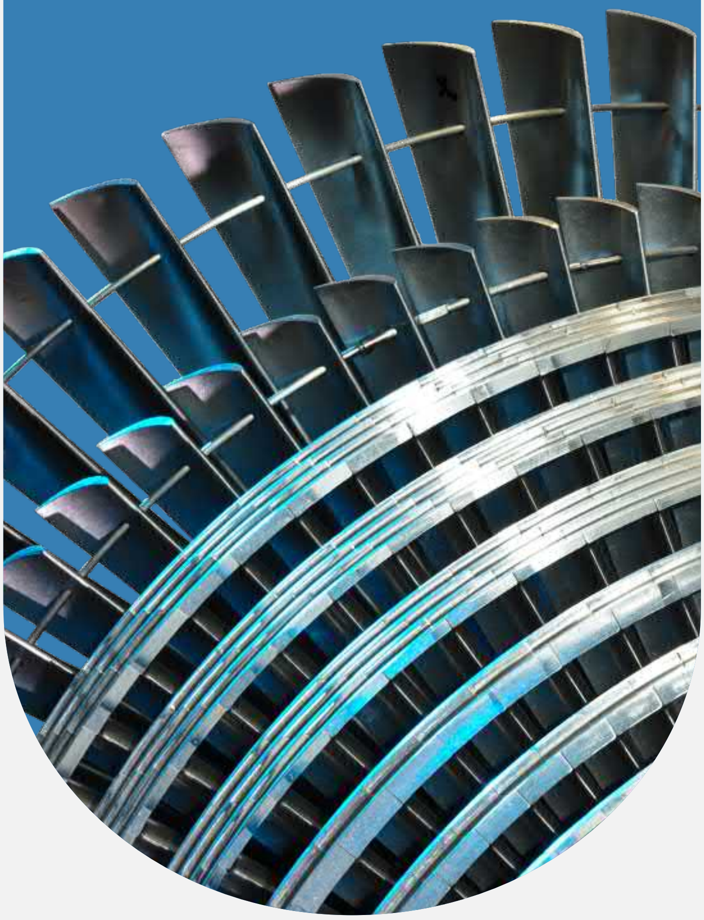

De Pretto industrie

Steam turbine retrofit and lifetime extension

An article published on
Industrial Plants magazine

“Case study
A major refinery in the Middle East region was experiencing severe problems with 2 backpressure-extractione steam turbines used to feed the refinery steam utilities lines as well as to generate power.”

Written by Edoardo Busato

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Steam turbine retrofit and life time extension

A complete engineering study with a root cause analysis has identified the possible causes of the performance limitations and has led to a retrofit solution to increase power output, efficiency, reliability and availability

Edoardo Busato , Regional Sales & Service Manager, MENAT Region
De Pretto Industrie

De Pretto Industrie is an Italian turbomachinery manufacturer. The company was established in 1885 and for more than 80 years has been part of leading global organizations. De Pretto Industrie Is today an Independent company acting as an Original Equipment Manufacturer (OEM) for new steam turbine generator sets up to 50MW but also as an independent Service Provider (ISP) of any rotating equipment manufactured by any OEMs in the market, thanks to its reverse engineering capabilities and its technical dept of 30+ engineers covering all key domains (thermodynamic/construction/instrumentation/system).

De Pretto Industrie has extensive engineering competence in repair and revamps of turbomachinery, developing customized solution for each product and make. One stop solution provider for any rotating equipment, repair in emergency situations, OEM-equivalent warranties as well as cost and lead time advantages are the main benefits we can provide our customers with. Innovative thinking is applied to manufacturing and upgrading of turbomachinery control systems according to the highest market standards, latest normatives and best practices.

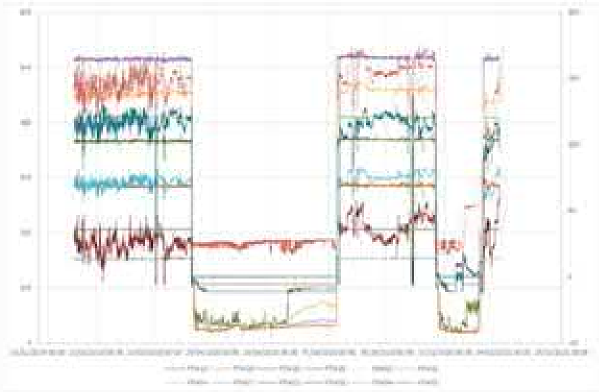
"De Pretto Industrie applies a customized and tailor-made approach on all its projects, but at the same time making sure the resulting capital and operating expenditures are minimized for the end-users

Case study

A major refinery in the Middle East region was experiencing severe problems with 2 backpressure-extraction steam turbines used to feed the refinery steam utilities lines as well as to generate power. DPI proposed to the end-user to perform a complete engineering study with a root cause analysis to identify the possible causes of such limitations and a retrofit solution to increase power output, efficiency, reliability and availability.

The thrust bearing of those units had been the main source of concerns since the initial installation, leading to frequent failures due to overheating, high vibration levels and, as a result, partial load operation with impacts on steam and power production. Thermal efficiency and reliability of the units were also affecting

LOAD CASE N°			1	2
Period – Start time / End time			01/01/2020 00:00 10/04/2020 20:00	14/08/2020 13:00 07/11/2020 10:00
Intermediate stop 1 Start time / End time			11/03/2020 16:00 11/03/2020 17:00	16/08/2020 12:00 16/08/2020 15:00
Intermediate stop 2 Start time / End time				17/10/2020 13:00 19/10/2020 08:00
Live steam				
— pressure	PPI414	bar a	121,9	121,8
— temperature	PTI413	°C	515,0	518,7
— mass flow	PFI401	t/h	145,5	158,0
Wheel chamber				
— pressure	PPI427	bar a	72,0	77,2
— temperature	PTI423	°C	449,7	460,5
Extraction				
— pressure	PPI423	bar a	36,7	36,8
— temperature	PTI420	°C	366,3	370,0
— mass flow	PFI402	t/h	25,2	38,5
Exhaust-steam				
— pressure	PPI434	bar a	15,4	15,3
— temperature	PTI425	°C	285,2	286,7
— mass flow	PFI403	t/h	116,6	116,2
Turbine speed	PSI402	rpm	8.196	8.198
Power at generator terminals	PEI432	kW	13.080	14.064



the normal operation, after 40+ years from initial installation.

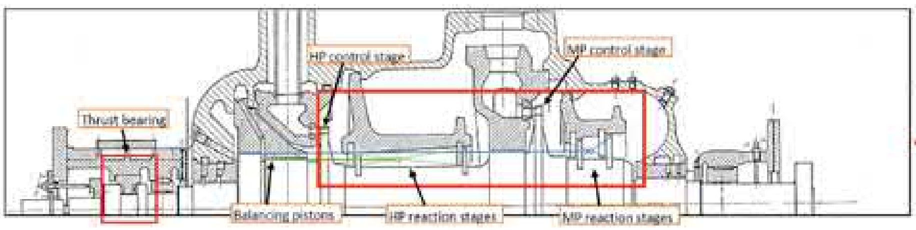
Engineering Study – Performance Analysis

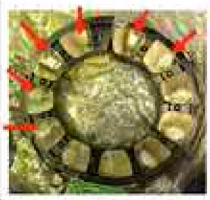
Data acquisition for thermodynamic assessment
The performance calculations are based on process values given by the Refinery. Engineering studies and performance analysis were carried out with the aim to acquire data for an accurate thermodynamic evaluation.

Assessment of thrust forces
The Refinery is reporting severe problems with the steam turbine thrust bearing: frequent faults because of overheating, vibration levels. As a result, machine is operated at partial load (around 15MW) while nominal power output is 21,5MWe. Modified bearings have been installed without considerable improvements. A first visual evaluation of the steam turbine layout shows that the balancing pistons are well contributing to balance the HP and MP reaction stages (according to the rule of "same dP-same average diameter"). While the additional thrust generated by the HP and MP control stages were not taken into consideration in the original design of the steam turbine. The thermodynamic simulations indeed confirmed the above assumptions are correct. In fact, control stages show a reaction grade of 15% for HP control wheel and 10% for MP control wheel which lead to a delta pressure on each control wheel and a corresponding thrust force.
If we consider those thrusts forces, the residual thrusts acting on the thrust bearing at full load are in the order of 50 ÷ 60 kN, towards the steam flow direction.
The thrust bearing on the active side has an area of 10,620 mm2; the specific pressure is consequently ≈ 5 ÷ 6 MPa, a much higher value than the one indicated in the original thrust bearing drawing (max 3.3 MPa).
From De Pretto Industrie design experience, this type of thrust bearings should be able to work up to 3.5 ÷ 4.0 MPa of specific pressure, before reaching the temperature limit values. The optimal working range to target in the design phase is up to 2 MPa.
This confirms the historical temperature behavior of the thrust bearing, which rises with the load until it reaches the limit value of 110 ° C, resulting on partial load operation of the steam turbine around 15 MWe.

Engineering Study - Rotodynamics

Consistency of original design
Rotordynamic calculation is required to accurately predict the location of the high speed and low speed shaft line later critical speeds. De Pretto Industrie engineering standards impose critical speeds to be located either 10% below operational speed or 15% above operational speed to ensure a stable behavior of the rotating equipment. Journal bearing clearances and oil film as well as supports stiffness are also taken into consideration in the overall calculation.
Results shown steam turbine first critical speed is well below critical operating range and second critical speed is well above the same. Intermediate shaft first





critical speed is inside the critical operating range. This could lead to vibration issues if the shaft is not properly balanced or if the alignment is not properly done.
Lateral analysis turbine side (high-speed shaft line) with new turbine bearings having 1,2‰ clearance. Improvements are visible:

- Steam turbine first critical speed is still well below critical operating range, and second critical speed is still well above the same.
- Intermediate shaft first critical speed is now outside the critical operating range (above operating speed +15%)
- Generator first and second critical speeds are between the 1x and 2x operational speed and outside the critical operating range.
- Intermediate coupling first critical speed is above 2x operational speed and just outside critical operating range.

Advantages of the Retrofit Solution

Upgrades of performances

- DPI is able to design and customize a retrofit solution in order to increase the thermal efficiency of the unit.
- Retrofit with performance improvement includes the full redesign of the steam path using latest advanced blade profile technologies with the following new internal parts to be manufactured accordingly:

a) New rotor and new stator blade carriers
The new internals, having foot print design to fit the existing turbine casing axial and radial constraints, will avoid major modifications. The steam path will be redesigned as follows:

- HP control stage: new design to r educe reaction grade and thrust forces
- HP blading section: 9 stages as the existing configuration
- MP control stage: will not be installed as not required
- MP blading section: 5 stages instead of then existing 3 stages

b) New balancing piston
New balancing piston, designed to better compensate the thrust forces of the blading and reduce the axial forces on the thrust bearing. If possible with the actual space constraints, spring loaded sealing rings will be used as an upgrade to improve ef ficiency and reliability

c) New HP and LP gland bushes
New HP and LP gland bushes designed to ensure proper leakage ratio. If possible with the actual space constraints, spring loaded sealing rings will be used as an upgrade to improve efficiency and reliability

d) New HP and LP journal bearings
New HP and LP jour nal bearings with required reduced clearances according rotordynamic design (1,2‰ clearance), designed to improve stability and oil flow, having oil orifice inside the bearing housing.

e) New thrust bearing
New thrust bearing, designed to withstand the axial forces all over the operating range of the turbine, avoiding overheating or load limitation

The retrofit will allow to upgrade quite considerably the power output and thermal efficiency, given the same load conditions, in detail:

- Nominal 21,5MWe case: actual required inlet steam flow of 192,24 t/h (almost never reached during plant life time) – retrofit solution 185,9 t/h
- Load case 1: actual measured power 13.080 kW – retrofit solution up to 14.415 kW (+10,2%)
- Load case 2: actual measured power 14.064 kW – retrofit solution up to 15.905 kW (+13,0%)

LOAD POINT			NAMEPLATE INLET COND.	NOMINAL 21,5 MWe	1	2
Live steam						
– pressure	PPI414	bar a	122,6	122,6	121,9	121,8
– temperature	PTI413	°C	520,0	520,0	515,0	518,7
– mass flow	PFI401	t/h	180,0	190,7	145,5	158,0
Wheel chamber						
– pressure	PPI427	bar a	83,0	87,3	69,8	74,5
– temperature	PTI423	°C	470,0	475,5	449,7	456,3
Extraction						
– pressure	PPI423	bar a	36,48	36,54	36,7	36,8
– temperature	PTI420	°C	353,8	352,7	358,7	356,2
– mass flow	PFI402	t/h	40,0	40,0	25,2	38,5
Exhaust-steam						
– pressure	PPI434	bar a	15,2	15,2	15,4	15,3
– temperature	PTI425	°C	255,3	249,6	271,1	268,6
– mass flow	PFI403	t/h	139,3	150,0	119,6	118,8
Turbine speed	PSI402	rpm	8.196	8.196	8.196	8.196
Power at generator terminals	**PEI432**	**kW**	**19.635**	**21.500**	**14.415**	**15.905**

As a result of the study, the retrofit project showed the following main benefits for the end-user:

- Higher Efficiency

With rising fuel prices and consumption and considering the increasingly stringent environmental regulations, the improved thermal performance of a steam turbine is a key factor to reduce the carbon foot print of plants and their OPEX

- Higher Power Output

The increasing demand for power puts pressure to the existing plants to increase capacity. With this retrofit solution, we have been implementing the latest technologies allowing for more power output with the same steam input and output configuration.

- Hligher Flexibility

With the increased shares of renewable sources, existing thermal plants must operate with higher flexibility. Combining latest engineering technologies and digital control systems, a retrofitted turbine can respond to the power demand fluctuation with high efficiency and minimal stress.

- Greater Reliability and Availability

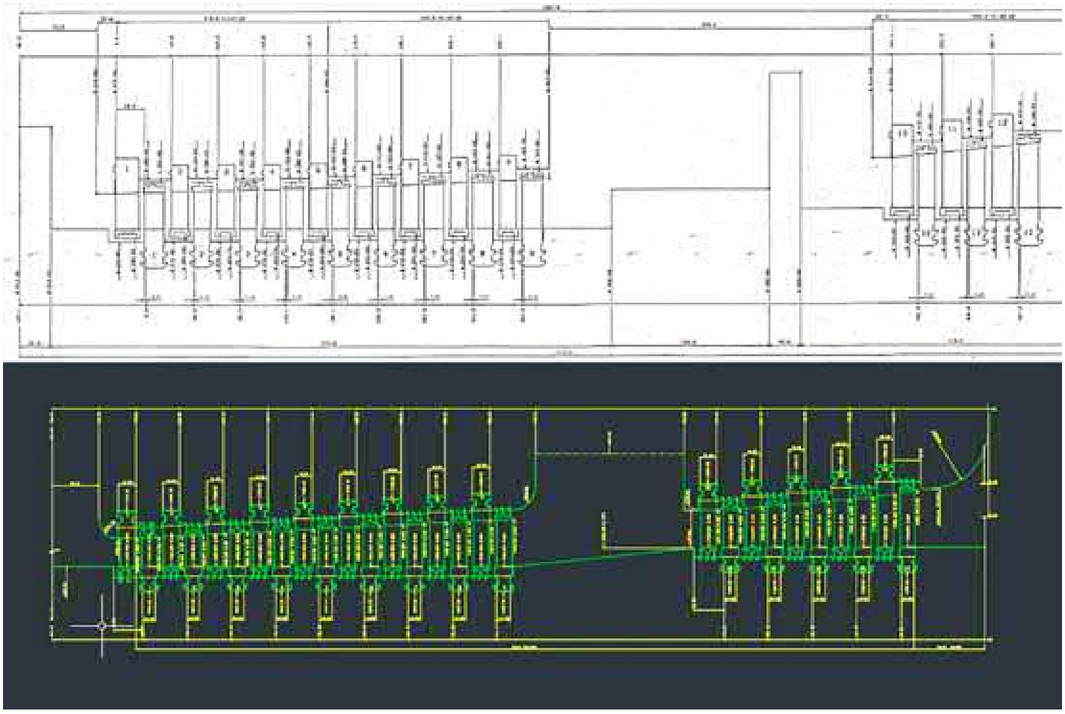
Operators are more and more looking to run their assets as long as possible avoiding/minimizing downtimes. By replacing old components with equivalent but more modern and robust ones, a retrofit not only reduces maintenance requirements and intervals but can also enhance the unit's lifetime.

- Profitability

The economics of retrofitting compare favorably with the cost of a new plant and the lead time is much shorter. Our services range from technical direction to complete turnkey installation (typically executed within a scheduled outage period). Return on investments are achieved within a couple of years and performance guarantees are provided.

Highlights of the Retrofit Solution

- Comparison between old steam path and new steam path



- Details of upgrades – blading and seals

BEFORE

AFTER

- Details of upgrades – valves and servomotors

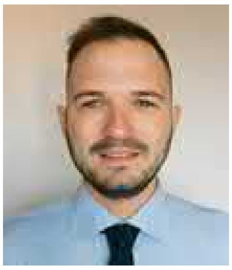
BEFORE

AFTER

- Details of upgrades – control system

BEFORE

AFTER



Edoardo Busato

Mr. Busato is the Regional Sales & Service Manager for De Pretto Industrie in charge of the MENAT region.
He has more than 12 years of experience in the turbomachinery industry, having acquired lots of knowledge in oil & gas and power generation field.
He started his carrier in the company as Service Engineer, with specialization in design, manufacturing, repairs, modifications and upgrades of rotating equipment. His responsibilities are now business development and project management, supporting customers all over the region with his team.

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