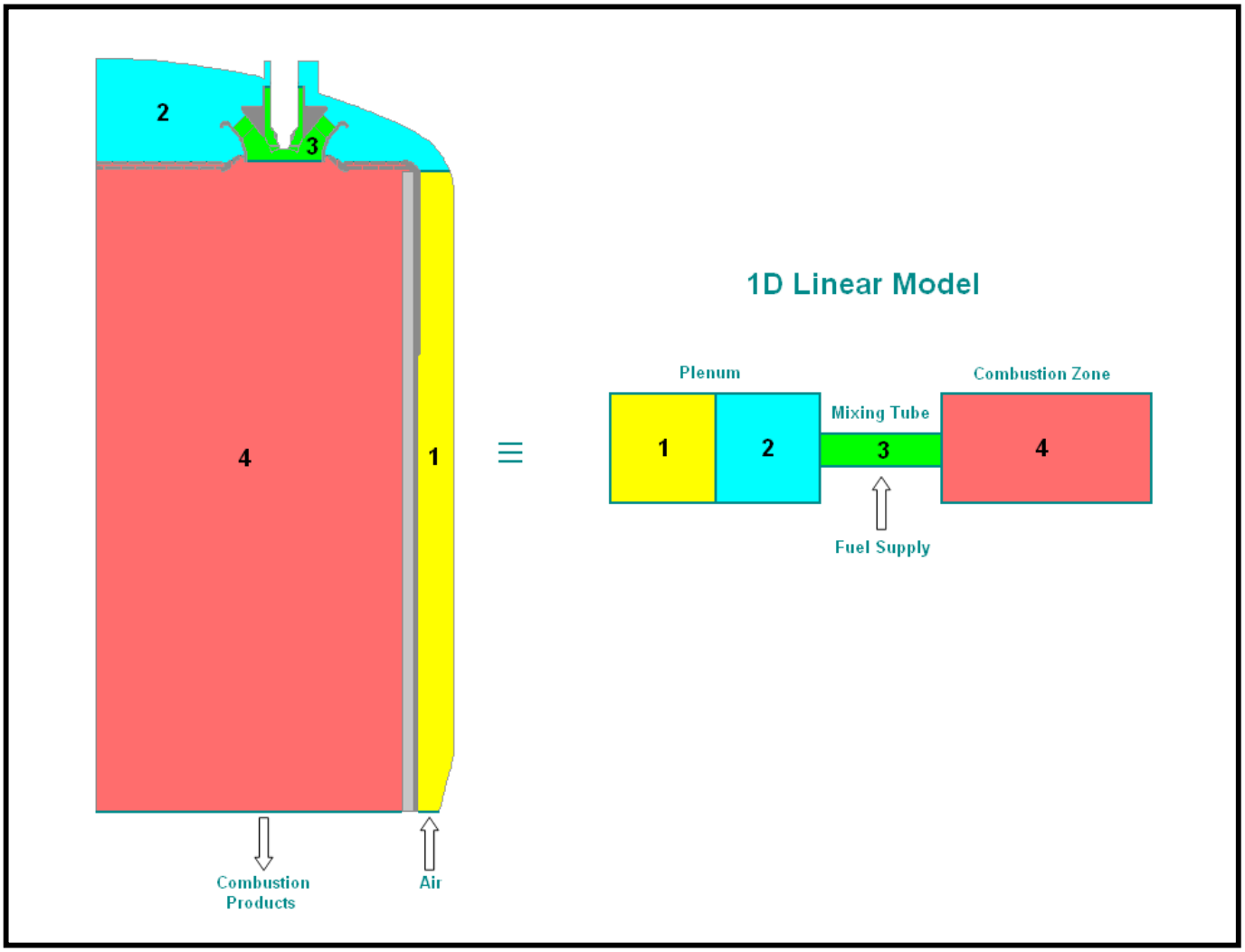


Fig.5- Correspondence between 1D instability code and MGT-70 combustor

Conclusion

The humming problem is typical of MGT-70 gas turbine at certain loads and further, at a certain speed at the start-up. Thorough investigations showed that through diluting the fuel-air mixture, one can overcome the flame interaction problems and undermine the humming phenomenon. Pursuant to a number of well-designed tests, practical data to manipulate IGV position effectively to bypass the critical humming were extracted. The procedure was successfully implemented on a number of units to ensure the flawless effectiveness and it is fed into the automatic control system to eliminate extra manual efforts required of the operators.

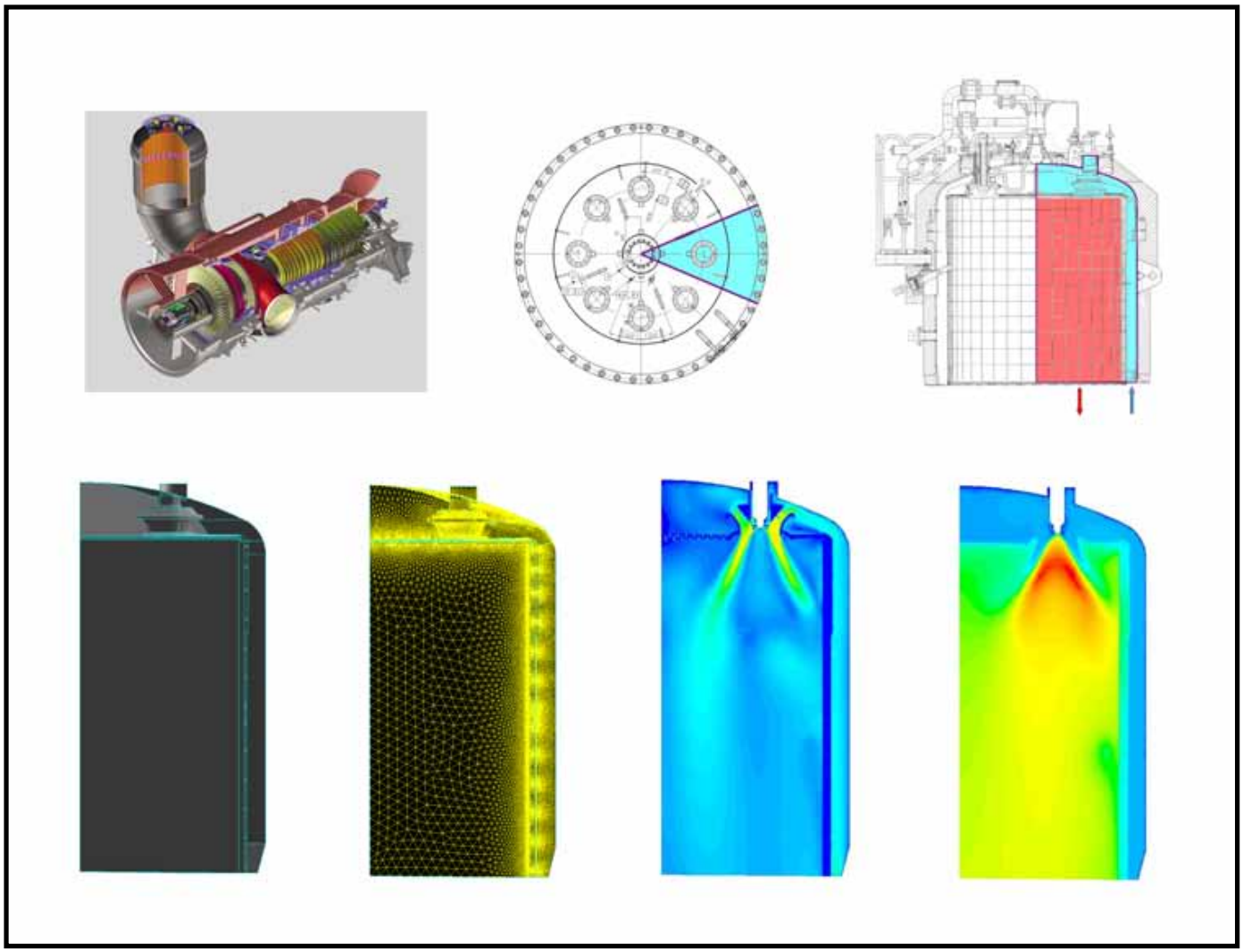


Fig.6- CFD Simulation of Reactive Flow

6-Cool-down Rotor Turning, Back on an Even Keel

Introduction

The rotor turning mechanism is intended to provide the machine with a smooth and uniform cooling rate after a normal or emergency shut-down. Furthermore, when there is a need to restart the machine after a rather long period of downtime, turning mechanism serves to rotate the shaft train for a few hours so as to stabilize the shaft line and prepare the machine for a new start-up. Fig.1 shows the Pelton wheel mechanism employed to serve this purpose.

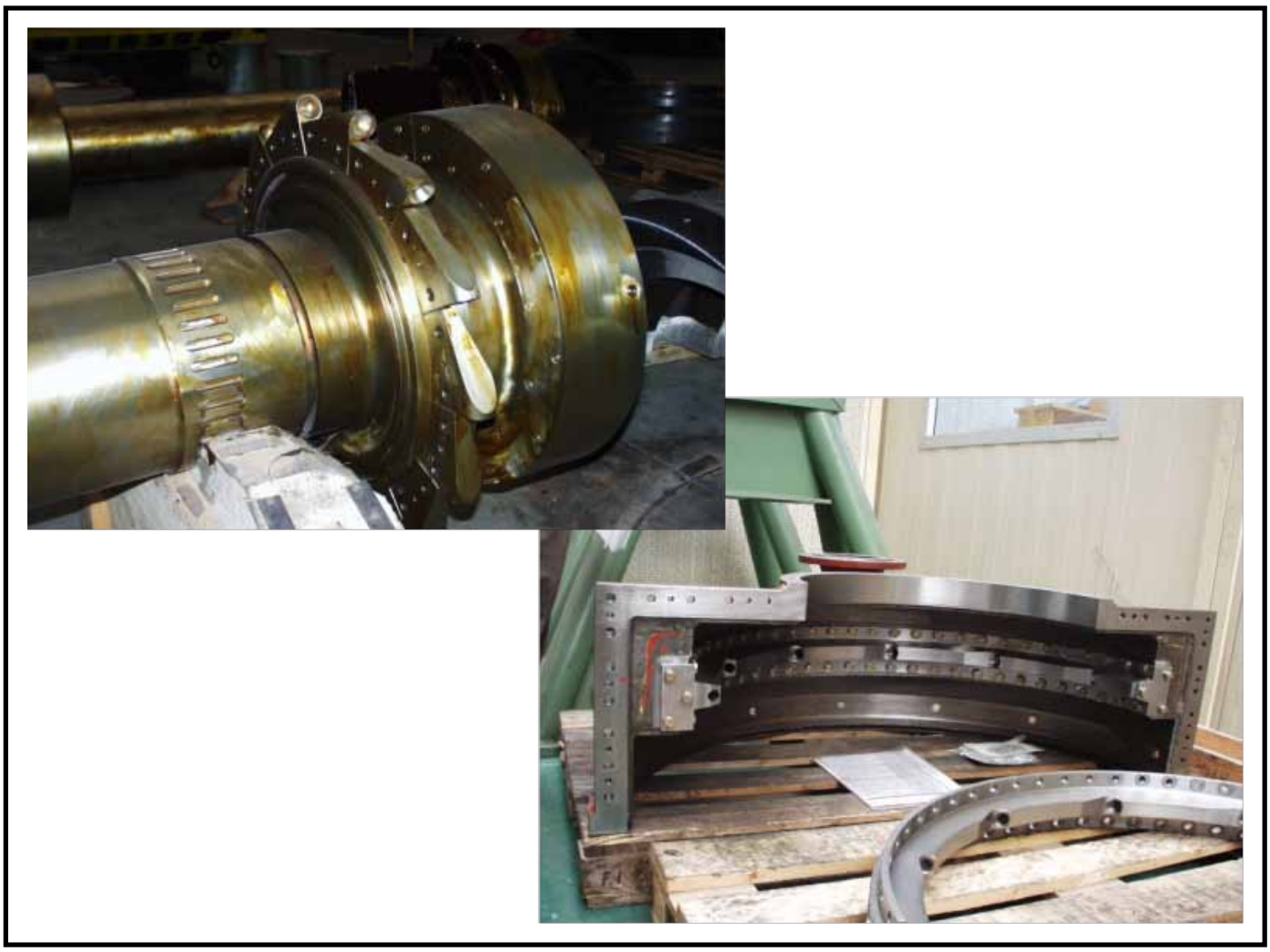


Fig. 1 Pelton blades mounted onto the Intermediate shaft and the oil injecting device fixed onto the stator cover

Once assembled, the oil supplied from the upper duct of the cover can be injected toward the Pelton blades as shown in fig. 2 and rotate the shaft train with a speed of around 100 RPM (normally some where between 80 to 120 RPM).

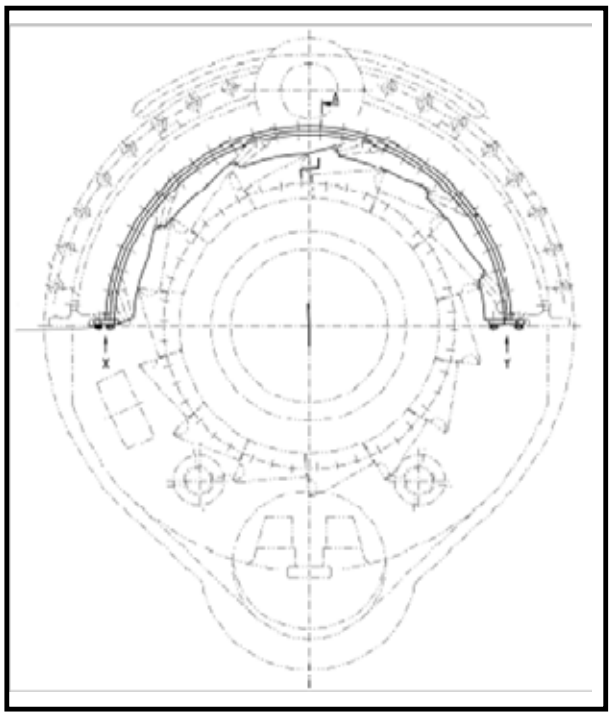


Fig. 2- Assembled turning mechanism and oil jet injection through the 6 nozzles toward the Pelton Blades

Problem Description

This mechanism, also very simple and straightforward, may prove ineffective in some occasions for the following reasons:

1- Assembly tolerances leave enough room for an axial mismatch of 0 to around 2 mm between the nozzles and the spherical buckets of the Pelton wheel. The radius of the spherical portion is 20 mm and a mismatch of say 1 to 2 mm can substantially impair the efficiency of the mechanism.

2- As the shaft rotates at a higher speed, the impact of the oil jet on the Pelton blades loses strength because of the reduction in relative speed between the jet and the blades' buckets. This is an intrinsic shortcoming of this mechanism that makes the design highly sensitive to the number of blades, oil flow rate and oil density.

3- This mechanism is based upon the impact of the freely flowing oil jet to the buckets. So, formation of foam in the oil which in turn can lead to a lower density and thereby lower momentum of the oil jet is inevitable. This makes the design heavily dependent on the oil tank capacity (size, vents and cooling) to give the returning foamy oil enough time to cool down and release the bubbles.

4- Oil temperature can lead to fluctuations in the density both directly and indirectly (by increasing the potential for cavitations and foam formation). So, again, oil tank and cooling design can dramatically affect the efficiency of the turning mechanism. Furthermore, the pumping system should be capable to provide the required function in a wide range of design parameters.

It has actually been the case in a number of power plants that this mechanism has failed to increase the speed of the shaft train to the required level. If not fixed promptly, this can lead to non-uniform cooling of the machine and residual bending in either shaft or stator casings and /or shaft-bearing jamming. As simple as the problem may appear, the consequences may lead to substantial downtime and cost.

Remedial Action

A fundamental solution to the aforementioned problem is making use of a mechanism, independent on the main lube oil system. A gear rim is bolt-assembled onto the intermediate shaft instead of the Pelton blades. It is driven by a pinion, getting its power from an independent hydro-motor.

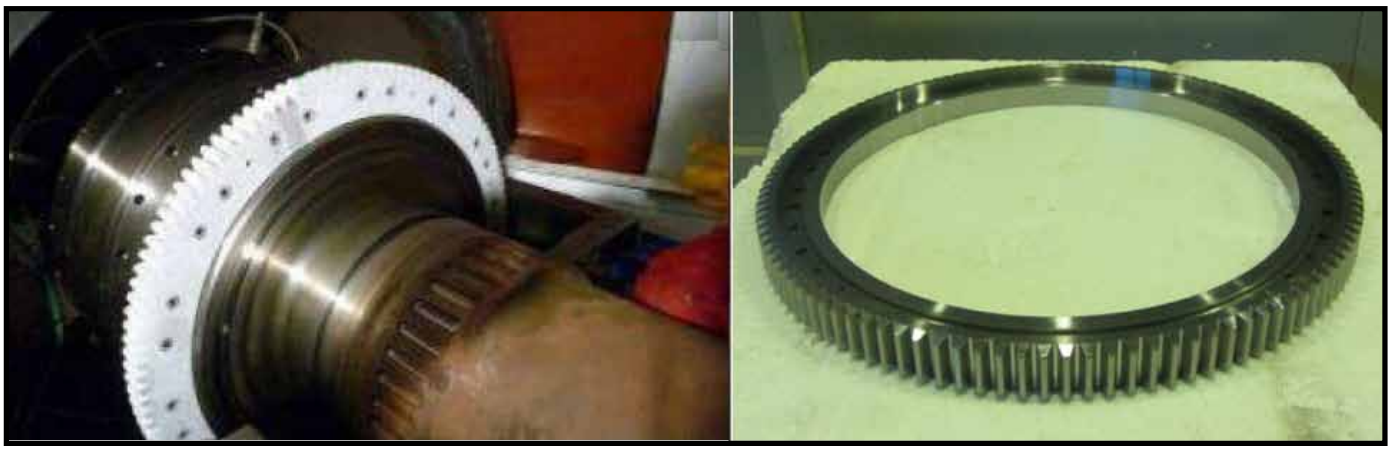


Fig. 3- Assembled gear rim onto the intermediate shaft instead of the Pelton blades

The bearing pedestal cover should be also modified to accommodate the hydro-motor, its integral pinion and the relevant engaging mechanism. This modified version is shown in fig. 4.

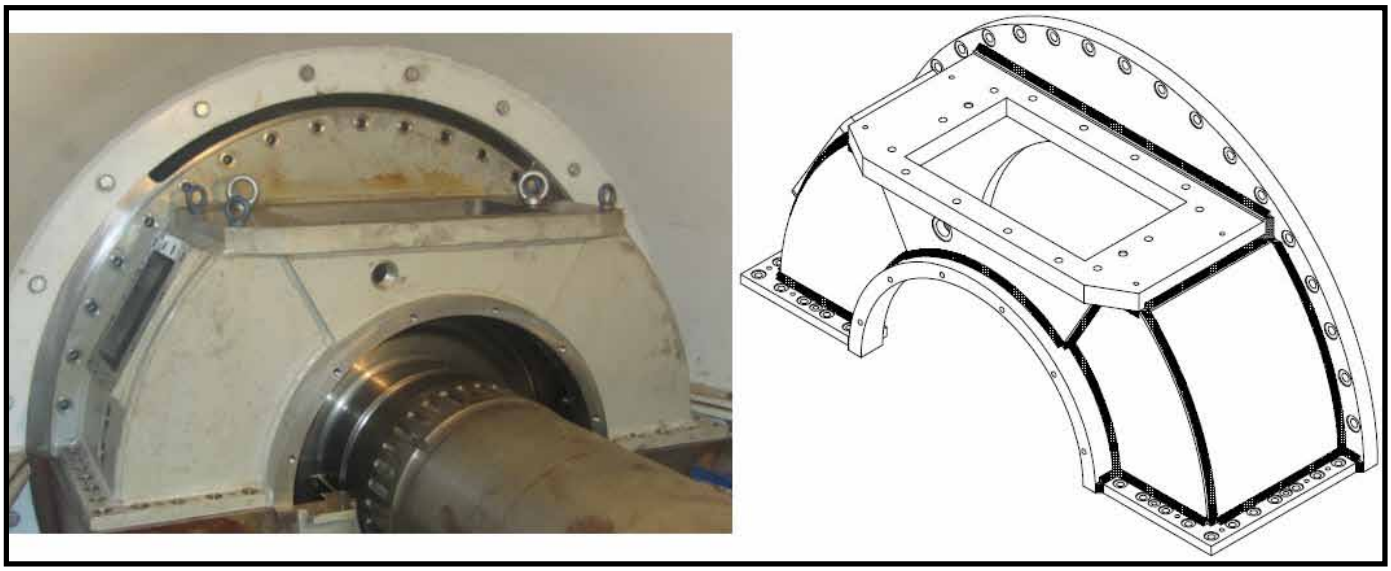


Fig. 4- Modified Bearing Pedestal Cover to accommodate the new turning mechanism

There is an engagement mechanism to engage and disengage the turning pinion. Furthermore, with a built-in control system, this mechanism, checks if the power transmitting pinion is engaged with the gear rim appropriately. This has to be guaranteed at both start-up from stand-still (zero speed) and shut down of the machine (Shaft speed of around 150 RPM). The latter is provided, by giving the pinion pitch diameter a linear speed equal to that of the gear rim pitch diameter. This has been depicted in fig. 5.

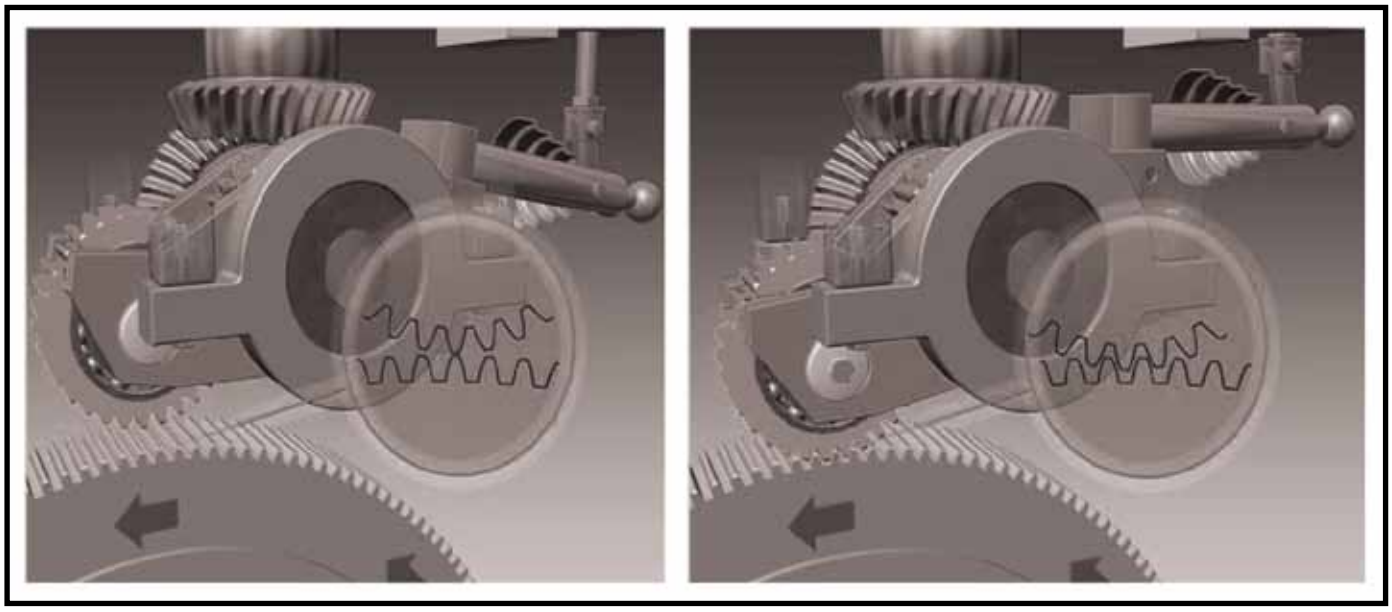


Fig. 5- Engagement checking process

An independent power pack provides the hydro-motor with its required flow and gives the driving mechanism a capacity to apply a fixed maximum torque of around 1000 Nm regardless of the existing conditions for the main lube oil, and provide the shaft train with an always achievable speed of around 100 RPM.

Fig. 6- The complete assembled system; main flow pipe to the hydro-motor and the engagement mechanism are shown

Conclusion

The original straightforward design of the turning mechanism has brought about a few problems, solved by replacing it with an independent hydraulically driven pinion-gear mechanism. This provides a smooth turning for the shaft train with a rather constant speed, regardless of the main lube oil physical parameters. The appropriate engagement of the driver pinion with the gear rim assembled onto the intermediate shaft is provided through an integral engage-disengage mechanism built in the new system.

7- MAPNA Gas Turbine Simulator MGTS-70.1

Introduction

MGTS-70.1 is a product of MAPNA Turbine Company that is capable to simulate MGT-70 gas turbine in thermal power plants. This simulator is a strong tool for monitoring a wide range of data and also for data acquisition as well as data storage. High accuracy models have been used to simulate the turbine itself and its auxiliary systems. Turbine governor system and distributed control system (DCS) are designed in an environment which enables the operator to follow the turbine logic system in start-up and normal operation conditions online.

Having a simulator is deemed to be essential to serve several reasons including but not limited to the following:

1. It enables the companies that are active in power plant projects to test the turbine new logic and see the results before implementing it on turbine governor or DCS system. This would increase the reliability and prevents undesirable costs resulting from practical trial and error process.

2. As a valuable educational tool, it can help turbine experts have a better understanding of the turbine logic and use it for fault diagnosis purposes.

3. It could be used to train the turbine operators in an interactive virtual environment that closely approximates the real conditions and can serve to improve the required skills to make the best decisions responsively enough at the times of need.

4. Enables simulating the extremely dangerous operating conditions, even those which might take place few and far between during the turbine life cycle and get an idea of what turbine response would be like in those conditions.

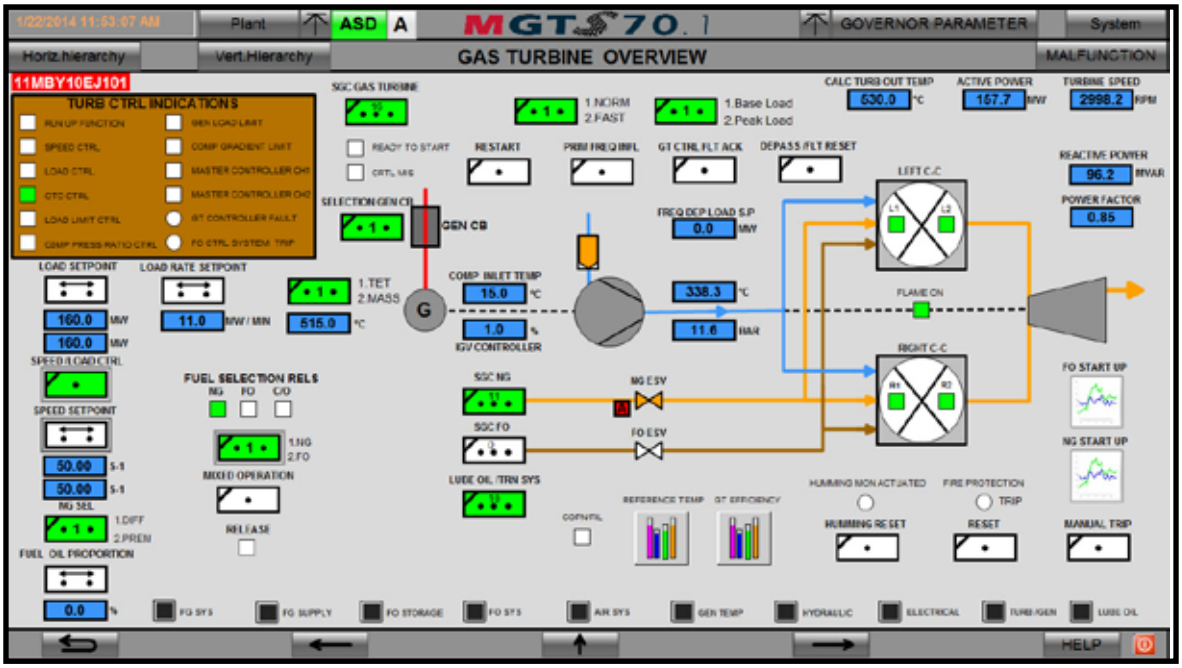


Fig.1 -HMI overview

Technical specifications

Graphical software

For monitoring, data storage, and data acquisition, WINCC software has been used. Graphical features in WINCC have been designed to accurately duplicate the TXP system (Siemens standard package) deployed in gas turbine power plants.

Hardware package

This simulator can operate in PCs and portable computers. No specific hardware is necessary.

Logic

In order to implement the Turbine Governor and DCS LOGIC, STEP 7™ software package has been used that enables the user to have access to the logic at the same time as they operate the simulator, just like a real power plant system.

Running time

This simulator is capable of running in “real -time” mode. For instance, the time necessary to start a gas turbine up in a real power plant is equal to that in MGTS-70.1 simulator.

Processing the Turbine Logic

One other strong point of MGTS-70.1 simulator is its WINAC processor. It converts PC operating system to a real-time or simultaneous processor. In other words, it converts the PC to a real flawless PLC.

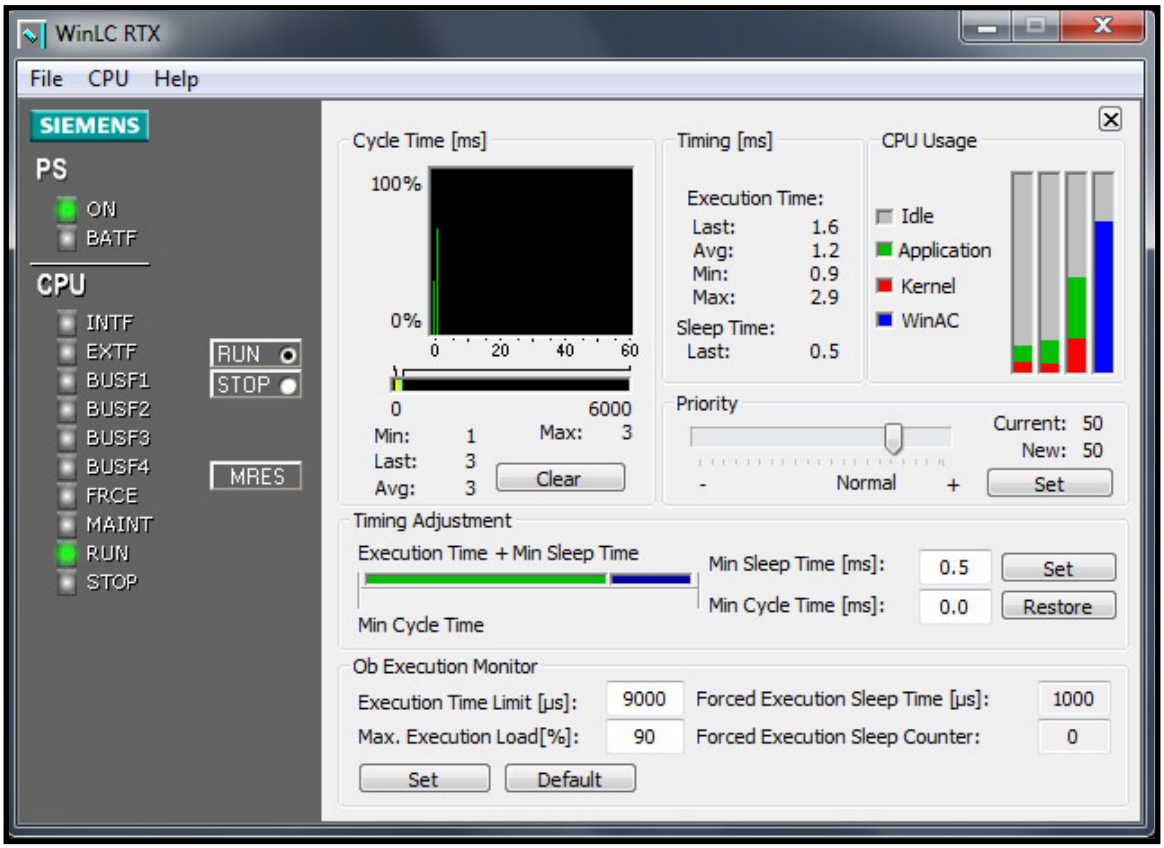


Fig.2 -WINAC run time overview

Modeling

An accurate thermodynamic model of turbine operating cycle has been used which is one of the latest products of MAPNA Turbine company. This product is known as MGTPC and has been developed by the design department at MAPNA Turbine. This software employs Turbine and Compressor characteristic curves which had been derived from experimental tests.

Using an iterative algorithm, the package detects the operating point of the gas turbine and computes the turbine outputs by doing component matching between the gas turbine components (compressor, combustion chambers, and expander). This software is capable of simulating the gas turbine behavior in a wide range of operating conditions, including part load and base load in different environmental conditions.

The MGTPC software has been developed using FORTRAN and has the ability to get the characteristic curves of the compressor, turbine, combustion chamber, and the generator as inputs and also the operational conditions of the gas turbine. Furthermore, it has the ability to warn the user of the faulty inputs and the capability to take the turbine aging into account while running the calculations. It is possible to use different fuel compositions in the model with accurate results. The output of the model has been validated by comparing the software outputs with field data and has reflected a good conformity.

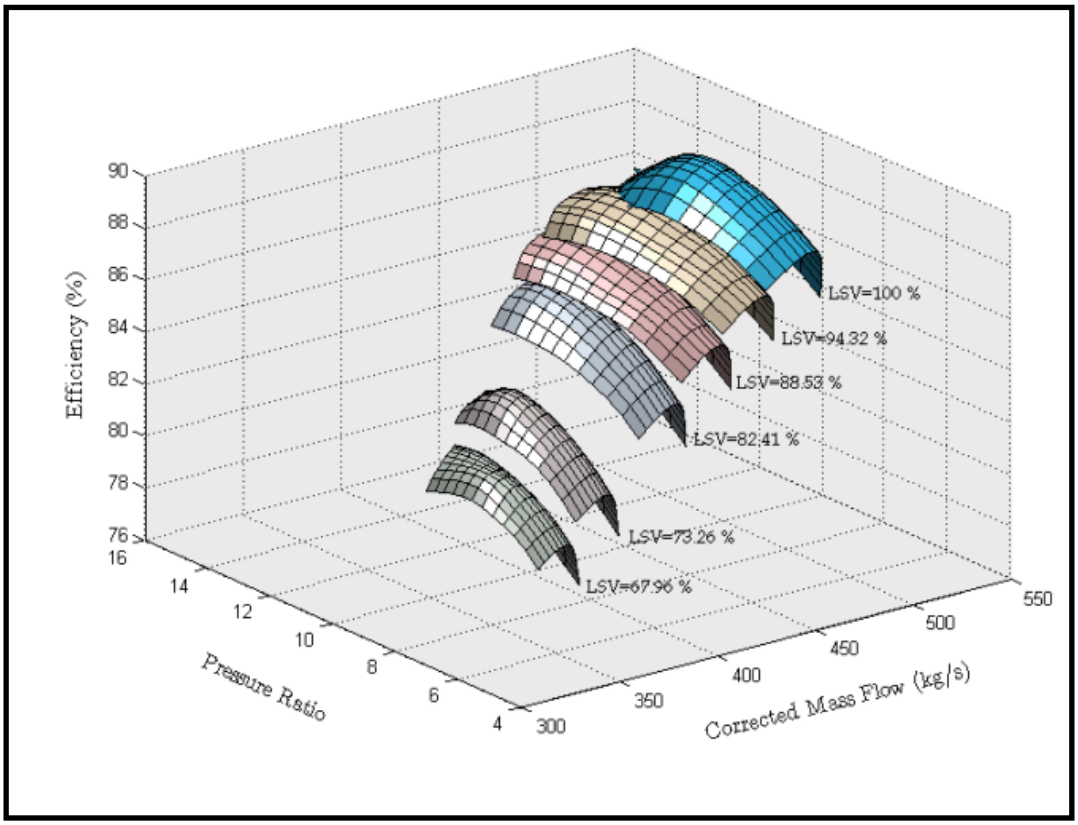


Fig.3 -4D compressor characteristic curves

Simulation and control response of gas turbine

There are several control philosophies to control gas turbines in operation. This simulator is capable to analyze and model different control philosophies, including: Constant Turbine Outlet Temperature, Constant Turbine Inlet Temperature and Constant Inlet Guide Vane Position. MGTPC is capable to simulate MGT-70 Gas turbine when two out of five variables: turbine outlet temperature, inlet guide vane position, turbine inlet temperature, fuel mass flow and output power, are known.

Simulating the different fuels used in gas turbine (fuel gas, fuel oil ...)

Considering the fact that fuel composition and characteristics could vary due to changing fuel supply sources or the tolerance in fuel specifications for different seasons, one should be able to analyze gas turbine performance and output by having fuel composition and heat value available. MGTPC is not only capable to model standard fuels used in gas turbines but also able to deal with fuels whose specifications have been customized by users.

Simulating the lubrication oil system

Lube oil skid has been simulated by using PIPENET™ which was validated using site data. Furthermore, in order to use lubrication oil model in simulator software, all the equations have been programmed using MATLAB™. In this program, inputs of the model include: operation mode of the system, pump characteristic curves, on/off signals of the pumps and on/off signals of the exhaust fans. Outputs of the model are: pressure and flow rates at each point of the system.

Simulating the fuel gas system

This model has been developed through programming using MATLAB™. In this program, ANSI/ISA-75.01.01-2002 has been taken use of to model fuel valves (Including shut off valve, fuel control valves, and pilot control valves). In order to model pressure drop in the gas filtration section, a quadratic equation has been used. An algorithm has been deployed to search for system operating point given the openness positions of main and the pilot control valves and the combustion chamber pressure. The outputs of the system are pressure and mass flow rate in different parts of the system. Simulation results were validated using site data and the average error was below 2% in control valve opening position.

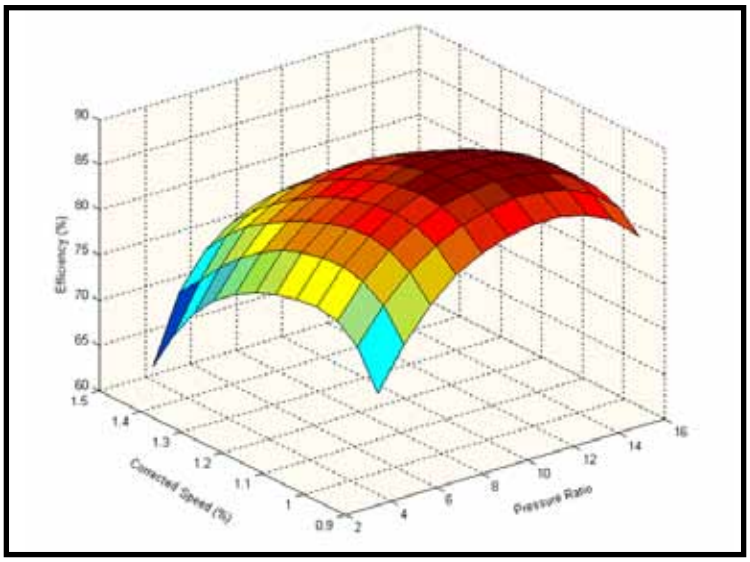


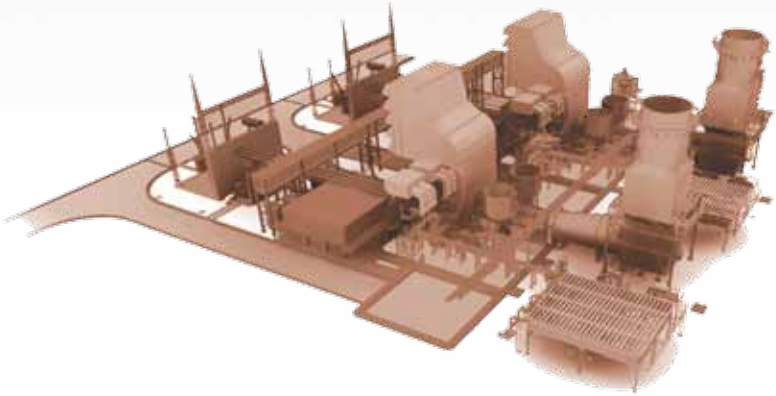
Fig.4 -Turbine isentropic efficiency 3D curve

Advantages:

1. Online monitoring of the turbine operating point shown on turbine characteristic curve
2. Access to the turbine governer logic similar to the real control system format
3. Access to the turbine DCS logic in Siemens TXP format
4. Ability to change, test, and download the turbine logic
5. Ability to change parameters of the turbine governor
6. Simulation of gas turbine operation in real time and customized time step modes
7. Alarm Logging system
8. Event Logging system
9. Ability to plot, log, and print all analog signals
10. Malfunction simulation ability
11. Online monitoring of operating points of pumps, fans, etc., shown on the corresponding characteristic curves
12. Responding to 16 users simultaneously for each server
13. Ability to connect several servers (e.g. combined cycle simulation)
14. Ability to save and re-use all signals without any restriction
15. Ability to set initial conditions
16. Customizing ability to meet customer needs

MGT-70.1

MAPNA GAS TURBINE SIMULATOR



Factory:
Fardis, Karaj - I.R.Iran.
Post code: 31676-43594
Tel: +98 (26) 36183364
Fax: +98 (26) 36612734

Head Office:
231 Mirdamad Ave. Tehran - I.R.Iran.
P.O.Box: 15875-5643
Tel: +98 (21) 22908581
Fax: +98 (21) 22908654

www.mapnaturbine.com
tr@mapnaturbine.com

The technical and other data contained in this Technical Review is provided for information only and may not apply in all cases.