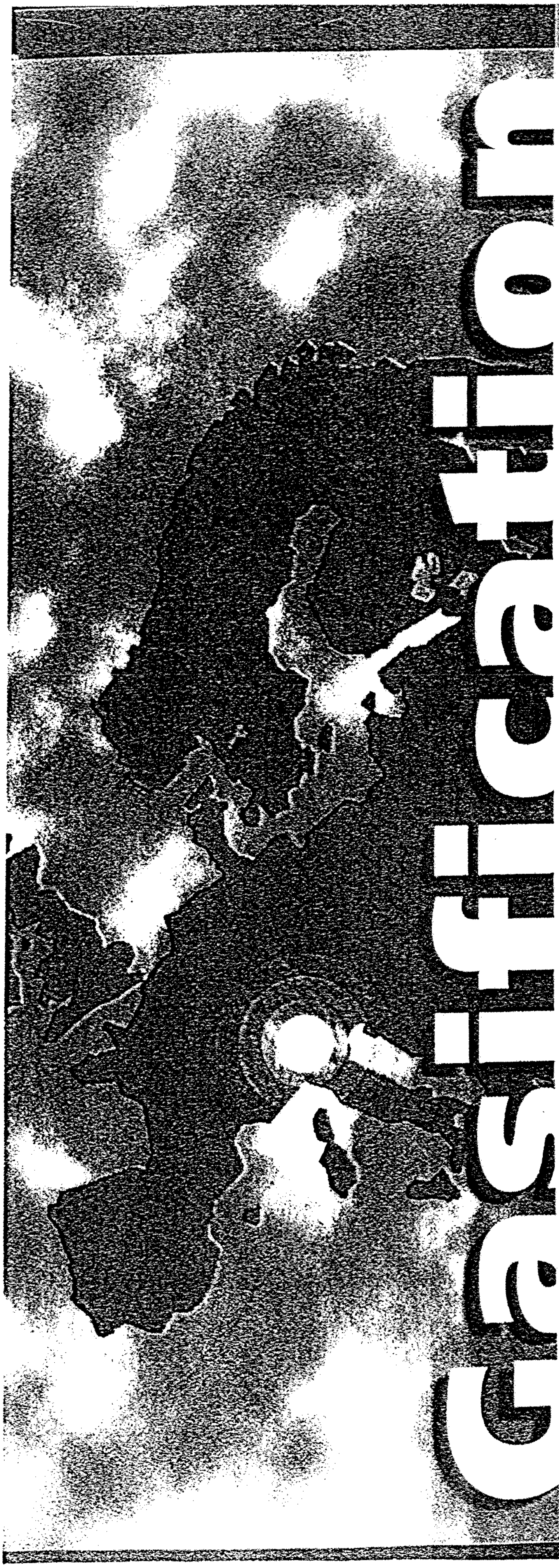

Gasification technology in practice

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DYNAMIC SIMULATION: AN ENGINEERING TOOL TO OPTIMIZE ISAB ENERGY IGCC PLANT DESIGN, CONTROL AND OPERABILITY

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ABSTRACT

In the course of the execution of detailed engineering of ISAB Energy project, a Dynamic Simulation Study of the Integrated Gasification Combined Cycle Plant is under development.

Dynamic Simulation is an engineering tool necessary to check and to finalize the overall plant design.
The dynamic simulation which is commonly applied to CCU plants, is particularly important for IGCC Complex where the integration between the Gasification section and the CCU section, is essential for the correct and safe operation of the Plant. The simulation model is used to predict the transient behaviour of the IGCC plant subsequent to a planned or unplanned disturbance of the steady-state operation.
Complete plant responses (stream flows, temperatures, and pressures) to these events are predicted and evaluated for their acceptability.
The paper describes in detail the steps which are being followed in the development of a dynamic simulation study of the ISAB Energy IGCC Plant:

a) the dynamic model is built assembling equipment design data, operating data, control valve and controller data, process flow and logic diagrams;

b) the planned and unplanned events to be simulated are defined in accordance to the plant operating modes and the operating requirements specified by the electric power purchaser (i.e. plant load variations, gas turbine load rejection, disconnection from the electric grid, island operation etc.);

c) the simulations are performed and their results discussed. If necessary, modifications to equipment and control devices are implemented;

d) finally all the information relevant to the control of the plant, derived from the dynamic simulation are implemented in the control system (i.e. ramp for planned load change, controller parameters, advanced control strategy etc.).

PURPOSES OF THE DYNAMIC SIMULATION STUDY

The Dynamic Analysis is by now an engineering tool, commonly applied in the design of Combined Cycle plants. This is due to the operating features of these plants: frequent load variations, large operating flexibility, sudden disconnection of plant from the electric network, possible island operation. The expected transients are imposed to a plant consisting of sections with different time responses: very quick for the machines, much longer for the steam cycle.

FWI developed several dynamic simulation studies for Combined Cycle and Cogeneration Units: the first one for FIAT AUTO Mirafiori plant (2 x 60 MWe Units) in 1988, following for SERENE Project (8 x 50 MWe Units), for a Refinery Cogeneration Units (25 MWe) and for CENTRO ENERGIA projects (2 x 150 MWe).

The questions described for CCU are furtherly stressed in the IGCC plants, where the feed to the CCU is supplied by a Complex Plant connecting intrinsically the fuel and the power productions: the integration between the Gasification Section and the CCU section is essential for a flexible and safe operation of the Plant.

Based on these considerations a Dynamic Simulation Study has been planned for the ISAB Energy IGCC Project, and is under development.
It consists in building a dynamic simulation model describing the sections of the plant which are dynamically significant. Then the simulation model is used to predict transient behaviours of plant variables such as temperature, pressure, flow, caused by planned or unplanned events.

The Dynamic Simulation Study performed during the engineering phase of the ISAB Energy IGCC project is aimed to the following targets:

- Check of the equipment sizing; the dimensions defined on the basis of one or more operating and design cases, shall be suitable to withstand the transients which might prove more critical than the steady state operations.
- Check of the control strategy, development and finalization of the control system; this includes definition of ad hoc control philosophy to solve particular problems, and to ensure that no undesirable or unsafe conditions are expected during transients; check of control valve size and characteristics.
- Selection of safe operating procedures such as rate of load changes.
- Estimate of controller parameters, allowing a shorter tuning on field.

For the study execution many detail information relevant to equipment geometry, control devices data and characteristics, are needed. It is performed as soon as these data are available from the Vendors, trying a compromise between the need to forward the check of the equipment and the control system, and the availability of the required data.

PROCESS AND CONTROL DESCRIPTION

The ISAB Energy IGCC Plant is designed to process heavy oil residues (i.e. Asphalt, Visbroken Vacuum Residue, Fuel Oil, etc) coming from the adjacent refinery.

The Plant is composed mainly of the following sections:

- Gasification: two Texaco Partial Oxidation Reactors using steam as moderator and oxygen as oxidant, of direct water quench type, each followed by one scrubber, to remove the soot and ash from syngas.

- Carbon Recovery and Recycle to recover soot from soot water and recycle it to the gasifiers.

- Syngas Heat Recovery section where raw gas from Gasification is cooled by generating steam and hot water, with separation and condensation of most water vapour. The catalytic hydrolysis of COS to H_2S is also achieved in this section.

- Acid Gas Removal where raw gas is scrubbed by means of formulated MDEA in order to selectively remove H2S, minimizing CO2 co-absorption.

- Purified gas is repeated, expanded by producing additional electric power, and humidified with water heated in the above mentioned Heat Recovery Section.

- Finally syngas enters the Combined Cycle Unit composed of two identical trains consisting of the gas turbine, the heat recovery steam generator with post-combustion, the steam turbine.

In addition to these main sections, the IGCC Complex includes the Metals Recovery Section, the Sulphur Recovery and Tail Gas Treatment Section and all the Utility Systems required for the operation of the Plant.

The IGCC Complex control system is aimed to manage the electric power production of the five power generators connected to the national electric distribution grid.
The IGCC Complex operate either in the power control mode or in the feed control mode.
In the power control mode the amount of power produced by the complex is a set point defined by the management of the power distribution grid.
In the feed control mode the amount of power produced by the complex is limited by the amount of available feed up to the maximum throughput capability of the complex. In essence the feed control mode is a specific case of the power control mode where the specified power output is the maximum possible.

In other words, during normal operation a fixed amount of electric power shall be produced or a fixed quantity of asphalt shall be destroyed. Variations in both requirements promote an unbalance between the syngas production and the syngas consumption. The unbalance produces a variation of pressure in the raw syngas header.
When the electric power production requirement is to be changed, a new set point is entered. This is compared against the measured power output, activating the signal to CCU to change the power output. This causes a variation of the syngas requirement and consequently of the clean syngas header pressure.

The clean syngas header pressure activates the expander controller to maintain constant the syngas pressure at the inlet of the Combined Cycles by throttling more or less on expander inlet and/or bypass. Consequently the raw syngas pressure in the Heat Recovery Section fluctuates and a variation of the syngas production from the Gasifiers is called. Steam, oxygen and hydrocarbon feed rates are changed to adjust the syngas production in order to match the clean syngas demand of the Combined Cycles and re-establish the raw syngas header pressure.
This type of control maintains constant the pressure at the gas turbine inlet, during the transient period, while the raw syngas pressure upstream the expander is let to fluctuate, utilizing as a buffer for capacity adjustment, the large gas inventory existing in the system operating at high pressure.
The same procedure is applied when a feed rate variation is necessary.

The above described functions are performed through four main control systems:

- The IGCC complex controller which monitors and controls the raw syngas header pressure by sending signals to the gasifier control system and/or to the Combined Cycle master control system to balance the raw syngas make and the clean syngas consumption: the IGCC Complex controller allows the front end of the complex where syngas is produced to match up quickly to the back end of the complex, where syngas is consumed. This will minimize the response time of the complex to changes in plant power output or plant feed rate.

- The gasifier control system which signals the two individual gasification train control systems to control the train throughput of the respective gasification train. In so doing, the gasifier control system controls the total raw untreated syngas production from the two gasification trains.

- The Combined Cycle master control system which signals the two individual Combined Cycle Unit controllers to control the clean syngas input to one or both of the respective combined cycle units and in so doing controls the total treated syngas consumption in the two combined cycle units.

  During normal operation the unit controller optimizes the power generation efficiency by the distribution of load between the two trains, and within each one, between the gas turbine and the postcombustion.

- The raw syngas header pressure control system which maintains the raw syngas header pressure upstream of the gas expander to allow efficient heat recovery from the hot syngas from gasification.

The dynamic model of the ISAB Energy IGCC Plant describes the whole process involving syngas, starting from its generation in the gasifiers, through cooling, H_2S washing, expansion, humidification and combustion in the CCU. These systems are connected, from the operating point of view, by the mentioned main controllers.

The other ancillary sections (i.e. Metal Recovery, Sulphur Recovery and Utility Systems) are not simulated as the associated dynamics are not significant.

DYNAMIC MODEL PREPARATION

The model for each section describes the main components, the piping and the associated control system; it integrates all the information necessary to evaluate the mass, thermal, hydraulic balances, predicting dynamically stream flows, temperatures and pressures during the transient.

Data Gathering

The following plant and equipment data will be assembled to build the dynamic model:

a) Process flow diagrams of the plant

b) Equipment physical data. This includes volumes, surfaces, dimensions, geometric arrangements and design characteristics of mechanical equipment in order to simulate off-design component behaviour for gasification and combined-cycle components and associated valves and piping.

c) Operating point data. Heat and mass balance for base-load operating condition. This includes all stream information (mass flow rates, pressures, temperatures, enthalpies, and compositions).

d) Controls and logic drawings for the equipment and plant. Control valves and controllers data.

e) Plant operating philosophy.

Model Preparation

The model will be built using a commercial dynamic simulation software of modular type. Some additional modules will be customized to describe adequately the ISAB Energy IGCC Plant.
The following steps are followed:

a) First, a model schematic is generated. This involves laying out the process which defines the scope of the model.

b) A diagram is then created which depicts the selected software modules and their connections used to simulate the process.

c) Most components can be simulated using modules from the standard software library. New modules for unique components will be developed, as necessary.

d) The next step is to superimpose a process heat balance with enough information to define the pressure, flowrate, enthalpy, and composition of each stream at operating point condition.

e) Drawings of control strategies are developed from the operating procedures and plant controls and logic drawings.

f) With the plant scope defined, all modules selected, all data gathered, a dynamic model of the plant is configured. The model will include all the main components (e.g., coolers, gasifiers, exchangers, drums, absorber, expander, saturator, combustors, turbines, heat recovery steam generators, valves and all associated piping) in the plant as a series of resistance and volume modules connected together in a thermal/hydraulic network.

g) Once the model is created and all appropriate variables initialized, a quick next step is to test the model at steady-state conditions to choose if the model variables match the heat balance at the operating condition, both in design condition and in offdesign condition.

h) The next step is to dynamically test the model. Test disturbances are introduced into the model and the system's response in terms of flows, pressures and temperatures observed. The system should pass from the original steady-state condition to a different final steady-state condition through a transient which can be properly discussed.

EVALUATION OF PLANT TRANSIENTS

Based on plant operating philosophy and operating experience with similar plant, planned, unplanned or upset events for dynamic evaluation will be identified.
Planned events are Gasification and Combined Cycle load variations. The simulation study is aimed to define the faster load ramp, accepted by the equipment, minimizing the impact on their life.

The expected upsets of the CCU operation like:

- sudden disconnection of the Unit from the national grid;
- island operation feeding only the CCU auxiliaries;
- trip of one gas turbine;
- trip of one steam turbine;
- trip of HRSG postcombustion system;

will be studied in their effects on the whole Plant operation.

The same will be evaluated for upset conditions relevant to the Gasification and Syngas Treatment Sections, such as Gasifier trip , Expander trip ect.

Once the planned and unplanned plant events are selected, the model will be exercised for each of the transients. Complete plant responses (stream flows, temperatures, and pressures) to these events will be predicted and graphically presented. These responses will be evaluated for their reasonableness and acceptability. If a certain response has the potential for equipment damage or other unsafe conditions, plant design modifications will be investigated to preclude such conditions. Revised plant configurations will be re-evaluated for their acceptability.

The final product will be a dynamic model of the ISAB Energy IGCC combined-cycle plant with plant response predictions for the identified planned and unplanned (upset) events.

CONCLUSIONS

At present the Data Gathering and Dynamic Model Preparation phases are under development. The modelling of the ISAB Energy IGCC Plant is expected to be completed within four-five months and three months are scheduled for the evaluation of the plant transients.
As already happened for the developed CCU dynamic simulation studies, the IGCC dynamic model is expected to be a powerful tool to check the plant design, to optimize the control system and to explore the plant operability.

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