


Debottlenecking and Optimisation of Oil and Gas Facilities

by *En. Mustafa bin Mahmood* and *Mr. Youxin Ch'ng*

THE HYSYS process simulation program is an established oil and gas industry software used for generating heat and mass (H&M) balances and performing process simulations of various offshore facilities. Using the data from the H&M balances (and properties from the process streams), designs for facilities are developed from conceptual phase engineering to Front End Engineering Design (FEED).

More often than not, the design data used in the engineering phase differs significantly from actual operating conditions for offshore facilities. This may be due to a number of reasons, but mostly due to the oil or gas reservoir not behaving as predicted (since reservoir behaviour predictions are based on limited initial well test data). The variations in operating data compared with the initial design data may be:

- higher or lower gas oil ratio (GOR)
- higher or lower operating pressures/temperatures/oil or gas flowrates
- higher watercuts and produced water rates
- changes in compositions, wax, asphaltenes content, pour point, gel point, *etc*.
- contaminants difficult to identify from well tests, *i.e.* H_2S content, mercury, other trace metals

The aforementioned variations to design data or even planned changes to the original design cases, such as additional production from satellite tie-ins which were not considered during the design phase, will then impact the existing facilities and potentially create bottlenecks in the production systems which limit production or limit increasing production.

Identifying the bottlenecks can be a problem since, normally, a number of bottlenecks need to be addressed at the same time and then prioritised for a particular production case. For example, a higher GOR would result in more gas production than originally designed for, assuming the design oil rate is to be maintained. Therefore, the capacities of the gas processing equipment would need to be checked and this could include compressors, heat

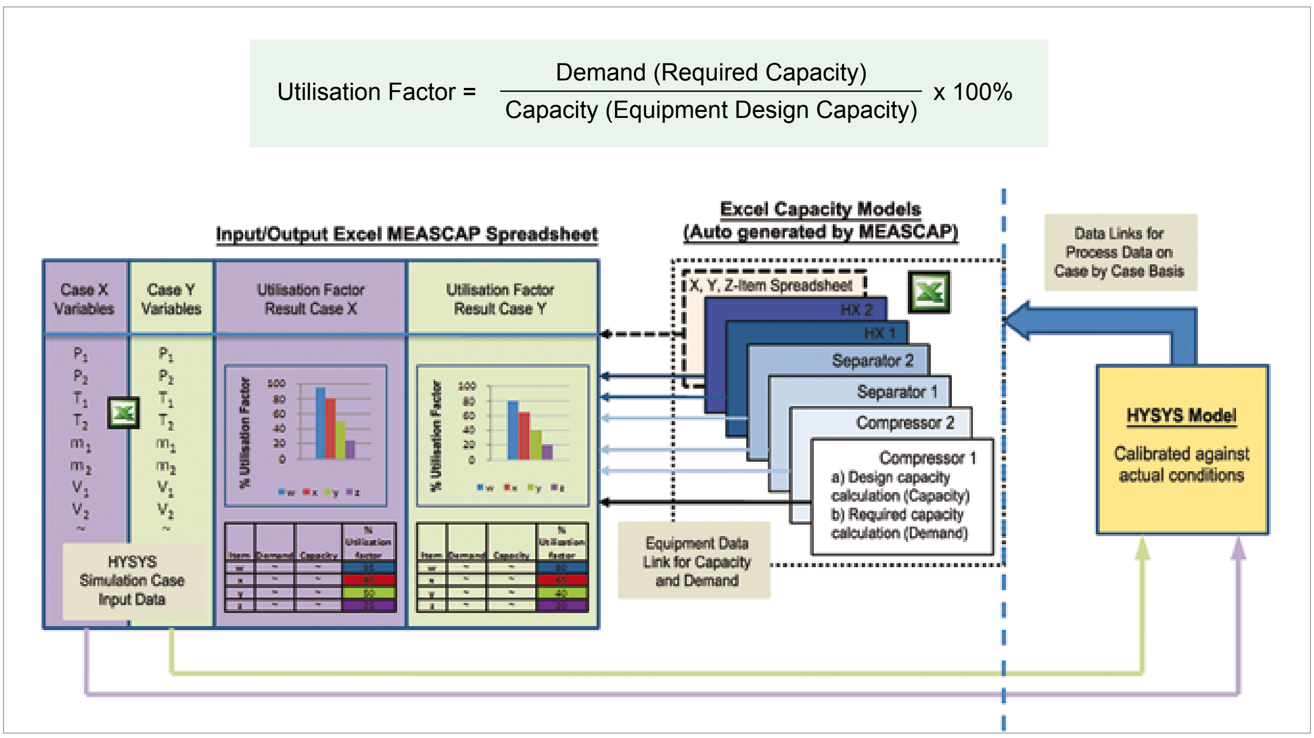


Figure 1: Meascap modelling structure

exchangers, separators, dehydration units, control valves (PCVs) and other equipment depending on the complexity of the gas processing system.

The whole gas process should be evaluated for bottlenecks, and assessing only certain individual items for their capacities should be avoided since an item that is not checked may actually prove to be a bottleneck. Certain gas processing equipment may have been designed with different design margins (design factors of 10% or 20%), which would allow it to accommodate higher gas flowrates and still remain within its design capacity.

This could apply to the PCVs or heat exchangers, but not necessarily the separators or the compressors. Therefore, the capacities of the separators and compressors could have exceeded before exceeding the design capacities of PCVs or heat exchangers.

Performing capacity checks for individual processing equipment items has often been a task designated to process engineers. During the design phase, the capacity of equipment items is determined and specified in process datasheets (PDS) for certain design cases. The design cases considered are normally limited to two or three cases, which provide an envelope for all normal operating scenarios with some margin. It should be noted that these design cases are based on certain operating conditions which are fixed in order to develop the design of a particular facility, *i.e.* perform HYSYS simulations and generate the necessary H&M balances.

When a facility actually goes into production mode, it may not operate as per design conditions as the parameters may change. These parameters could be pressure, temperature, flow, compositions, *etc*. The operator then adjusts the operating conditions in order to accommodate any small changes in P, T, flow, *etc*. However, sometimes, these changes are significantly different from those considered during the design phase. Therefore, in performing capacity checks on existing equipment, the engineer also has to take into consideration the actual operating conditions and not only those considered during the design phase (PDS).

Capacity checks are not always easily performed. If you have a complex process or a large number of items to check, this can be time consuming, particularly if a number of operating scenarios are to be considered. Take, for example, an offshore gas facility that has 15 pieces of equipment and the operator wishes to consider the implications of two different GORs (higher GORs) on its processing capacity. This could result in 30 capacity checks being performed. To consider an additional sensitivity for two inlet pressures would then double the capacity checks to 60.

Poyry has developed a software tool called Meascap, which can easily identify potential bottlenecks and perform capacity checks by comparing the required capacity (Demand) of an equipment item with its design capacity (Capacity). By making this comparison, it is possible to identify how close certain pieces of equipment operate to their design limits for a given production case, thus highlighting potential bottlenecks within the process. Multiple cases can be run simultaneously and, therefore, different production profiles or operating cases can easily be evaluated.

Meascap is a simple Excel-based spreadsheet tool which extracts the process data generated by a HYSYS simulation and uses it to calculate the actual design capacity (Capacity) and required capacity (Demand) of the equipment items using Capacity Models. The capacity models are worksheets which are automatically generated by Meascap based on the equipment simulated in HYSYS, *i.e.* each separator, heat exchanger, compressor, pump, valve, etc, will have its own capacity model. The capacity models are used to specify the design capacity for each piece of equipment.

Different capacity checks for the same piece of equipment can be specified such as duty, tubeside pressure drop and gas capacity checks for a heat exchanger. A list of capacity checks available in Meascap for various types of equipment is presented in Table 1. Meascap then uses these design capacity (Capacity) results and compares them with the actual required capacities (Demand) as determined from the data extracted from the HYSYS simulation. A Utilisation Factor is then calculated for each piece of equipment to indicate, in

Table 1: List of capacity checks performed by Meascap

Equipment Type	Capacity Check Performed by Meascap
Compressor	Gas Capacity - Nameplate
	Gas Capacity - Max Speed Curve
	Gas Capacity - Multiple Curve
Pump	Head and Flow - Nameplate
	Power - Nameplate
	Pump Curve
2 Phase Vessel	Gas Capacity - Nameplate
	Gas Capacity - Horizontal / Vertical
	Gas Capacity - Vane Pack
	Inlet Nozzle - Rho V Squared and Erosional Velocity (bpd)
	Inlet Nozzle - Rho V Squared and Erosional Velocity (mmscfd)
	Liquid Capacity - Nameplate
	Liquid Nozzle - Rho V Squared
	Liquid Nozzle - Velocity
	Vapour Outlet Nozzle - Rho V Squared and Erosional Velocity
3 Phase Vessel	Gas Capacity - Nameplate
	Gas Capacity - Horizontal / Vertical
	Gas Capacity - Vane Pack
	Gross Liquid Capacity - Nameplate
	Gross Liquid Capacity - Horizontal / Vertical
	Inlet Nozzle - Rho V Squared and Erosional Velocity (bpd)
	Inlet Nozzle - Rho V Squared and Erosional Velocity (mmscfd)
	Oil Capacity - Nameplate
	Oil Outlet and Water Nozzle - Rho V Squared
	Oil Outlet and Water Nozzle - Velocity
	Vapour Outlet Nozzle - Rho V Squared and Erosional Velocity
	Water Capacity - Nameplate
Heat Exchanger	Duty - Nameplate
	Gas Capacity - Nameplate
	Liquid Capacity - Nameplate
	Pressure Drop - Shell Side
	Pressure Drop - Tube Side
Heater	Duty - Nameplate
	Duty - Constant UA
	Gas Capacity - Nameplate
	Liquid Capacity - Nameplate
	Pressure Drop - Outlet Velocity
Cooler	Area - Calculated
	Duty - Nameplate
	Duty - Constant UA
	Gas Capacity - Nameplate
	Liquid Capacity - Nameplate
	Pressure Drop - Outlet Velocity
Valve	Gas Capacity - Nameplate
	Gas Capacity - Cv
	Liquid Capacity - Nameplate
	Liquid Capacity - Cv
Liquid-liquid Hydrocyclone	Liquid Capacity - Nameplate
	PDR Ratio
	Oil in Water Specification
Membrane Filter	Gas Capacity - Nameplate
	CO_2 Concentration Specification
	Pressure Range
	Temperature Range

percentage, how close the equipment is required to operate compared to its design capacity. Refer to Figure 1 for the Meascap modelling structure.

Meascap presents the results of the utilisation factors for each item in both tabular and graphical formats (refer to Figure 2).

Obviously, if the Utilisation Factor exceeds 100%, a design constraint for that piece of equipment has been exceeded. Data filters are available and can be used to filter results so as to only identify an equipment of interest which exceeds a certain value (*i.e.* only present results for equipment with a utilisation factor greater than 90% or greater than 100%). At the same time, Meascap also identifies how much capacity is available for each equipment item.

This type of capacity approach makes Meascap an ideal tool for use on Enhanced Oil Recovery (EOR) projects and for debottlenecking/ optimisation studies for maturing offshore facilities. It could also be used by new facilities to check the robustness of the design using the latest operating conditions and production data in order to plan for future operating conditions and where potential bottlenecks could occur. Running multiple cases for different operating conditions or production profiles is relatively easy once the initial model has been calibrated in HYSYS and the design capacity worksheets (capacity models) have been completed. It should be noted that very low utilization factors should also be checked since some process equipment efficiencies are significantly affected below a certain turndown limit.

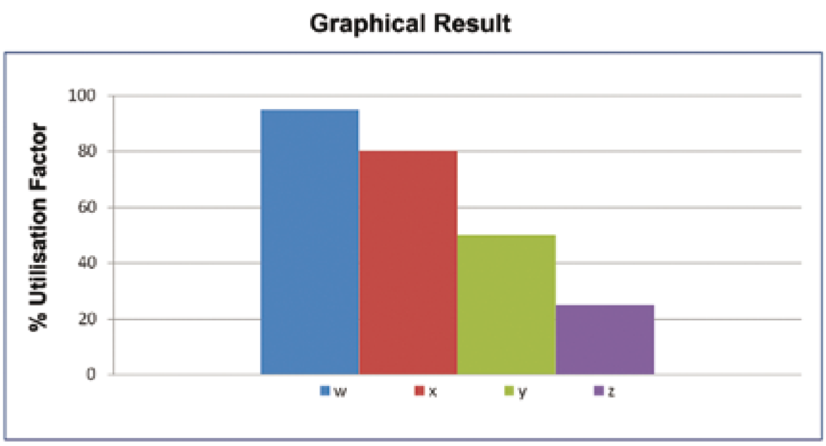
Case Study

A debottlenecking study was performed using Meascap for a large offshore complex in Southeast Asia. An integrated HYSYS model was developed (refer to Figure 3) and calibrated against actual operating data and included the following facilities:

- Production from five wellhead platforms (WHP)
- One central processing platform (CPP)
- One oil processing facility
- One CO_2 removal platform

The fully integrated HYSYS model included a CO_2 removal membrane system, two hydrocyclone systems for produced water treatment and a propane refrigerant system along with the usual process equipment such as separators, compressors, pumps, heat exchangers, valves, *etc*. The total number of equipment items simulated in HYSYS was 220 while 80 well production streams were defined in terms of compositions (GOR), pressure, temperature and flow. Dummy wells were also included to incorporate future production scenarios. A total of 660 capacity calculations were performed for a given case.

Since the HYSYS simulation and the Meascap evaluation is based on steady state operating conditions,



Tabular Result

Item	Demand	Capacity	% Utilisation factor
w	~	~	95
x	~	~	80
y	~	~	50
z	~	~	25

Figure 2: Utilisation factor results

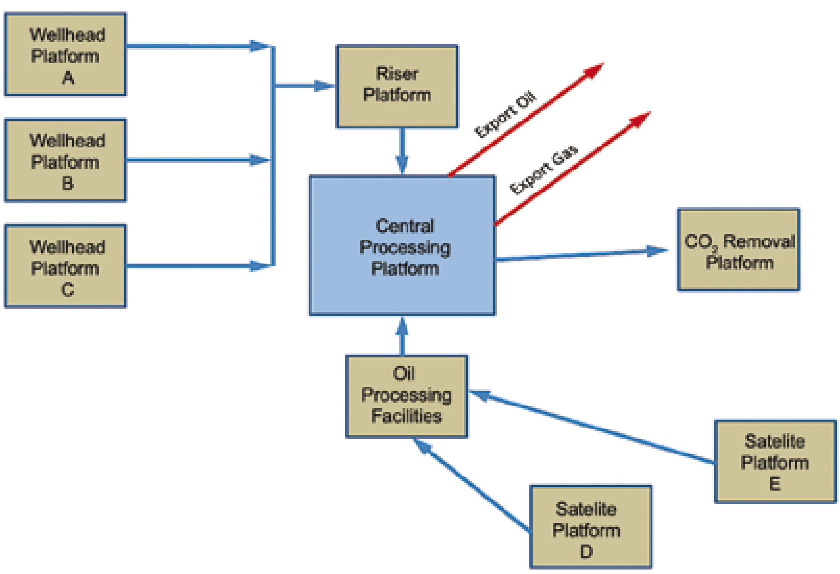


Figure 3: Case study-integrated HYSYS model

the control set points was fixed in the HYSYS simulation by specifying the temperature, pressure, flow or composition of a particular stream. However, these can be changed in Meascap for different operating scenarios since they are process variables. For example, if the operating pressure for a vessel is controlled by a PCV, the inlet stream pressure to the vessel could be specified at the control value, and the same goes for temperature control where the process stream temperature is specified to be the temperature control set point value.

In Meascap, the evaluation of the heating medium and cooling medium systems was limited to calculating individual heat exchanger duty requirements and comparing them with their design duties, so these systems were not modelled in HYSYS. However, the total duty for the heating medium and cooling medium system was calculated in HYSYS in order to compare with the utility systems design duty.

Only if the system design duty is exceeded (*i.e.* sum of the individual heating or cooling duties) should a separate HYSYS and Meascap model be developed to identify any bottlenecks within the utility system itself. Depending on the client's preference, the cooling and heating mediums can be modelled and simulated. A propane refrigerant system was modelled for this case study rather than just comparing the cooling duty for the primary and secondary chillers with their design duties.

The debottlenecking study was conducted over a six-month period and was split into three distinct phases:

(i) Develop a HYSYS fully integrated facilities model and calibrate against actual operating conditions (30%).
(ii) Collate design data for input into Meascap Capacity models (55%)
(iii) Checking Meascap results and input data particularly for items with a Utilisation Factor > 100% (15%)

A total of 30 items were identified as potential bottlenecks since their utilisation factors were greater than 100%. These included the following:

- Separator gas capacities and liquid residence times and vane pack capacities
- Control valve liquid capacities and Cvs
- Heat exchanger duties and shell side pressure drop
- Pump discharge head
- Compressor discharge head

A further 45 items were identified as having exceeded design constraint, but these were soft design constraints such as inlet nozzle momentum limits and gas capacities based on assumed k values for separators and vane packs. It is at the operator's discretion whether exceeding the soft design constraints such as inlet nozzle momentum is acceptable.

As part of the development of the fully integrated HYSYS model, inter field pipelines were modelled in HYSYS using a PIPESIM Link, which then incorporates the pipeline pressure drop and pipeline heat loss results into the HYSYS simulation.

The design data and operating data for all the items identified as being potential bottlenecks is to be checked again, and the client is to review the design data and operating data used to produce the previous findings. Once this review is complete, the operator intends to perform Meascap evaluations as part of its EOR program.

Therefore, Meascap is an ideal tool for both projects group and operations group for operating companies looking either to increase production using their existing facilities or optimise production on maturing facilities. Meascap identifies potential bottlenecks within a process and helps prioritise the bottlenecks in terms of equipment capacity (utilisation factor). Once the bottlenecks have been identified, and with the aid of cost benefit analysis, a value can be put on any changes necessary to improve or increase production. ■