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RIGHT SIZE GAS TURBINES FOR UPSTREAM COMPRESSION SYSTEMS

WITH GT-SIM™ AND LIFE OF FIELD APPROACH

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KBC ADVANCED TECHNOLOGIES

In Upstream facilities, gas turbines are widely used to generate electricity and provide mechanical shaft power to operate production related equipment such as gas compressors and pumps. Gas turbine performance is dependent on several operational parameters which change across field life, for example, fuel gas composition, fuel gas temperature and pressure, inlet air temperature, pressure and relative humidity. Changes in fuel gas composition can affect power by 3-10% and an increase in inlet air temperature of 5.5°C or 10°F would reduce power by 3-5%. In this paper we discuss the adverse impact this has on capital costs and asset productivity, and show how a new generation of fully integrated simulation models can help avoid the twin pitfalls of either oversizing the equipment due to being too conservative, or constraining the system due to failure to account for all the factors.

Impact of gas composition and ambient condition to gas turbine performance

As gas is produced at different amounts from different sources over the life of a field, the gas turbine performance would constantly change. When the gas composition is lighter, more mechanical power is required to compress the gas. Fuel gas is often an offtake from the production gas, hence a source gas compositional change would affect the gas turbine performance.

The rise of ambient air temperature or humidity decreases the air density leading to lower gas turbine air intake which reduces the gas turbine's performance. Both of the conditions caused by ambient conditions could be overcome by the installation of turbine air inlet cooling or conditioning facilities, however this option may not always be feasible for upstream floating facilities such as FPSOs (Floating Production, Storage and Offloading) or FLNGs (Floating Liquefied Natural Gas) due to deck space limitation.

Gas turbine modelling challenges

Simulating gas turbines is traditionally disintegrated from processing facilities. In addition, the variations in fuel compositions and ambient air conditions are usually not accounted for. This disjointed method of modelling would potentially lead to significant production losses, power shortages, gaslift shortages and operational issues such as the examples below:

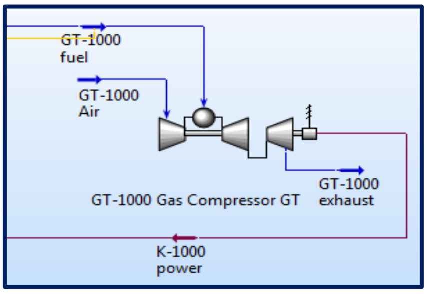
- A Canadian FPSO's gas turbine system was 40% underdesigned on gas handling and power. A $750 million retrofit was required and there was a 3 year delay to achieving target NPV (Net Present Value).

- A UK FPSO required an additional 4th Gas Turbine package as there was a further 30% power requirement due to variation in production and fuel gas compositions. This led to $350 million in delayed production and cost overrruns.

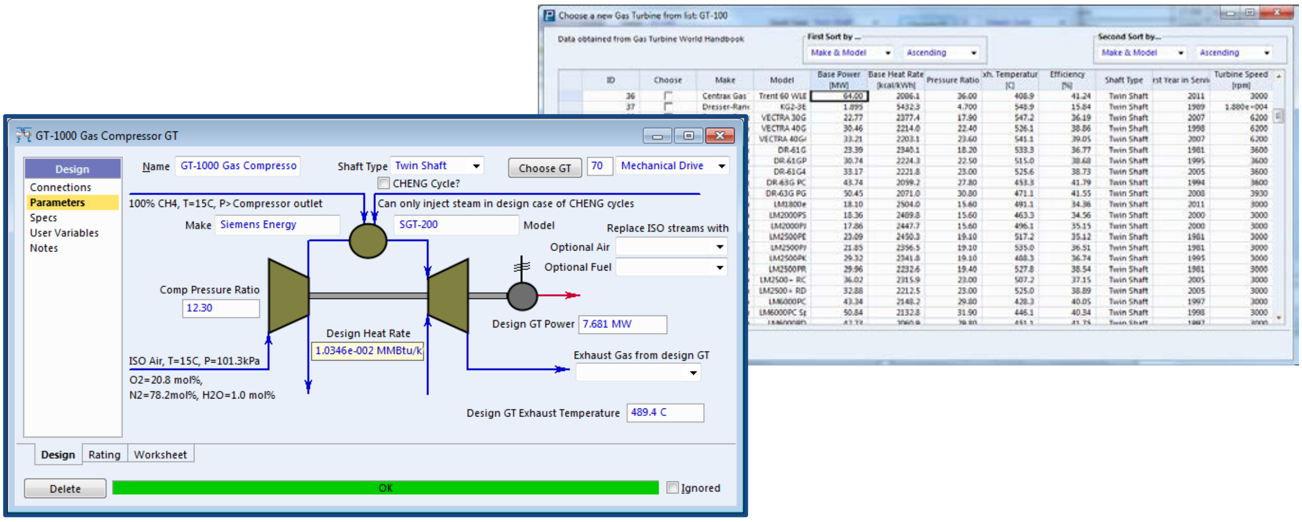
In the past, building a gas turbine model in a process simulation environment was a tedious procedure as it required the combination of three individual unit-operations; air compressor, combustor and expander in the process flowsheet. When conducting gas turbine sizing sensitivity analysis, several inputs need to be painstakingly updated and verified. This older practice is inefficient and susceptible to human errrors. Running parametric case studies was also time consuming and onerous, and therefore the full range of options are rarely considered systematically.

GT-SIM – A New Technology

GT-SIM, an advanced gas turbine simulation model from KBC, can be integrated with processing facilities simulation in Petro-SIM™ to model the gas turbine performance across field life at the feasibility level onwards. The gas turbine simulation integrates the compositional, pressure and temperature variations of both the export gas and fuel gas streams. Average monthly relative air humidity and ambient air temperatures could be included in the model if these parameters change significantly across the different seasons.



GT-SIM unit operation



Data obtained from Gas Turbine World Handbook

First Sort by ... Make & Model Ascending

Second Sort by... Make & Model Ascending

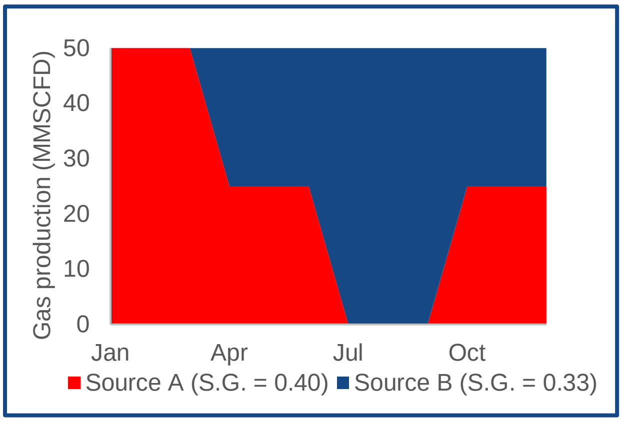
ID	Choose	Make	Model	Base Power [MW]	Base Heat Rate [kcal/kWh]	Pressure Ratio	xh. Temperatur [C]	Efficiency [%]	Shaft Type	rst Year in Servi	Turbine Speed [rpm]
36	☐	Centrax Gas	Trent 60 WLE	64.00	2086.1	36.00	408.9	41.24	Twin Shaft	2011	3000
37	☐	Dresser-Ranc	KG2-3E	1.895	5432.3	4.700	548.9	15.84	Twin Shaft	1989	1.880e+004
			VECTRA 30G	22.77	2377.4	17.90	547.2	36.19	Twin Shaft	2007	6200
			VECTRA 40G	30.46	2214.0	22.40	526.1	38.86	Twin Shaft	1998	6200
			VECTRA 40G	33.21	2203.1	23.60	541.1	39.05	Twin Shaft	2007	6200
			DR-61G	23.39	2340.1	18.20	533.3	36.77	Twin Shaft	1981	3600
			DR-61GP	30.74	2224.3	22.50	515.0	38.68	Twin Shaft	1995	3600
			DR-61G4	33.17	2221.8	23.00	525.6	38.73	Twin Shaft	2005	3600
			DR-63G PC	43.74	2099.2	27.80	453.3	41.79	Twin Shaft	1994	3600
			DR-63G PG	50.45	2071.0	30.80	471.1	41.55	Twin Shaft	2008	3930
			LM1800e	18.10	2504.0	15.60	491.1	34.36	Twin Shaft	2011	3000
			LM2000PS	18.36	2489.8	15.60	463.3	34.56	Twin Shaft	2000	3000
			LM2000PJ	17.86	2447.7	15.60	496.1	35.15	Twin Shaft	2000	3000
			LM2500PE	23.09	2450.3	19.10	517.2	35.12	Twin Shaft	1981	3000
			LM2500PJ	21.85	2396.5	19.10	535.0	36.51	Twin Shaft	1981	3000
			LM2500PK	29.32	2341.8	19.10	488.3	36.74	Twin Shaft	1995	3000
			LM2500PR	29.96	2232.6	19.40	527.8	38.54	Twin Shaft	1981	3000
			LM2500+ RC	36.02	2315.9	23.00	507.2	37.15	Twin Shaft	2005	3000
			LM2500+ RD	32.88	2212.5	23.00	525.0	38.89	Twin Shaft	2005	3000
			LM6000PC	43.34	2148.2	29.80	428.3	40.05	Twin Shaft	1997	3000
			LM6000PC Sp	50.84	2132.8	31.90	446.1	40.34	Twin Shaft	1998	3000

Name: GT-1000 Gas Compresso
Shaft Type: Twin Shaft
☐ CHENG Cycle?
70
Mechanical Drive
100% CH4, T=15C, P>Compressor outlet
Can only inject steam in design case of CHENG cycles
Make: Siemens Energy
Model: SGT-200
Replace ISO streams with
Optional Air
Optional Fuel
Comp Pressure Ratio: 12.30
Design Heat Rate: 1.0346e-002 MMBtu/k
Design GT Power: 7.681 MW
ISO Air, T=15C, P=101.3kPa
O2=20.8 mol%,
N2=78.2mol%, H2O=1.0 mol%
Exhaust Gas from design GT
Design GT Exhaust Temperature: 489.4 C

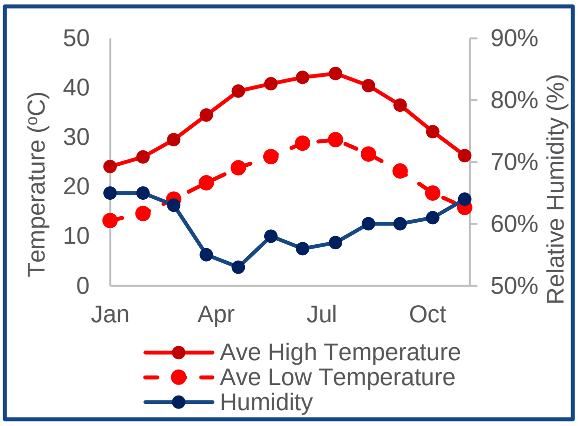
GT-SIM input page

Gas turbine design specifications from the Gas World Turbine Handbook are readily availlable as a built-in database in GT-SIM. In the below sample case, the design data of Solar Centaur 40 and Solar Centaur 50 Twin shaft gas turbines are referred to.

The below variations of production/fuel gas compositions and ambient conditions (Middle East) are evaluated:



Monthly target gas production

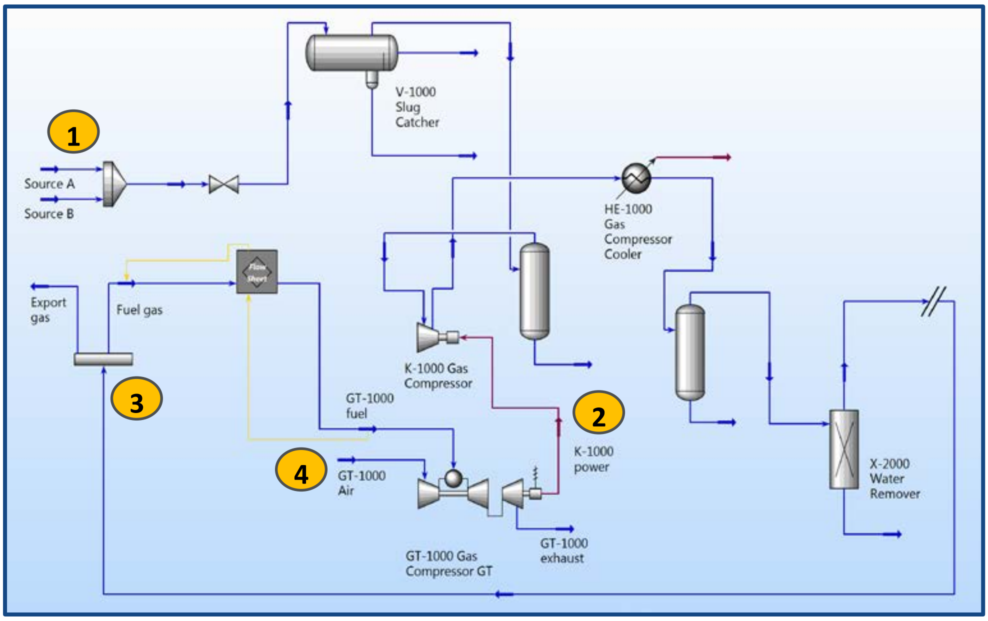


Monthly ambient conditions

Case Study Setup

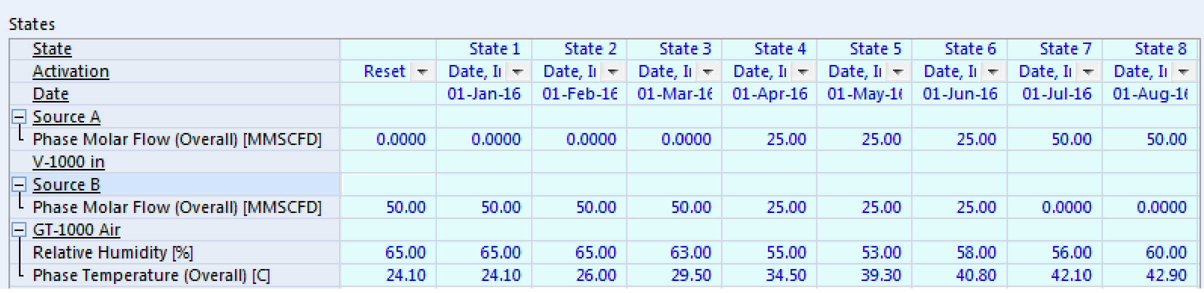
The integrated gas turbine-processing facilities simulation is setup as below:

1. Flowrates from Source A and B are set based on monthly target gas production
2. Gas turbine shaft power requirements are integrated with gas compression demand
3. Fuel gas composition to vary based on produced gas composition
4. Inlet air temperature and relative humidity are adjusted based on monthly ambient conditions



Integrated Gas Turbine simulation setup

As the difference between monthly high and low temperatures is huge, it is crucial to include both temperature extremes into the gas turbine sizing considerations. With the monthly production and ambient variations, if the user is to implement the traditional method to evaluate the gas turbine the user would need to perform 24 sets of runs. Using GT-SIM, the performance of the Centaur 40 over the year can be determined in a single run. This is performed by including the monthly gas production and ambient conditions in the Scenarios and Time Series functionalities, which are embedded in Petro-SIM.



States

State		State 1	State 2	State 3	State 4	State 5	State 6	State 7	State 8
Activation	Reset	Date, I	Date, I	Date, I	Date, I	Date, I	Date, I	Date, I	Date, I
Date		01-Jan-16	01-Feb-1	01-Mar-1	01-Apr-16	01-May-1	01-Jun-16	01-Jul-16	01-Aug-1
⊟ Source A									
Phase Molar Flow (Overall) [MMSCFD]	0.0000	0.0000	0.0000	0.0000	25.00	25.00	25.00	50.00	50.00
V-1000 in									
⊟ Source B									
Phase Molar Flow (Overall) [MMSCFD]	50.00	50.00	50.00	50.00	25.00	25.00	25.00	0.0000	0.0000
⊟ GT-1000 Air									
Relative Humidity [%]	65.00	65.00	65.00	63.00	55.00	53.00	58.00	56.00	60.00
Phase Temperature (Overall) [C]	24.10	24.10	26.00	29.50	34.50	39.30	40.80	42.10	42.90

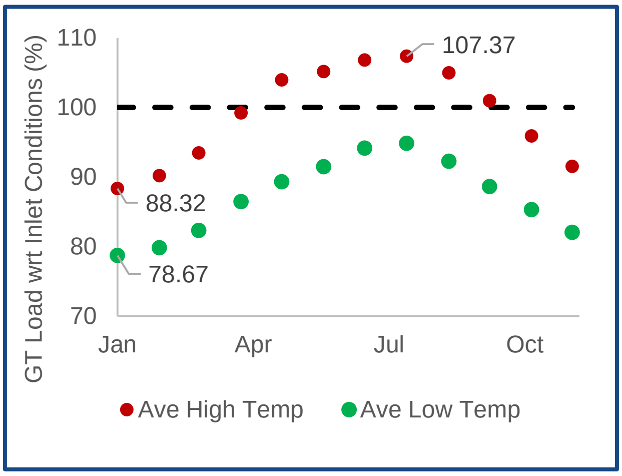
Scenarios and Time Series setup for monthly gas production and ambient conditions

Base Case: Solar Centaur 40

Due to the huge temperature difference between monthly high and low temperatures, the required gas turbine load for Centaur 40 varied between 9 to 15 %. From May-October, the gas turbine load exceeded 100% during daytime when the ambient temperatures were higher. Consequently, maintenance efforts may need to be increased to keep the gas turbine at optimum performance.

This leads to 3 options which can be conveniently evaluated with GT-SIM:

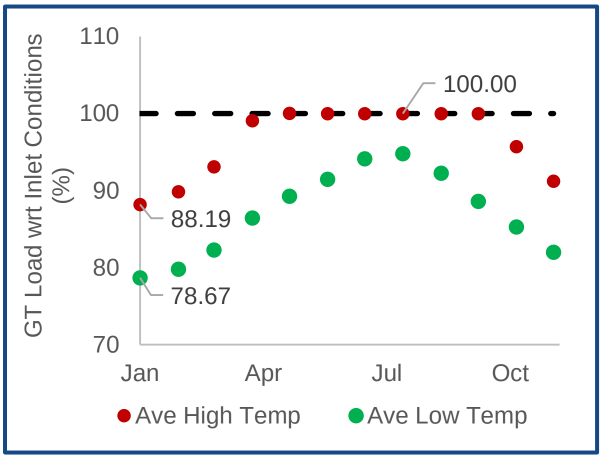
- Reduce gas production during summer by limiting the gas turbine load at 100%
- Install water fogging to cool the inlet air
- Install a bigger gas turbine, Centaur 50



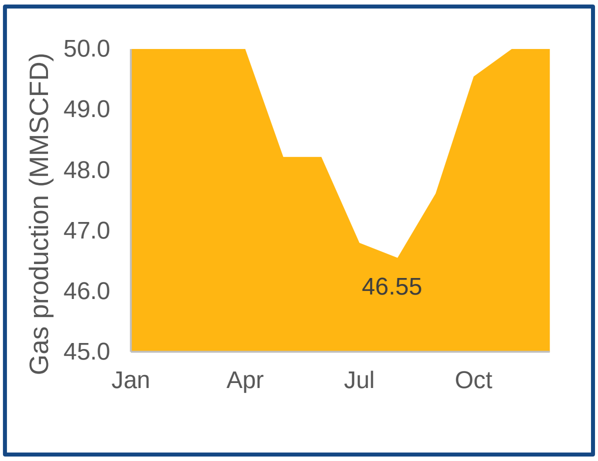
Significant impact of ambient temperature variations to Solar Centaur 40 operability

Option 1: Reduce gas production

If Solar Centaur 40 is to be used without any facilities upgrades, one of the ways to prevent the gas turbine from exceeding peak load is to reduce the gas production. The integrated run indicates that gas production from April-October needs to trimmed by up to 7.0% to prevent the peak load from exceeding. Although production reduction is the easiest way out, this option may not be desirable to some operators due to export contractual requirements. If the facility is already in operation and there is little that can be done to modify the process or equipment, the operator may leverage this result to discuss with the other stakeholders (eg: subsurface team, planners, customers) to produce more gas from January-March and November-December as there is gas turbine load during this period.



Solar Centaur 40 GT load with reduced gas production

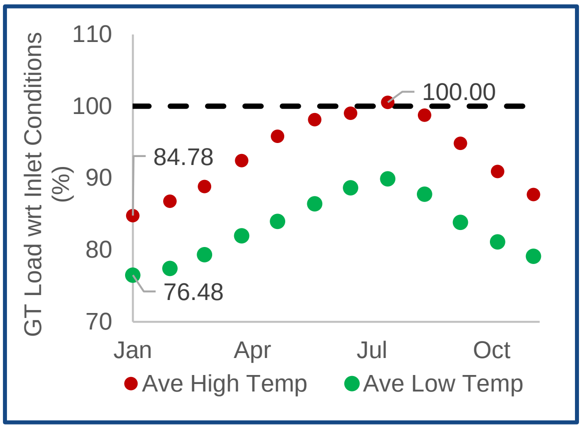


Reduced production rates up to 7% to prevent GT peak load

Option 2: Install gas turbine inlet air fogging

Water fogging could be considered to decrease the gas turbine inlet air temperature to reduce the gas turbine power output. Inlet air fogging comprises of spraying finely atomised water, also known as fog, into the feed air to the gas turbine compressor. As water droplets evaporate rapidly, it cools the air and decreases the compressor power intake, leaving more power to be output from the gas turbine.

For every of the 24 cases in the integrated simulation, which is performed in a single run, the cooled water flowrate added to the ambient air is optimised to achieve a fixed Relative Humidity of 90%. This is essential to prevent free water in the air inlet which would damage the gas turbine air inlet compressor. When comparing Option 2 with Base Case, with water fogging the gas turbine load reduces by 3 - 7% and enables operations without exceeding peak load.

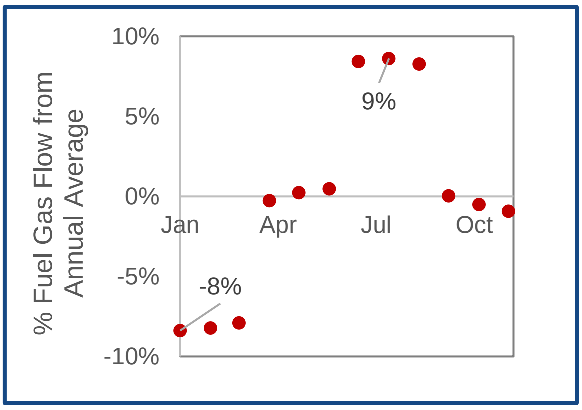


Inlet air fogging increases Solar Centaur 40 performance by 3-7%

The impact of composition change to the fuel gas flowrate is significant. The fuel gas flowrate varied from -8 to 9% compared to the annual average fuel gas flowrate.

Although the gas turbine load in March and December was similar, the fuel gas flowrate required in March was 8% lower.The saved fuel gas could be diverted to export or utilised for production purposes such as gaslift or gas injection.

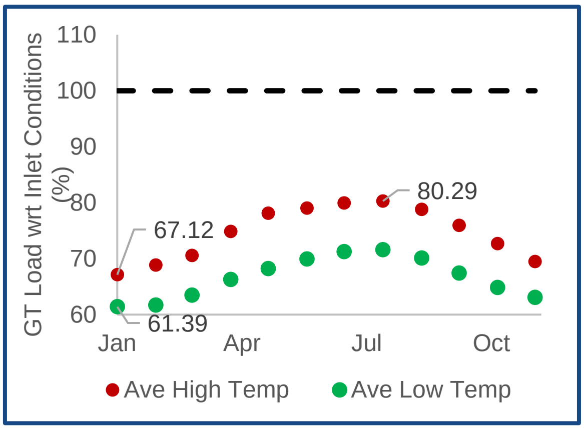
Meanwhile, the fuel gas flowrate required in July-September was 9% higher than annual average when the gas was lighter. During this period when the fuel gas demand was higher, less gas will be available for either export or production.



Gas compositional changes affect fuel gas requirements and supply for export / production usage

Option 3: Install a bigger gas turbine, Solar Centaur 50

Another option to meet the planned production profile is to install a larger gas turbine, Centaur 50. The Centaur 50 will not require water fogging as it operates below peak load. In addition, it provides a 20% load allowance, which would be useful if the produced gas is lighter than expected or an increased production is required during operations or redevelopment. However, the Centaur 50 will be about 10% heavier compared to Centaur 40 and this needs to be considered for offshore environments where additional equipment weight or footprint will translate to higher cost.



A bigger gas turbine, Solar Centaur 50 is able to operate within the peak load

Summary and conclusions

Below are the summarised pros and cons of each option:

Scenarios	Advantages	Disadvantages
Option 1 Smaller gas turbine with production cutback	• Minimal facilities • Lowest CAPEX and OPEX	• Unable to achieve production target (from April to October) leading to production deferment about $500,000 US per year.
Option 2 Smaller gas turbine with inlet air fogging	• Able to achieve production target • Inlet air fogging facilities are lighter and cheaper compared to a larger gas turbine	• 2nd highest CAPEX for inlet air fogging • Little load allowance for additional production

Option 3 Larger gas turbine	• Able to achieve production target • 20% load allowance for additional production	• Highest CAPEX for larger gas turbine • Gas turbine is 10% heavier and may lead to additional structural cost if there is no weight and space allowance

Neither Option 1, 2 nor 3 is perfect, so the best choice cannot be made until the cost and economics of the each scenario has been calculated and evaluated against the risk associated with each option. These evaluation factors will differ from project to project.

For this preliminary economic analysis assuming a project life cycle of 10 years, Option 2 yields a $4 million higher operating profit than Option 1. Despite the additional investment for inlet air fogging, the consistent export gas volumes without any production cutback offset the fogging costs. Meanwhile, option 3's operating profit is $3 million higher compared to Option 1, but is $1 million lower compared to Option 2 due to the additional cost with the larger gas turbine. Depending on the project circumstances, Option 3 may be better if there are opportunities for additional production in the future as a larger gas turbine has a 20% load allowance. If there is a weight or space constraint to install the larger gas turbine, the economic analysis outcome will need to consider the additional structural cost.

The essential life cycle results above would have been difficult to obtain from traditional gas turbine simulation procedures. Typically supplier inputs are required to determine the off design cases for alternative ambient conditions and fogging, and this can substantiallly slow down the process of machine selection. This either leads to over conservative assumptions (i.e. select the larger machine, with associated increase in Capex and platform weight) or costly surprises during operations. With GT-SIM, the interdependency of the gas turbine and the production system can be understood in a single integrated production-utility simulation with respect to field life. Consequently it enables the project team to holistically right-size and optimise the design especially for offshore or floating structures where retrofitting and upgrading works during operations are more costly and complex compared to onshore facilities.

About KBC

KBC Advanced Technologies is a leading consultancy and software provider to the global hydrocarbon processing industry. With over 30 years of experience, KBC combines industry leading technology with experienced engineers and operations personnel using robust methodologies to create personalised, sustainable solutions for its clients.

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