VISION CONTROL SOLUTIONS & GT PERFORMANCE

GT MONITORING & ENERGY SOLUTIONS

VISION CONTROL SOLUTIONS

GT PERFORMANCE

Aero Controls & DLE Consultants

www.vicosol.com
www.gtperformance.no
www.ac-dle.com

ABOUT US

Vision Control Solutions (VCS) was established December 2018 by specialists in Aero-derivative Gas Turbine Control Systems, all with 10+ years' experience.

We deliver and support control system solutions within the oil & gas industry, renewable energy and other onshore industries. VCS has developed a new control system platform design, that provides the customers with modern state of the art control system solution, based on the latest technology and enhanced functionality.

Our specialty is to turn old and obsolete control systems into new, modern and effective control solutions by using state of the art technology.

GT Performance (GTP) is a company specializing in gas turbine performance optimization. Particularly performance analytics, inlet air filtration- and water wash systems.

An efficient inlet air filtration system, combined with effective water wash, are the key elements to ensure high gas turbine performance and reduce the performance deterioration. Fouling in the compressor section of the gas turbines is the main cause of performance deterioration, and the fouling is removed by water wash.

Optimum design of inlet air filtration- and water wash systems, has a major impact on the production rates, production efficiency (PE), turbine efficiency and the economy of the plant. It entails lower fuel consumption and exhaust emissions (CO_2 and NO_x) and hence lower costs for fuel and reduced environmental impact.

Intellectual property

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GAS TURBINE **OPERATION**

There is global focus on decreasing carbon footprint. It's well known that fossil fuel power generation is a large contributor to the global CO_2 and NO_x emissions. A single cycle aero derivative gas turbine typically emits approximately 500kg CO_2/MWh.

As an example, the Norwegian O&G industry contributes to approximately 20 % of the national CO_2 emissions where 85 % of the emissions derives from gas turbine operations. This equals to ~11 Million tons CO_2 per year. As one of the first countries in the world, Norway introduced in 1991 tax on carbon emissions.

Maintaining your turbine efficiency will significantly reduce emissions.

A LM2500 as simple cycle has an iso efficiency of 36-39 %. While the real average efficiency ranges from 30-33 % depending on how the plant is operated and maintained.

The main contributors that reduced the turbine efficiency are mainly 3-4 individual aspects.

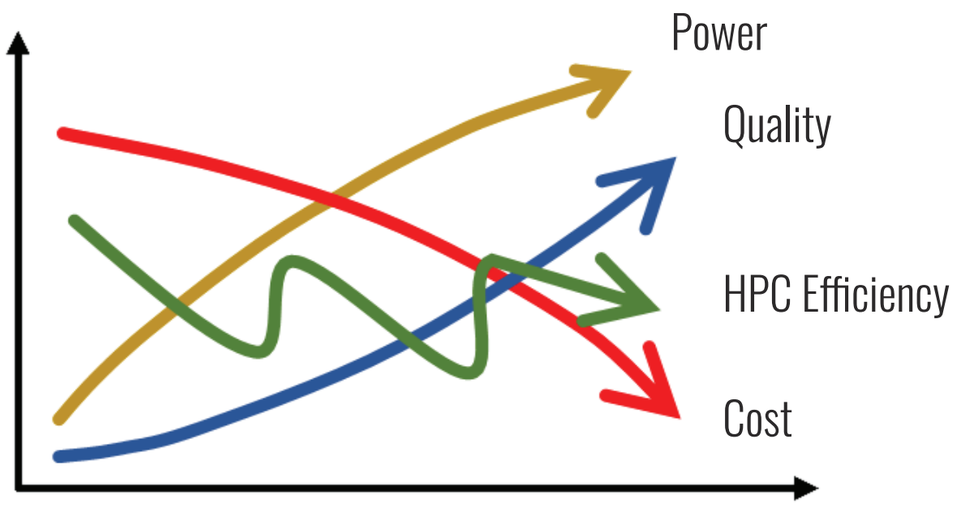
1. **Air inlet filter loss**
2. **Compressor efficiency loss**
3. **Operation profile (partial load)**
4. **Shroud/tip tolerance/wear**

Most of the efficiency "thieves" can be reduced if the plant is operated more optimal in respect to efficiency. Some of our enhanced functions and service offerings are direct solutions to the efficiency challenges:

1. **Optimized filter media/air flow analyzes and timely air filter replacements**
2. **Compressor efficiency monitoring and automated water wash solutions**
3. **Spinning reserve and load share optimization modules**
4. **Higher availability/reliability through advanced equipment monitoring and service**

"With political pressure and increased cost related to emissions, VCS has set out on a mission to develop some of the most advanced performance enhancing systems for the GE aero derivative gas turbines."

– Global Sales Manager – VCS



ABOUT ENHANCED FUNCTIONS

Historically the control system only provided "Real time data", but with the latest growth of the controller CPU horsepower we are now able to produce compared baseline data on the local controller much like a "digital twin".

VCS is developing several enhanced functions together with GT Performance. The keystone to the enhanced monitoring is embedded smart modules that are easily implemented or added in the control system, where a module is one to one with logic in the controller and visualization in the HMI system. The benefit doing this on a local level is that the models can run on real time unfiltered data, producing higher accuracy as well as more information at the user level rather than externally in a 3rd party system.

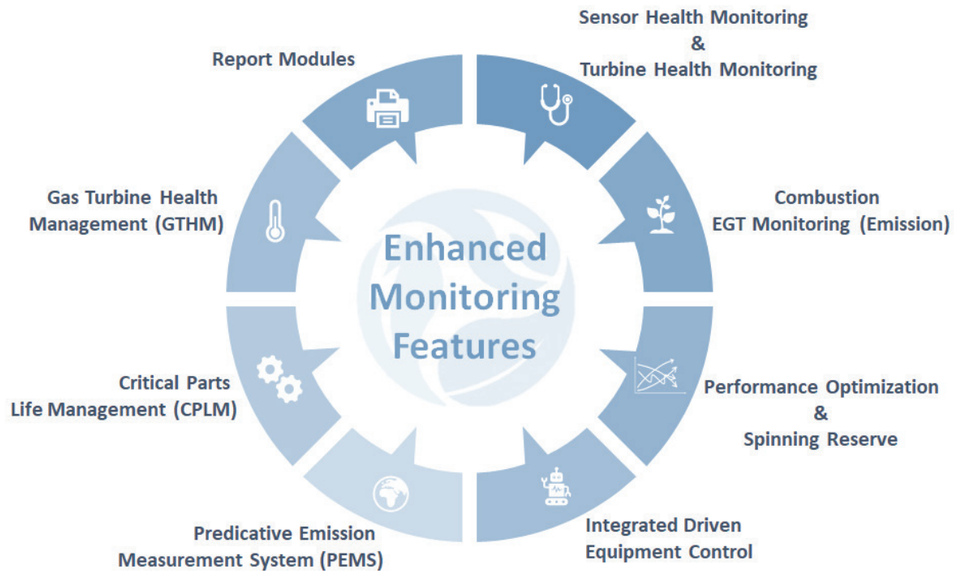
Our goal is to provide the customer with higher quality, improved reliability, increased available power output, higher HPC efficiency and significant cost reduction.

HOW TO GET

VCS can provide one or several of the modules, either as ad-on to existing system, as part of a control system upgrade or applied to plant PI data.

"VCS welcomes you to a new data acquisition beyond any imagination"

– Managing Director - VCS



INLET
AIR FILTRATION

A typical filter system consists of a vane separator stage upstream followed by two filter stages. In such a configuration you can have a higher filter grade at the high-efficiency filter, e.g. an EPA type filter that can give a better total filtration effectiveness.

The idea is that the more expensive high-efficiency filters can be protected and have a longer life by changing the pre-filters more frequently.

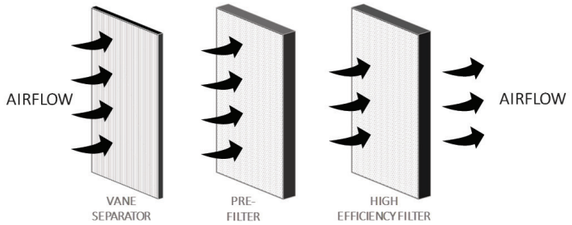
The downside is that you often compromise the total filter system differential pressure reducing initial turbine performance. Introducing more complex filter solution components in the filter housing, often result in more complex design and less maintainability.

The design and configuration of a filter system is a trade-off and balance between these areas.

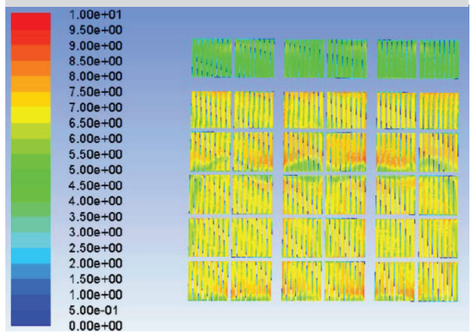
Selecting the correct filter type for the location and operating profile is crucial, e.g. good hydrophobic properties is important in an offshore/marine environment.

TYPICAL SETUP OF INLET AIR FILTRATION SYSTEM.

Below graphs shows uneven flow distribution (documented by CFD) at filter face due to geometry / flow restrictions.

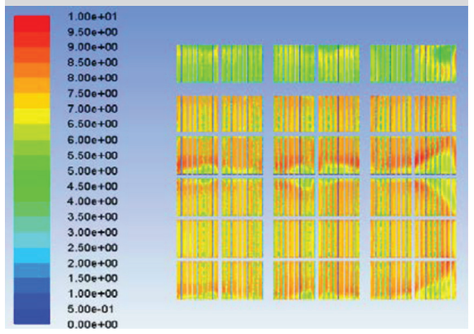


FILTER FACE VELOCITY DISTRIBUTION



Filter face velocity distribution (documented by CFD) in a combined combustion- and vent air intake (upper row vent)

UNEVEN / HIGH VELOCITY DISTRIBUTION



Uneven / high velocity distribution due to geometry / flow restriction upstream of filters (reference case to the left)

THE SOLUTION

We can support the customer in evaluation of their existing filter system.

We provide world-class air intake filtration solutions, where key features are high performance, low deterioration and excellent maintainability.

For offshore, marine and coastal environment, the key for high air intake performance is the ability to handle airborne salt-particles. Our filter house design has a high-efficiency upstream vane separator followed by filters with excellent hydrophobic properties, holding frame design and filter house drainage solutions, which all combined are success factors in good filter system design.

Reference case:
A reference case for aftermarket / retrofit in the offshore market, is a high-velocity single-stage filter system with Filtrair Drop Safe F7 filter (per EN 779:2012, MERV 15 per ASHRAE 52.2.2012). The filter house design is compact, clean and efficient. Excellent maintainability through special access door design, efficient drainage system, good provision for inspection and cleaning, as well as easy filter change. Our solution is well-proven from long-term offshore operation.

When required, a high-velocity two-stage filter system can be provided, where the prefilter is Filtrair Drop Safe M6, followed by a final filter stage Faist FV/FVX/FVXX in the range F8 to E12 (at customer specifications). Alternative filter types can be provided for other environments (such as land-based applications), or upon customer specifications.

BENEFITS WITH OUR SOLUTION

An upgraded and efficient filter system, will reduce the total dp of the inlet system, increase turbine power, increase intervals between offline washes / maintenance.

Typical figures for the effect of air filtration improvements (based on LM2500 SAC):

- **10+ tons annual NO_X reduction**
- **2000+ tons annual CO_2 reduction**
- **2 x times offline wash/maintenance interval**
- **1 % annual availability/PE gain**
- **2 % higher average shaft power**
- **Reduced taxation emissions**
- **Reduced GT package maintenance cost**

SAVINGS WITH SOLUTION

Annual savings taxes - CO_2 reduction	110k USD
Annual savings taxes - NO_X reduction	20k USD
Potential funding - NO_X fund	450k USD

*based on norwegian emission tax regulations as per 1/1-2020

WATER WASH **SOLUTIONS**

The main objective with performing water wash of the axial compressor is to reduce the compressor fouling. Offline washing shall be capable to remove the fouling and bring the unit back to baseline performance. The cost impact of performing offline wash is significant, hence the weighting of production loss vs performance loss is a typical dilemma.

Fouling in the compressor section of the gas turbines is the main cause of performance deterioration, and the fouling is removed by water wash.

The relative efficiency is over time reduced with several percent. Combining the effective offline water wash with a daily online wash, that reduce the deterioration rate until the next offline wash / maintenance stop, is recommended.

INEFFECTIVE OFFLINE WATER WASH

- Baseline is not restored after crank wash
- Frequent stops for crank wash
- Fouling is accumulating in the aft section of compressor
- May lead to compressor stall and trips
- Deterioration is worsening until next GG change (example: mid right picture)
- Engine shop visit cost increase
- Low availability

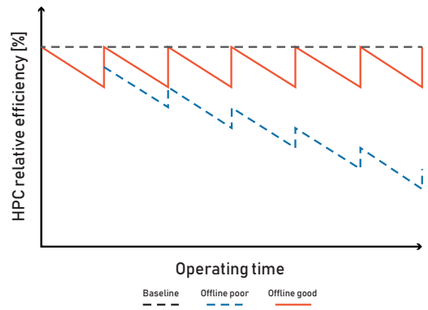
EFFECTIVE OFFLINE- AND ONLINE WATER WASH

- Baseline is restored after each crank wash
- Maximum engine performance and stall free operation are maintained
- Online wash daily reduce deterioration to a minimum
- Offline wash intervals can be increased, as well as intervals between GG change
- Engine shop visit cost decrease (example: bottom left picture, clean compressor, 200k USD saving HSR/OH)
- High availability (1 % or more PE gain annually)

EFFECT OF OFFLINE- AND ONLINE WATER WASH

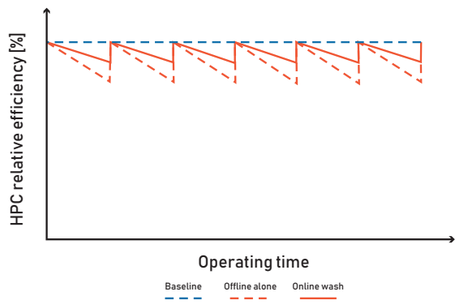
It is crucial to find the optimum combination of offline and online water wash. This to maintain the highest possible efficiency, with minimum emissions, at the lowest cost.

EFFICIENCY - OFFLINE WASH
The illustration under shows the effect of poor offline washing vs a good offline washing. By maintaining a good offline water wash system, with frequent cleaning, the reduction of efficiency can be kept low.



EFFICIENCY - OFFLINE + ONLINE WASH
The illustration under shows the effect of good offline washing, as well as the increased effect by performing regular online wash between offline washing.

Optimizing the system with the combination of offline + online washing, the reduction of efficiency can be reduced to a minimum. Offline intervals can be extended.



BENEFITS WITH OUR SOLUTION

An upgraded and efficient water wash system will increase turbine power and increase intervals between offline washes / maintenance.

Typical figures for the effect of water wash improvements (based on LM2500 SAC):

- **10+ tons annual NO_x reduction**
- **2000+ tons annual CO_2 reduction**
- **2 x times offline wash/maintenance interval**
- **1 % annual availability/PE gain**
- **2 % higher average shaft power**
- **Reduced taxation emissions**
- **Reduced GT package maintenance cost**

SAVINGS WITH SOLUTION

Annual savings taxes - CO_2 reduction	110k USD
Annual savings taxes - NO_x reduction	20k USD
Potential funding - NO_x fund	450k USD

*based on norwegian emission tax regulations as per 1/1-2020

VCS
PERFORMANCE MODULE

The main objective with the GT performance module is to monitor the turbine performance and degradation over time.

We have developed a software module that accurately calculate and visualize the turbine compressor degradation.

The module provides real-time trend data for:

- Maximum available gas turbine power
- Compressor/turbine deterioration rate
- Plant performance, turbine efficiency/ availability
- Emissions/carbon footprint

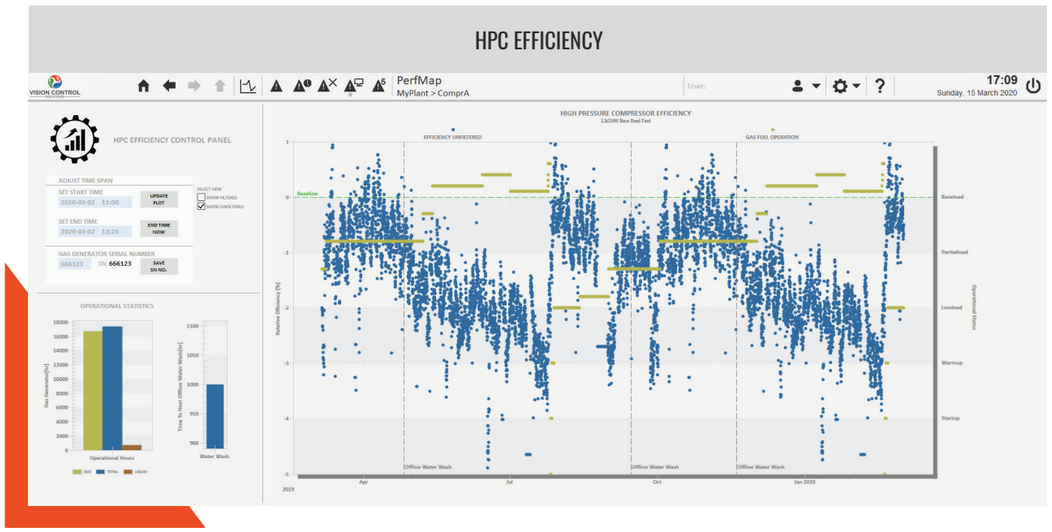
This enables the operator to efficiently plan maintenance activities such as off-/on-line water wash as well as inlet air filter change.

THE SOLUTION

By utilizing the turbine package instrumentation, together with the VCS performance module the GT degradation can easily be monitored.

The graph below shows an example of trending of the HPC corrected efficiency vs. time, with indications of water wash and the operation level for the turbine.

The GT degradation over time is easily seen and provides the operator with invaluable information for planning.



BENEFITS WITH OUR SOLUTION

Previous case study* proved:

Improved unit availability
- PE / availability increases of 1-2 % annually (longer intervals offline wash, reduce trips, reduce engine intervention due to fouling)
- Reduced maintenance time for inlet air filter change (complete filter set changed in 2 hours)
- Quicker / more efficient offline wash cycle

Unit efficiency
- Better compressor efficiency condition monitoring parameters for inlet air filter performance and deterioration rate vs. the traditional filter dp
- 4 % turbine efficiency loss yield 2 MW output power loss
- 10 mbar inlet air filter loss yield 1 MW output power loss

Reduced maintenance cost
- Reduced GT package maintenance cost of 100k USD annually

"A Field Study of Reduced Axial Compressor Performance Deterioration through Online Washing and Air Intake Filtration Upgrade."

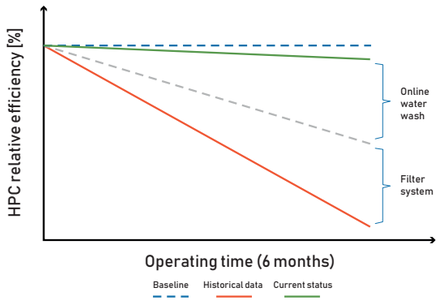
** Doctoral theses at NTNU, 2018:300 Stian Madsen (GT Performance):*

OPTIMAL
EFFICIENCY & EMISSIONS

A combination of efficient inlet air filtration and effective water wash system, are the key elements to maintain high turbine efficiency. Reducing performance deterioration results in lower CO_2 and NO_x emissions and increased plant efficiency.

Optimum design of inlet air filtration- and water wash system, has a major impact on the production rates, turbine efficiency and total plant economy. It entails lower fuel consumption and exhaust emissions (CO_2 and NO_x), hence lower costs for fuel and reduced environmental impact.

The graph below illustrates how water wash and improved filter system, over time impacts the HPC relative efficiency where the combination gives the best overall result.



BENEFITS WITH OUR SOLUTION

With our solutions and enhanced functions, the operators will have the following benefits:

- Increased efficiency
- Lower emissions
- Reduced operating cost and emission taxation
- Increased operation robustness

Typical figures for the effect of improved air filtration and water wash system and routines (based on LM2500 SAC)

20+ tons annual NO_x reduction

4000+ tons annual CO_2 reduction

3 x times offline wash/maintenance interval

2 % annual availability/PE gain

4 % higher average shaft power

Reduced taxation emissions

Reduced GT package maintenance cost

SAVINGS WITH SOLUTION

Annual savings taxes - CO_2 reduction	220k USD
Annual savings taxes - NO_x reduction	40k USD
Potential funding - NO_x fund	900k USD

***based on norwegian emission tax regulations as per 1/1-2020**

VARIABLE STATOR VANE (VSV)
MONITORING

The VSV settings are set from the repair shop (or when engine is new), however, the VSV schedule can drift, and should therefore be monitored closely.

A healthy and correct calibrated VSV system is a vital factor in order to operate the gas generator with highest efficiency.

Correct VSV schedule is important to ensure operations between the stall- and overspeed lines.

Operation towards the overspeed line will result in performance loss, while operation passed the stall line may lead to catastrophic failure

The optimal setting is within the limit lines on all engine loads, but closer to the stall-limit for best performance.

THE SOLUTION

VCS has developed an VSV Schedule and performance monitor software.

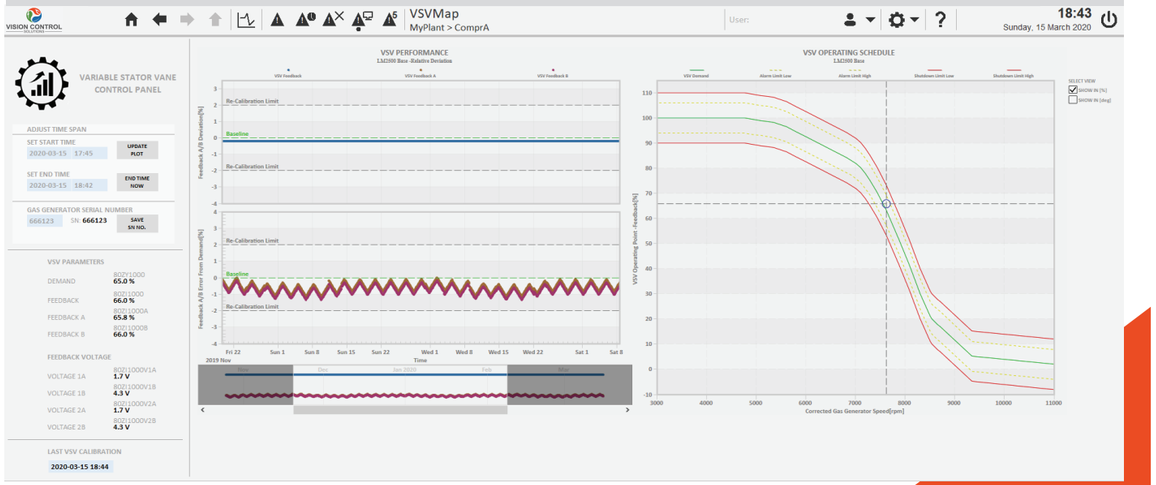
The software visualizes the VSV schedule and performance chart, alarm boundary limits as well as actual operation point. This gives the operator an instant view of the VSV system.

BENEFITS WITH OUR SOLUTION

With our VSV monitoring, the customers will have the following benefits:

- Increased operation robustness
- Improved monitoring
- Potential of increased efficiency – up to 1 MW gained with optimal tuned VSV
- Reduced operating cost and emission taxation
- Increased safety for catastrophic failure

VARIABLE STATOR VANE CONTROL PANEL (VSV MAP)



DLE ISLAND MODE OPERATION
EFFICIENCY OPTIMIZATION

The DLE Low NO_x technology utilize compressor bleed valves to control the combustion air flow. Bleeding of compressor air inherently reduce the overall turbine efficiency.

For Electrical Island mode or load-shared power-plants, that operates below max load, open bleed valves can contribute to significant efficiency loss.

From a operational combustion robustness perspective, each burner mode has a hysteresis or an overlap between each window of 3-4 MW resulting efficiency loss of upwards of 4 % depending on the burner of up to.

Total plant efficiency can be significantly increased with a more optimized operation of a multi-unit installation by optimizing the DLE operation point through actively adjusting the individual turbine load.

BENEFITS WITH OUR SOLUTION

Increased operational robustness due to:

- Optimized load rejection system
- Reduced emissions
- Reduced fuel consumption
- Developed together with DLE experts with 20+ years of mapping experience

8000+ tons annual CO_2 reduction

4 % Efficiency gain

Reduced taxation emissions

Reduced cost of fuel
~12 % reduced fuel flow

THE SOLUTION

With the VCS DLE Island mode operation efficiency software in combination with the VCS Efficiency will provide operator with a per unit efficiency operation point as well as a plant overall efficiency. Enabling the Island Mode efficiency will tune the Turbine load point and DLE operation point to the most optimized shared load operating point to ensure the best overall plant efficiency.

OUR SOLUTION IS DEVELOPED TOGETHER WITH DLE EXPERTS WITH 20+ YEARS OF MAPPING EXPERIENCE

"This has a huge cost saving potential for our DLE operators."

– Managing Director - AC & DLE

LM2500+G4 Examples

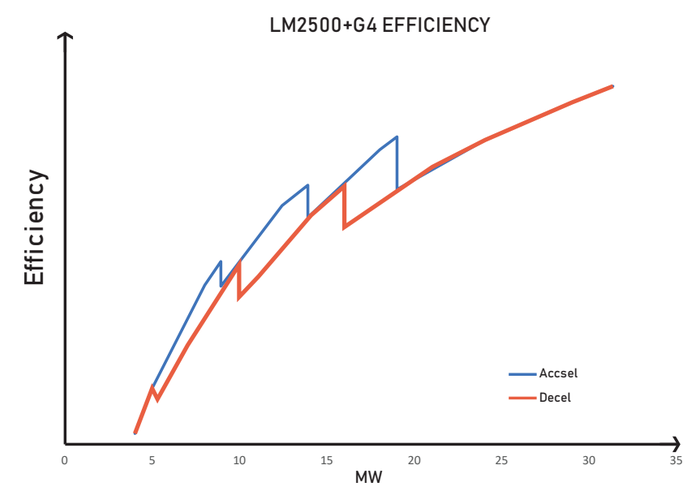
1

Island mode plant with total plant load of 36 MW.
a. Two units with an equal load of 18 MW operating in ABC mode has a total efficiency of 29,5 %
b. One unit operating in AB mode and one unit in ABC has a total efficiency of 31,2 %
c. Both units operating in AB mode has a total efficiency of 33,3 %

Difference between scenario a. and c. yields an efficiency difference of 4,3 %.

2

Island mode plant with total plant load of 60 MW.
Operating 2 units with 30 MW each vs 3 units with 20 MW each yields a efficiency difference of 5,5 %.



ISLAND MODE OPERATION
SPINNING RESERVE

VCS Spinning Reserve module for a generator drive uses gas turbine efficiency in real-time to calculate the maximum electrical power.

When a new gas turbine is installed a base line run must be performed to set the maximum electrical power limit.

The deviation from calculated electrical power deteriorated to current operating point is defined as Spinning Reserve for given operational condition.

Knowing the gas turbines exact power capability is a key factor to optimizing the plant load rejection system.

THE SOLUTION

VCS Spinning Reserve software module has a powerful online visualization that helps operators to keep track of the units power capability.

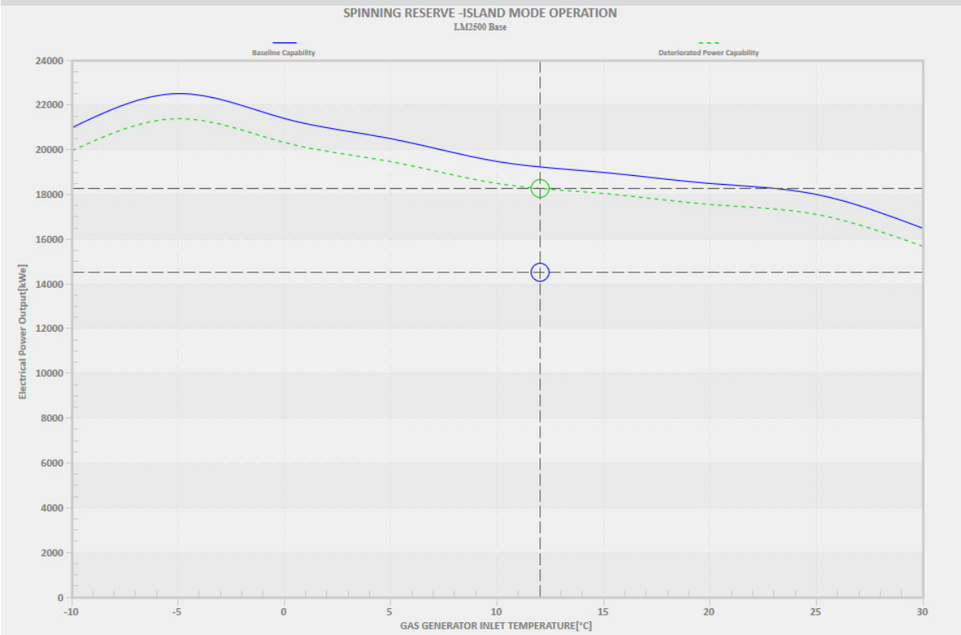
With high-level user logon to the control system the operator can also easily set the base line for any new installed gas turbine. Serial number and date of base line is also recorded.

BENEFITS WITH OUR SOLUTION

Increased operational robustness due to:

- Optimized load rejection system
- Improved control of large consumer starts
- Improved control of plant electrical power capability

SPINNING RESERVE - ISLAND MODE OPERATION



REPORT
MODULES

A modern control system has the capability of providing the operators with all relevant and important data. The challenge for the operators is to turn the logged data parameters into meaningful reports, dashboards, performance reports, etc. that easily can give the operator meaningful visualization and information.

BENEFITS WITH OUR SOLUTION

- Improved monitoring
- Easy and cost-effective solution to provide the customer with the reports they always wanted
- Quick and robust handling of detailed data

THE SOLUTION

Our enhanced modules provide unique and useful graphs and overview for the operators, customized for the enhanced module and its function. In addition, existing and new control systems log a lot of valuable raw data. With the Citect Dream Report fully integrated into the VCS HMI system, we can create informative and intuitive reports customized for our customer needs.

Alternatively, VCS can utilize PI dataset available. Through data validation with our specialized tool, VCS can provide site-specific dashboards and other valuable reports. The dashboard can easily display important data for the operators. The below shows a sample of a VCS dashboard, with the main KPI's setup for a plant running with four generator packages.

DASHBOARD **PERIOD - FEBRUARY 2020**

Gas fuel

Gen A	4,433	MSm^3
Gen C	4,002	MSm^3
Gen B	3,386	MSm^3
Gen D	1,539	MSm^3

Liquid fuel

Gen A	5 265	ltr
Gen C	7 371	ltr

Hours of operation

Gas fuel

Gen A	720	h
Gen C	650	h
Gen B	550	h
Gen D	250	h

Liquid fuel

Gen A	1	h
Gen C	1,4	h

Availability

Gen A	92	%
Gen B	90	%
Gen C	95	%
Gen D	89	%

Total Emission

CO2	29 308	ton
NOx	18,7	ton

Total Power Produced

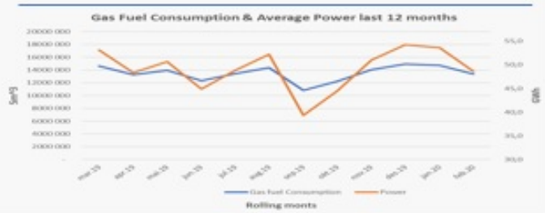
Gen A	9,2	GWh
Gen B	14,1	GWh
Gen C	12,5	GWh
Gen D	12,3	GWh

Reliability

Gen A	96	%
Gen B	97	%
Gen C	94	%
Gen D	88	%

Emission last 12 Months

GF Consumption & GWh Produced



Operational status

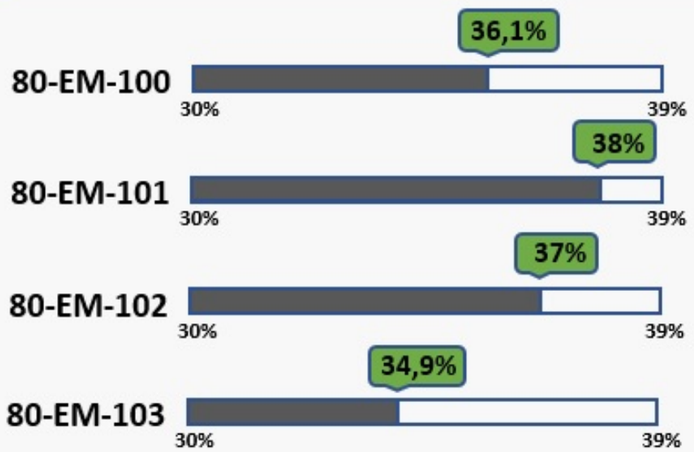
Total critical alarms	47	pcs
Total normal SD	6	pcs
Total ESD	5	pcs

Plant comfort & performance index

85%
Plant Comfort Index

0.7
Plant Performance Index

Efficiency relative to baseline all generators



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