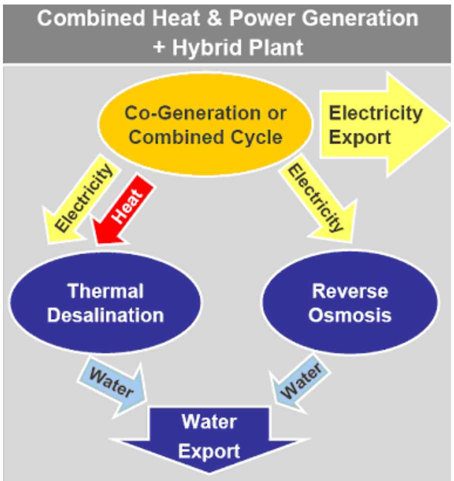
Performance Monitoring & Optimization

Fujairah Water and Power Plant

Basic infrastructure like Power and Water production has come into focus due to the rapid growth witnessed in the Middle East. Hybrid desalination plants have high flexibility and play a vital role in water and power production. Conservation of fuel resources in the existing scenario of increasing fuel prices make it necessary to produce power and water in a cost optimal way. The challenge in optimization lies in large range of operation possibilities, which exist in short term and long term operation planning.



This paper describes an approach to economical optimization of desalination & power plants, based on different online and offline optimization packages in the Water and Power Plant Fujairah (FWPP) in the United Arabic Emirates supplied by ABB in 2005.

Savings of more than 4% of the total fuel consumption have been achieved.

Fujairah Water and Power Plant

Introduction

Desalination plants play an essential role in power and water production in the Middle East to meet the dynamic increasing demand. Since hybrid desalination plants are flexible in meeting different levels and combinations of production they are built in increasing numbers today. Hybrid desalination plants use 2 (or more) different desalination process types in one plant. These plants have a complex system structure, which allows multiple possibilities of optimization.

The Fujairah Water and Power Plant is located next to the existing Qidfa Power Station approximately 5 km South of Khor Fakkan and 20 km North of the city of Fujairah, in the Gulf of Oman. The site allocated to the plant is positioned north of the existing Qidfa Power Station leaving a gap of about 200 m between the two. The site consists of a coastal plain, which is limited in the west and northwest by mountains, which are composed of basic igneous rocks with associated wadis, and outwash deposits such as gravel, cobbles and boulders.

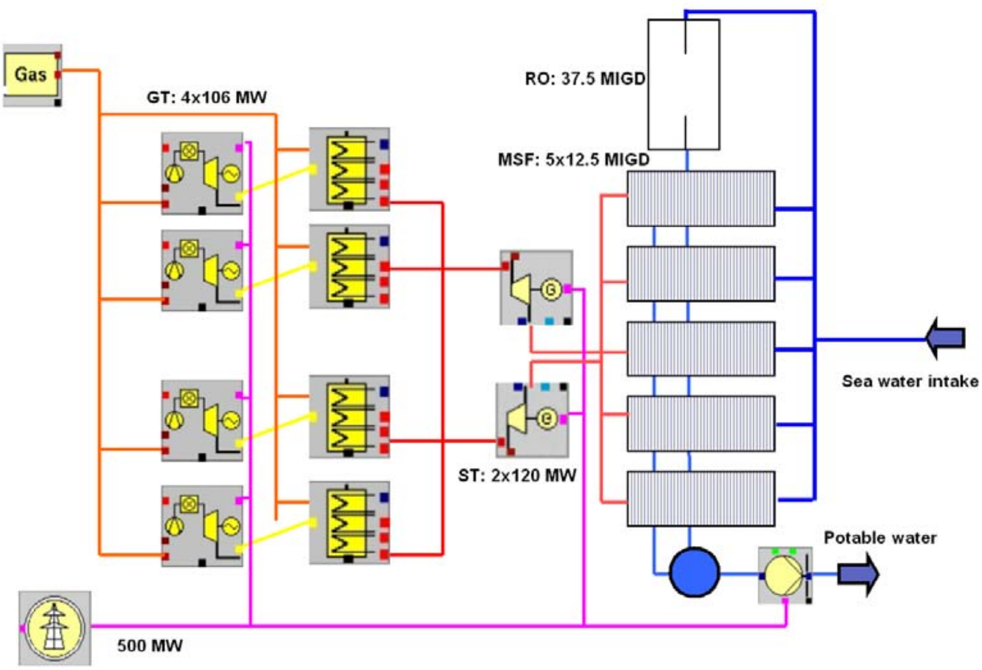
The plant consist of 4 Gas Turbines (GT), 106 MW each, with associated Heat Recovery Steam Generators (HRSG) and 2 Steam Turbines (ST), 119 MW each, at the electrical side. The water production is realized with 5 Multi Stage Flush (MSF) distiller, 12.5 million gallons per day (MIGD) each and 1 Reverse Osmosis (RO) Plant (2 stages) with 37.5 MIGD capacity. Such kind of plants with different desalination processes are called Hybrid Plants. In total the plant has a capacity of about 660 MW gross power and 100 MIGD water production.
The four HRSG's feed high-pressure steam to a common header. The low-pressure steam used by the MSF units is taken from the steam turbines outlet or reduced from the high-pressure steam by a reduction station.

Areas of Optimization
The fuel costs form the main costs in desalination plants besides the capital costs. From the total costs for fuel, chemicals and maintenance for GT, ST, MSF and RO, the fuel costs amount to more than 90%. This shows the main focus has to lie on fuel savings when optimizing.

Fuel savings is the aim of the following optimization tools:

- Load Scheduling
- Hybrid Optimization
- Process Optimization
  - MSF Optimization
  - RO Optimization
  - FD-Fan Optimization

The tools, which are used to optimize the fuel consumption additionally, allow improvements in the work process, e.g. maintenance improvements and workflow improvements (work process optimization).



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System Structure
The graphic below details the system structure of the optimization system realized in Fujairah. Real time data is collected from a Teleperm XP, a Win CC and a Mark V system. The data is stored in the **Power Generation Information Manager (PGIM)** also known as **PlantConnect**, a long term real time database and a Plant Information Management System (PIMS) which is used as a common source of data for all the optimization tools and other applications, e.g. Performance Monitoring, Fuel Demand Model, etc.

Optimization Solutions
The proven installation of a performance monitoring and optimization system in Fujairah water and power plant sums up the effectiveness of modern optimization techniques in power plants.

The optimization realized in Fujairah comprises the areas:

- Work Process Optimization
- Performance Monitoring
- Lifetime Monitoring
- Load Scheduling
- Hybrid Optimization
- MSF Optimization
- Fuel Demand Model

Work Process Optimization with Power Generation Information Manager (PGIM)
A common Plant Information Management System (PIMS) optimizes the work process in the plant Fujairah.

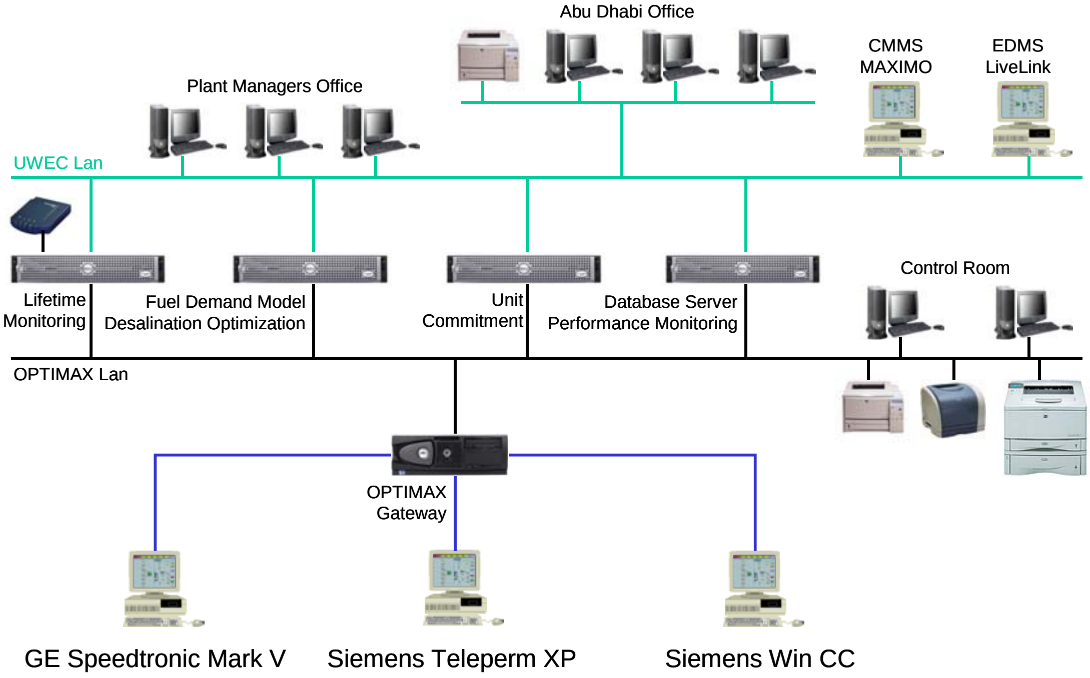
Areas are:

- Analysis of trends which are stored in a common database
- Common user interface on top of different Control Systems with access from the office network
- Automatic creation of logs and reports
  - Saves working time
  - Avoids manual entry errors.
  - Transfer logs to the Document Management System "LiveLink"
- Automatic exchange of data with MAXIMO (computerized maintenance management system)
  - Makes automated processes possibility
  - Automatic generation of work orders based on plant alarms and running hours.

In Fujairah more than 100 logs and reports have been automated. A daily saving of about 18 hours work can be estimated by using these automated logs & reports. Easy to use tools to configure different types of reports are developed by ABB using Microsoft Excel software in the system.

The **Power Generation Information Manager (PGIM)** offers the architecture to perform the following functions company-wide:

- Acquire, store and consolidate data from production, control systems and commercial systems
- Perfom a remote diagnosis of different plant sections



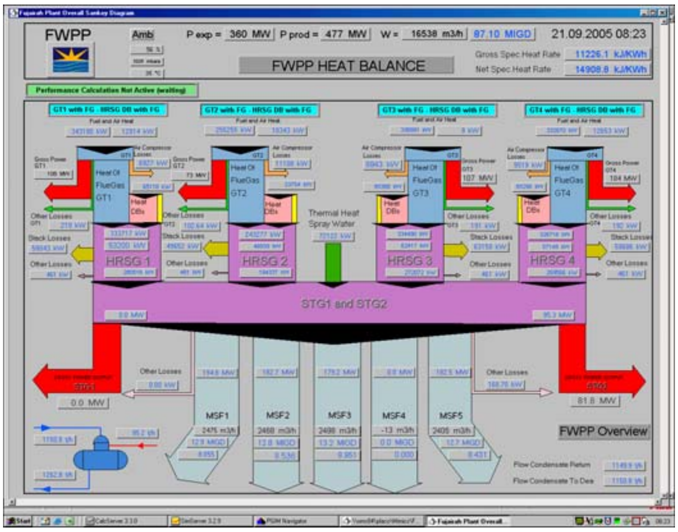
- Visualize and evaluate process values by means of a highly convenient user surface
- Make data available to other evaluating applications (e.g. calculation of characteristic values, optimization applications, EXCEL reporting)
- Provide maintenance and financial systems with process values, state variables and counter values
- Store data for any period of time

Performance Monitoring

In Fujairah water and power plant, performance calculations are performed for major equipments based on reconciled data:

- GTs
- HRSGs
- Steam Turbines
- Feed water pumps
- Multi stage Flash (MSF) desalination plant
- Sea Water intake pumps
- Reverse Osmosis (RO) desalination plant
- HP pumps

The graphics below show an example for result presentation of performance calculation.



The graphics and the respective trends are used for analysing the performance of the entire plant as well as for individual areas. Comparisons between actual and expected performance in connection with supervisory identifiers makes the analysis simple and effective.

Lifetime Monitoring for Boiler, Steam Turbine and Gas Turbine

BoilerLife is used to calculate, monitor and analyze the lifetime exhaustion of highly stressed thick-walled components of the 4 HRSG in accordance to the German rule "TRD" (Technische Regeln für Dampfkessel = Technical rules for steam generators).
The calculations are based on online measurements for pressure, temperature and flow available in the DCS system.

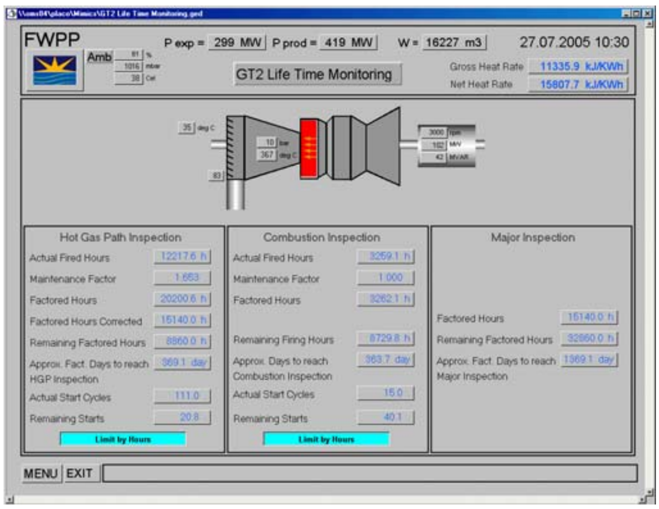
For all four boilers HRSG1, HRSG2, HRSG3 and HRSG4 the following components are monitored:

- HPHTSH Outlet Header
- HPHTSH Inlet Header
- HPITSH Outlet Header
- HPITSH Inlet
- HPLTSH Outlet
- HPLTSH Inlet
- HP DRUM

For power generation four General Electric Gas Turbine PG 9171E and Siemens NG90/90 steam turbines have been installed in the Fujairah Water & Power Project. The lifetime and monitoring applications for these machines have the purpose to give the user a continuous information about the aging and efficiency decrease of certain equipments. This information shall enable the user to plan the inspection intervals and efficiency increasing actions more accurately.

The monitoring functions are

- GT Lifetime Monitoring
- ST lifetime monitoring
- GT air intake monitoring
- GT compressor washing monitoring



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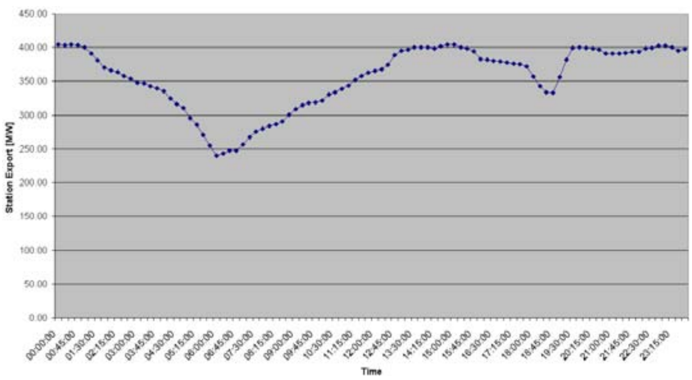
GT and ST lifetime monitoring algorithm give an indication to the current lifetime of the equipment, based on operating hours, start/stop cycles etc. and also information on how much longer the equipment can be run before an inspection is recommended by the equipment manufacturer.

The GT air intake-monitoring algorithm gives an indication of the contamination level of the air intake filter and the resulting decrease in the GT performance. This is accomplished by observing the air filter pressure drop increase in comparison to the new and clean state, which is an indication to the necessity to replace the filter.

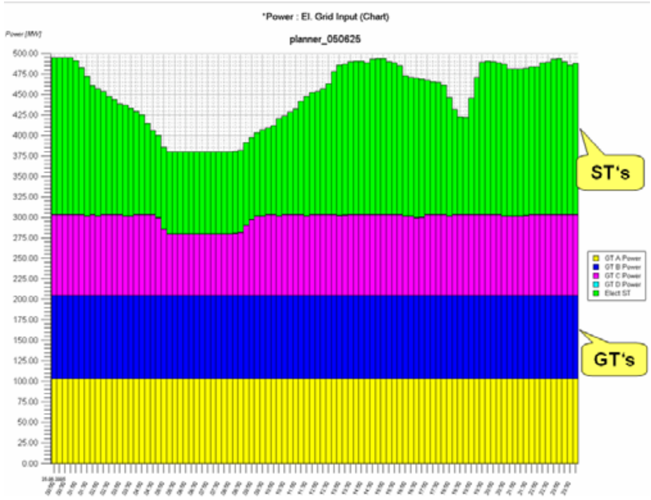
The GT compressor washing monitoring algorithm indicates the reduction in compressor efficiency due to compressor contamination in comparison to the clean state. This provides the user with the possibility to schedule efficiency increasing actions, i.e. offline compressor washing, more accurately in order to assure high compressor efficiency, and thus decrease fuel consumption.

Load Scheduling with PowerFit
The loads, which have to be provided by Water & Power Plants, vary over the day. The following graphic shows an example of an electrical daily load curve of Fujairah Water & Power Plant.



It is remarkable that the plant operates between 50% and 80% of the total net capacity within one day, which is a big change. Other examples may not show such a big load change, but a 20% change is normal. A load change of more than 150 MW is equivalent to about 1.5 times of one GT's maximum capacity.

The task for a load scheduling system is to find the optimized combination of production for the different units taking into account electrical and water demond of the total plant.



Above graphic shows an example for a pre planned optimized day ahead schedule for the gas and steam turbines created by **PowerFit**. In this example only three of the four GTs are running. The load change over the day is adjusted by the steam turbines.

In Fujairah shift charge engineers who share the results via tables with the operators realize the planning and operation. Via trend pictures the planning and the current plant operation can be monitored online. Automatic reports allow post operation analysis.

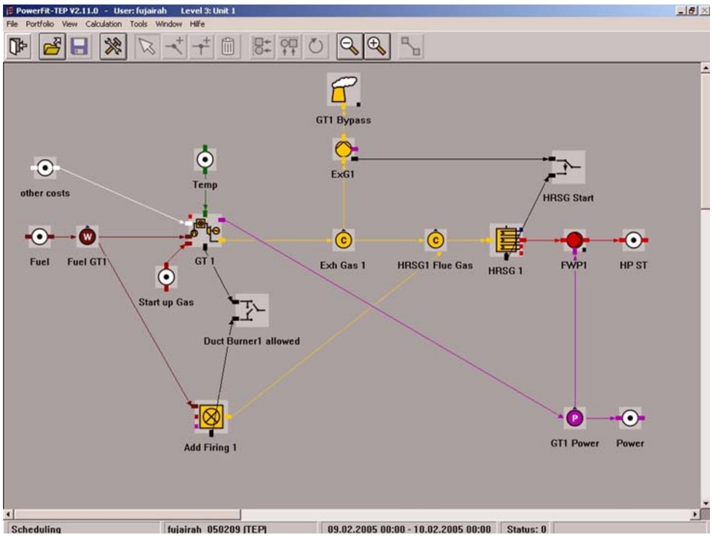
It has been observed, that the main benefits are realized from

- Finding the best combination between GT and ST production,
- Finding the best combination between ST production and bypass steam flow,
- Finding the best combination between MSF and RO production and
- Utilizing the storage possibilities of water.

This saves up to 2.7% of the fuel costs in Fujairah.

Fujairah Water and Power Plant

The user interface is fully graphical which allows an easy way to define the complicated mathematical model running in the background. With the capabilities of the GUI, the user is able to understand the model of the power and water plant (and later is able to enlarge the system).

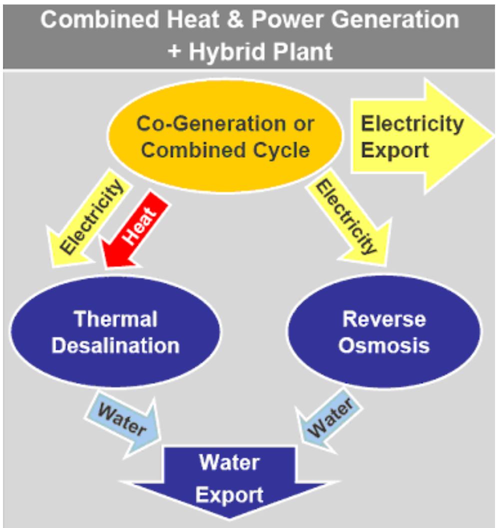


During the definition of the model different targets have to be weighted:
On one hand could be precisely an exact picture of all the components, that describes the way how the fuel and seawater are input to the plant and power and potable water produced.
On the other hand it's intended, to get a preferably simple design of the technical correlations, because higher accuracy causes higher calculation time (mathematical iterations) of the optimization system and therefore lower response time. The response time within Fujairah for a 1-day calculation in 1-hour steps is normally only a few minutes.
Even with some simplifications the mathematical description fits to the reality with satisfactory accuracy.

Hybrid Optimization
Fujairah Water Plant is of hybrid nature. Water is produced by MSF and RO units. The water quality of both processes differs. The potable water output of the plant has to fullfil defined quality limits.

The water produced with MSF units is nearly demineralized and the water produced by RO unit is of high quality. So the mixed potable water from the two processes has still to be mineralized by the Potable Water Plant to reach the minimum mineralization criteria stipulated by the health authorities.

The RO-Plant in Fujairah is a modern plant built by Degremont. The construction follows the actual know-how available for this type of potable water production. It consists of 2 lines. Each line has 2 passes. The salinity of the 1st pass output is in the range of 500 ppm. The salinity of 2nd pass output is in the range of 15ppm. Some water is bypassed the second pass and is mixed at the output of the 2nd pass. The water produced by the RO plant before the optimization maintained salinity in the range of 80-100 ppm.

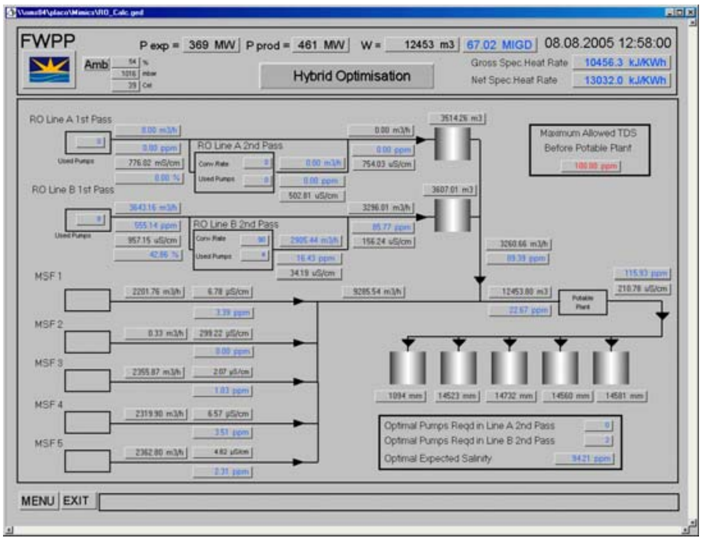


The optimization task was to find the minimum number of 2nd path racks, which still allow meeting the guaranteed water quality of the total plant.

This saves:
- Electrical consumption for 2nd path rack pumps (0.5 MW per pump)
- Maintenance costs for 2nd path racks
- Chemical costs in potable water plant

In addition to the above, water production by the RO plant is increased as a result of the reduction of running racks in the 2nd pass since each of the second pass rejects approximately 10% of the water, which passes through it (conversion rate 2nd pass ~ 90%).

This saves energy and maintenance costs for the same total amount of water produced.



The above graphic is used in Fujairah for Hybrid Optimization. In this production example 2-second pass racks can be taken out of service compared to the standard approach by using 1 second pass rack for every 2 first pass racks in operation (1:2 ratio).

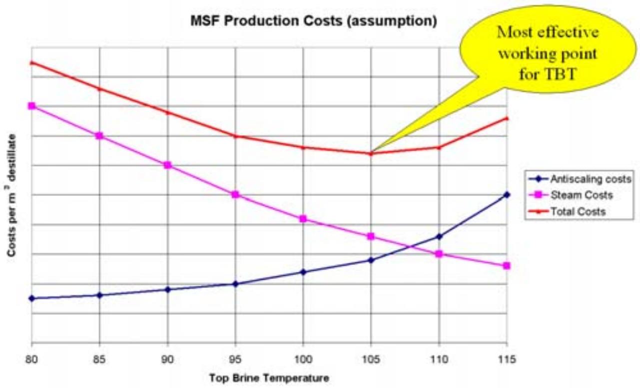
The above example shows the online optimization; additionally an offline tool is also provided for modelling different scenarios. The offline tool is used for planning purposes. As an example the effects of a maintenance shutdown of all MSF units had been predicted success-fully.

MSF Optimization with PowerCycle

The main operational costs in a MSF plant are:

- Costs for the energy input by steam
- Costs for chemicals additives
- Costs for electrical energy consumption by the plant equipment (e.g. pumps).

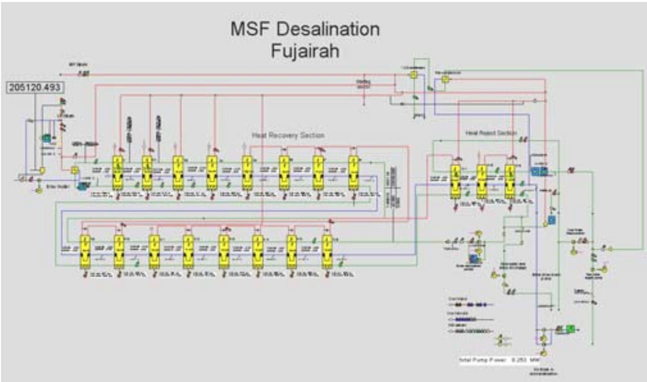
The task of the optimizer is to reduce the sum of the specific costs (cost per cubicmeter distillate) by calculating other set point keeping the water production constant.
The principle curve of the costs depending on the Top Brine Temperature (TBT) is like follows:



The steam costs per m3 distillate decreases with higher TBT because the Performance Ratio (PR) increases.

The chemical costs (here antiscaling) per m3 distillate increases with higher TBT because of higher scaling at higher temperatures.
The total costs (sum of the above steam and the antiscaling costs) shall be minimum in an optimized situation.

For the MSF optimization a process simulation package is used which is capable to model MSF units down to stages level. By using this method and other necessary components (e.g. brine heater, pumps, …) a model of the MSF line is configured as shown below:

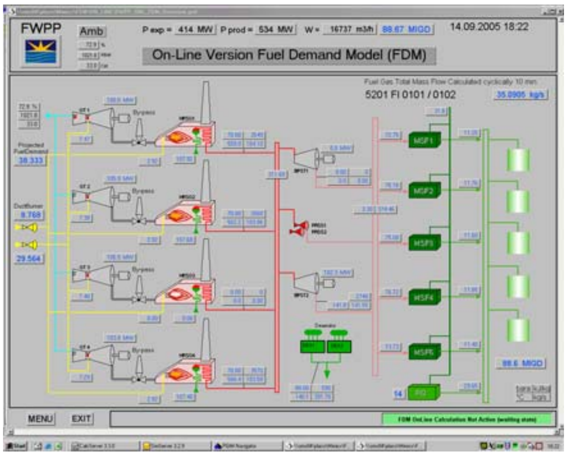


PowerCycle is able to simulate and to calculate optimized set points for the mentioned parameters.

Fuel Demand Model with PowerCycle
For the calculation of the Projected Fuel Demand at various load points, with different combination of operating units and at various ambient conditions the tool **PowerCycle** is used.

PowerCycle has a comfortable graphical user interface, which allows to design thermodynamic loops similar to a P&I scheme and to generate the mathematical model automatically in the background. Base for this is a comprehensive library, which contains major plant components and its connections as well as modules for control of variables and signal transmission. That's why modelling of even very complex systems like combined cycle power plants with desalination (MSF) is possible just intuitively from the normal view of a thermodynamic engineer.

The plant data calculated by the FDM is based on the maximum fuel efficiency that can be achieved within the dispatched operating configuration for the dispatched capacities of Power and Water.



Off-Line FDM

> **PowerCycle** has a base module "Simulation", which is designed for steady-state simulation of a power plant. For this purpose, the entire process status is described by the use of the entered specification parameters and characteristic curves for all plant components and a relative small number of physical values (pressure, temperature, flow rate). The total number of additional manual inputs is high.

On-Line FDM

> On-Line FDM uses the same base module as described in Off-Line FDM. The manual inputs are replaced by On-Line measured process values.

Conclusions
The proven installation of a performance monitoring and optimization system in Fujairah water and power plant sums up the effectiveness of modern optimization techniques in power plants.

Savings of more than 4% of the total fuel consumption are reached in the areas:

- Work Process Optimization
- Performance Monitoring
- Lifetime Monitoring
- Load Scheduling
- Hybrid Optimization
- MSF Optimization
- Fuel Demand Model

The benefits achieved in this project show the big potential also for other hybrid and non-hybrid plants.

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