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REALISING OPTIMAL ENERGY CONSUMPTION VIA ENHANCED iCON® UTILITY OPTIMISER (iUO 2.0)

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ABSTRACT

iCON® utility optimiser (iUO) was first introduced in PETRONAS in 2010, and it has been extensively utilised in energy review studies across PETRONAS' downstream processing plants. The tool is the first in PETRONAS to use the first principal steady-state simulation with customised unit operations to perform mass and energy balance of a steam plant. An enhanced version of the optimiser, iUO 2.0, was released in 2019, offering much-improved robustness, accuracy, and flexibility. The software enhancements focused on three objectives: increased robustness, improved accuracy, and enhanced applications. Greater robustness and speed are achieved by auto-generating the property package and the migration from source original point (SOP) objects to script-based unit operations. Accuracy is enhanced by offering more specification handles for the user to benchmark against the actual operation. These include specifications for efficiency, energy loss, heat rate with a correction factor, compression/expansion ratio, vendor performance customisation for GTG, and a sectionalised section for boiler and HRSG. Enhanced applications of the unit operations include linking to historian data and plant monitoring of the specific equipment for modelled variables such as equipment efficiency. Efficient and timely utility equipment monitoring will allow improved productivity and operational efficiencies at the site. Plantwide steam network modelling allows a structured review of optimisation opportunities of the steam network system as a whole. The enhancements in iUO 2.0 promise a better realisation of the targeted benefit from desktop modelling to site implementation; and improve its readiness for future digital transformation and implementations. This paper showcases 3 example applications of iUO 2.0 using a gas turbine, HRSG, and a plantwide example case to demonstrate the robustness and opportunity evaluation for a utility plant optimisation.

Keywords: *Simulation, modelling, steam system, industrial application, energy*

INTRODUCTION

As operating energy expenditures of a processing plant increase annually, profit margins become slimmer, necessitating continuous improvements of how the plant is operated. A structured energy review analysing short and long-term opportunities to improve energy generation and consumption has become crucial. The traditional method of steam network monitoring uses a spreadsheet linked to plant data historians doing mass balance calculations. Having a dedicated simulation package to model major energy-related equipment would allow seamless first-principle modelling of a steam network that would allow monitoring a steam system, provide a structured way of constructing a descriptive and predictive utility plant digital twin, and perform optimisation studies.

MATERIALS AND METHODS

The study utilised a first principle process simulation software. The main process simulation engine is Symmetry (iCON®) version 2020.3.41, which included all the new unit operations in iCON® utility optimiser (iUO) 2.0. Simulation models were constructed using the plant's actual steam network layout derived from plant PFDs, P&IDs, equipment datasheet, and DCS screenshots. Operating parameters for case studies include design data and actual plant operating conditions derived from the plant data historian.

RESULTS AND DISCUSSION

The study has successfully produced an extension package to iCON® simulation software with customised script-based unit operations to perform a steam plant's mass and energy balance. The software enhancements achieved three main objectives, i.e., increased robustness, improved accuracy, and enhanced applications. Results for the three achieved objectives will be shown via three case studies.

Case study 1: Configuring an Advanced Gas Turbine model using Vendor data

A gas turbine is a combustion engine that can convert fuel to kinetic energy, driving a generator for power generation. Traditional modelling of a gas turbine using a standard process simulation software includes modelling three major equipment: an expander, a reactor to model the combustion chamber, and a compressor. Manually modelling the unit can be complicated and can result in a slow convergence time due to the internal controllers calculating the power balance. The new iCON® utility optimiser (iUO) allows users to model rigorously gas turbines for power generation as a single unit operation with multiple user input combinations. This gives the user flexibility in specifications to better match either design or actual plant performance. Figure 1 shows the expanded features of the Advanced Gas Turbine modelling in iCON iUO 2.0.

iUO 2.0 introduced new parameters to match equipment design characteristics better, as specified in the vendor datasheet. The heat rate, defined as the ratio of the thermal energy input supply by the fuel to the turbine's actual work output, can be used as a handle to better match vendor data and the actual performance of an installed gas turbine. A regression of heat rate as a function of power can be generated from vendor data using a quadratic equation or other equations for an optimal curve fit, as shown in Figure 2. The heat rate can also be further tuned using a Heat Rate Correction Factor, which would further tune the heat rate to actual plant power generation. The calculated turbine power can also be further corrected by including the effects of the ambient air temperature. The turbine power is approximately a linear function of the ambient temperature. The correction factor will be defined as the ratio of the Actual Turbine Power to the Design Turbine Power.

Case study 2: Configuring a Heat Recovery Steam Generator (HRSG) model using actual plant data

The HRSG is a complex heat transfer equipment which goal is to recover energy for steam production. Typically, HRSGs generate steam utilising the energy in the exhaust of gas turbines with the option of having an internal combustor for supplementary firing. Manual modelling of the unit operation is complex due to the combination of exhaust, fuel, flue, and steam sides energy balance that requires controllers, which slows down the convergence time, especially in a plantwide model with multiple HRSGs. The new HRSG Unit Operation developed in iUO 2.0 wraps all the complex components of an HRSG as a single unit operation with multiple handles, as shown in Figure 3.

To calibrate the model against plant data, the critical factors to match include steam production,

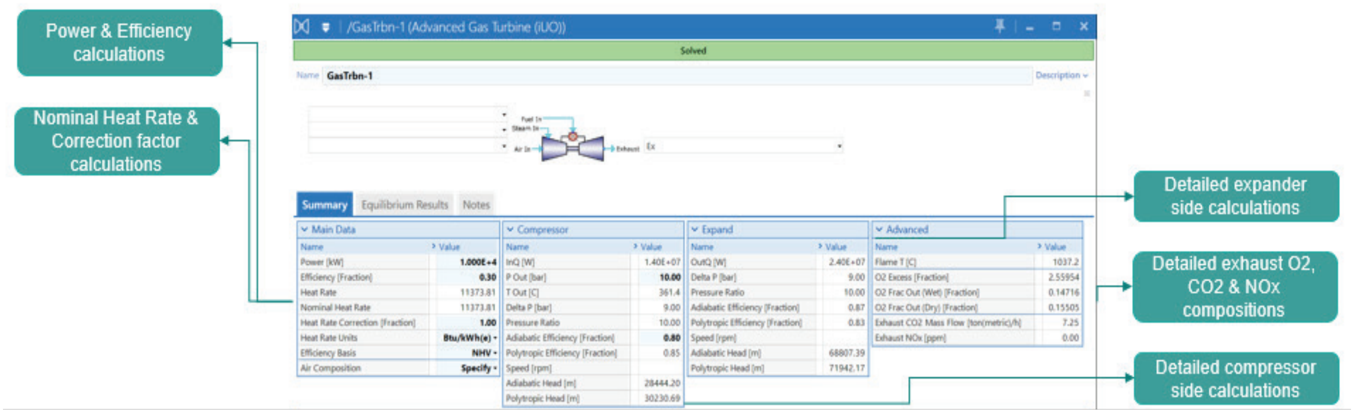

Figure 1 Features of an advanced gas turbine (GTG) in iCON® Utility Optimiser 2.0

Heat Rate vs. Power from vendor data (Rich Gas)

Power Output [kW]	Heat Rate (LHV) [kJ/kWh(e)]
4571	15102
5486	14044
6400	13245
7314	12645
8228.7	12173
9143	11934

Heat Rate vs. Power from vendor data (Lean Gas)

Power Output [kW]	Heat Rate (LHV) [kJ/kWh(e)]
4562	15118
5475	14057
6387	13258
7299	12657
8271	12184
9124	11944

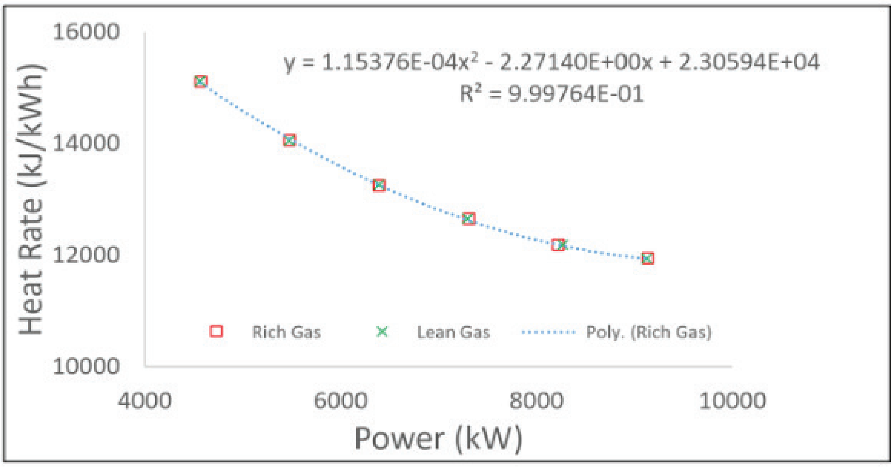

Figure 2 Configuring a GTG using power vs heat rate regression

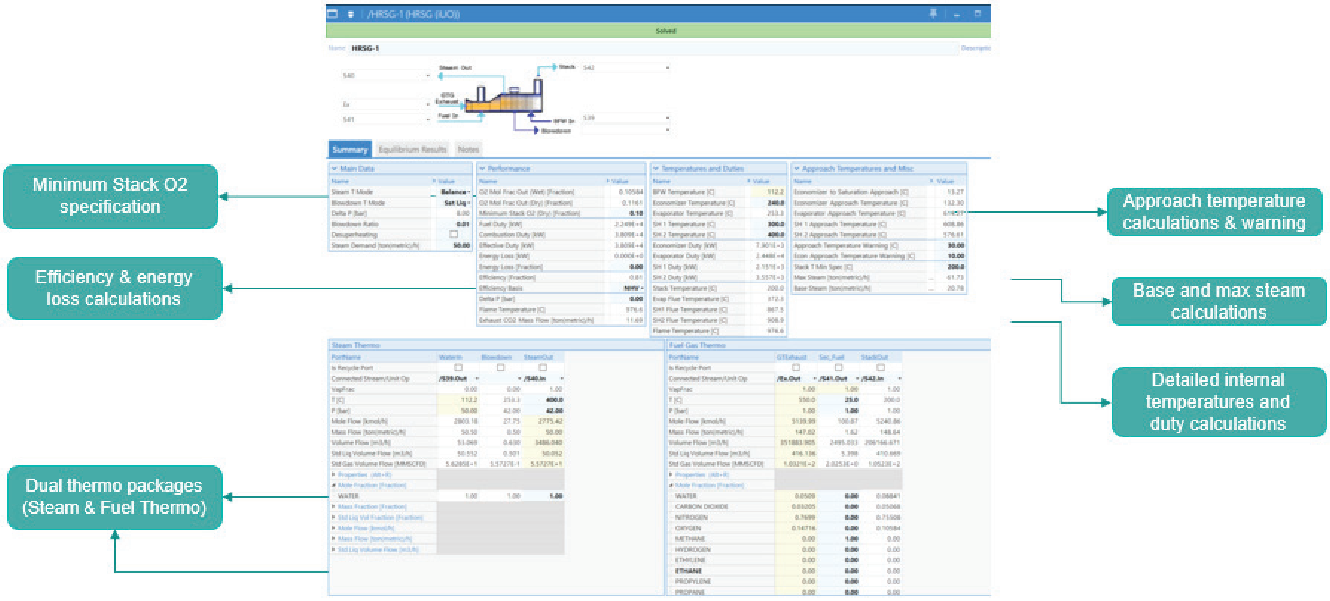

Figure 3 Features of a heat recovery steam generator (HRSG) in iCON® Utility Optimiser 2.0

supplementary fuel consumption, and stack temperature. Regression equations can be utilised to fit a scatter plot of actual plant data of steam production versus extra fuel and stack temperature, respectively. The regression equations can be input to the model to predict stack temperature and supplementary fuel consumption with varying steam demands.

Using the internal and approach temperature calculations of the HRSG, the regression can be further improved with a minimum approach temperature tuning methodology with an external controller to tune fuel flow to match the economiser ΔT between the BFW outlet and the flue. The energy loss factor and supplementary fuel flow can be tuned to match a specified economiser approach temperature. The main advantage of this ΔT min model is the ability to simulate the effect of boiler feed water temperature on HRSG fuel consumption and stack temperature. The calculated difference with plant data is less than 5 per cent and acceptable given the expected scatter in actual plant data.

Case study 3: Plantwide steam network modelling and optimisation

Plantwide model of a steam network was performed for multiple sites for steam balance accounting and performing site-wide fuel gas optimisation studies. The steam network models are linked to a financial spreadsheet that calculates the total savings of each

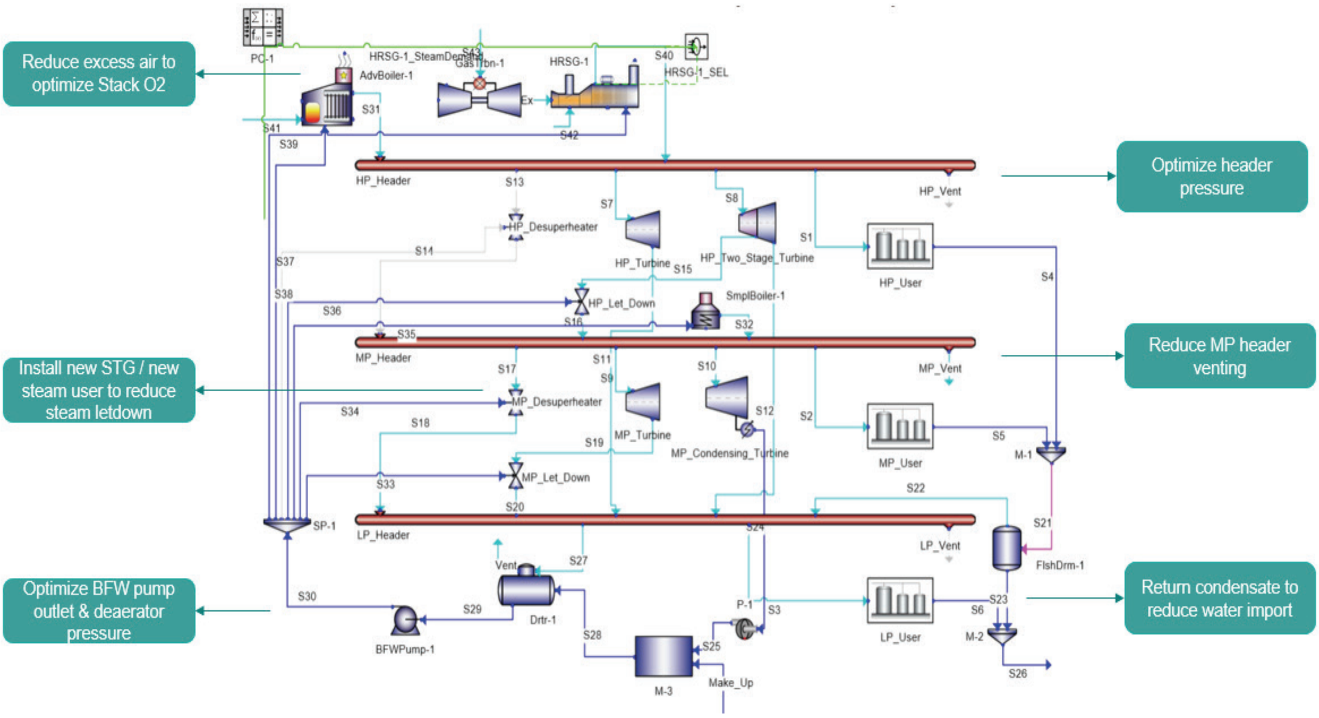

Figure 4 Plantwide steam network simulation model

opportunity identified and evaluated. With this set-up, the energy savings from steam quality or consumption optimisation will be directly back-calculated to the fuel gas reduction economic savings without the need for assumptions. Figure 4 shows some identified opportunities for steam network optimisation at different steam header levels and equipment.

CONCLUSION

The main objectives of increased robustness, improved accuracy, and enhanced applications were achieved utilising the new and improved iCON® utility optimiser (iUO). The enhancements in iUO 2.0 promise a better realisation of the targeted benefit from desktop modelling to site implementation; and improve its readiness for future digital transformation and implementations.

ACKNOWLEDGEMENT

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