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Application Solution

Summary

This document describes the value of using Dynamic Simulation for a hypothetical refinery steam system, consisting of two gas turbines with dedicated heat recovery steam generators (HRSG) and a three-level refinery steam distribution system.

Business Value

Dynamic Simulation ensures standardization, cost efficiencies and consistent knowledge transfer by:

- Validating process control system design
- Validating response time of backup steam generators
- Assisting in Electrical Islanding analysis
- Developing steam load shedding strategy
- Providing Pre-tune controls for first time startup
- Avoiding shutdown of refinery units due to loss of steam supply

SimSci™

Dynamic Simulation Example:

Refinery Steam System Analysis

INTRODUCTION

Industrial steam systems (such as cogeneration facilities, refinery steam systems, and integrated gasification combined cycle (IGCC) plants) are often large, highly integrated, multi-pressure level steam distribution networks which can be fed by fired boilers, heat recovery steam generators, and process waste heat boilers. Tight operational constraints are often placed on steam and power production as the reliability and stability of these systems is vital to maintain normal plant operation. Thorough evaluation of these types of systems must include steady and transient analysis of the steam generator capacities and response times, distributed control system, steam distribution header hydraulics, and letdown valve capacities.

DYNAMIC SIMULATION BENEFITS SUMMARY

- Validate process control system design
- Validate response time of backup steam generators
- Electrical Islanding analysis
- Develop steam load shedding strategy
- Pre-tune controls for first time startup
- Avoid shutdown of refinery units due to loss of steam supply

This document describes a hypothetical refinery steam system consisting of two gas turbines with dedicated heat recovery steam generators (HRSG) and a three-level refinery steam distribution system. The objective of the analysis is to determine if the controls can maintain acceptable steam pressure in the refinery HP, MP, and LP steam headers in the event that one of the gas turbines trips.

DYNAMIC SIMULATION MODEL

The dynamic model simulates a typical steam system consisting of gas turbine generator/heat recovery steam generators (GTG/HRSG) that feed high-pressure steam to a three-level refinery steam system. DYNSIM® simulation, from SimSci-Esscor™, has four flow sheets which are executed simultaneously. These are:

1) GTG/HRSG Train A
2) GTG/HRSG Train B
3) Refinery North End — includes the steam letdown stations and steam turbine generators (STG)
4) Refinery South End — includes some large steam consumers

Figure 1 shows GTG/HRSG Train A. The gas turbine exhaust at 958°F generates high-pressure steam in the HRSG, which supplies the Refinery North End. The HRSG consists of a superheater, boiler, economizer, and steam drum. The HRSG supports supplemental firing of natural gas using the excess oxygen in the gas turbine exhaust. The steam drum level is maintained with a three-element control system. The GTG/HRSG Train B flow sheet is nearly identical and is not shown.

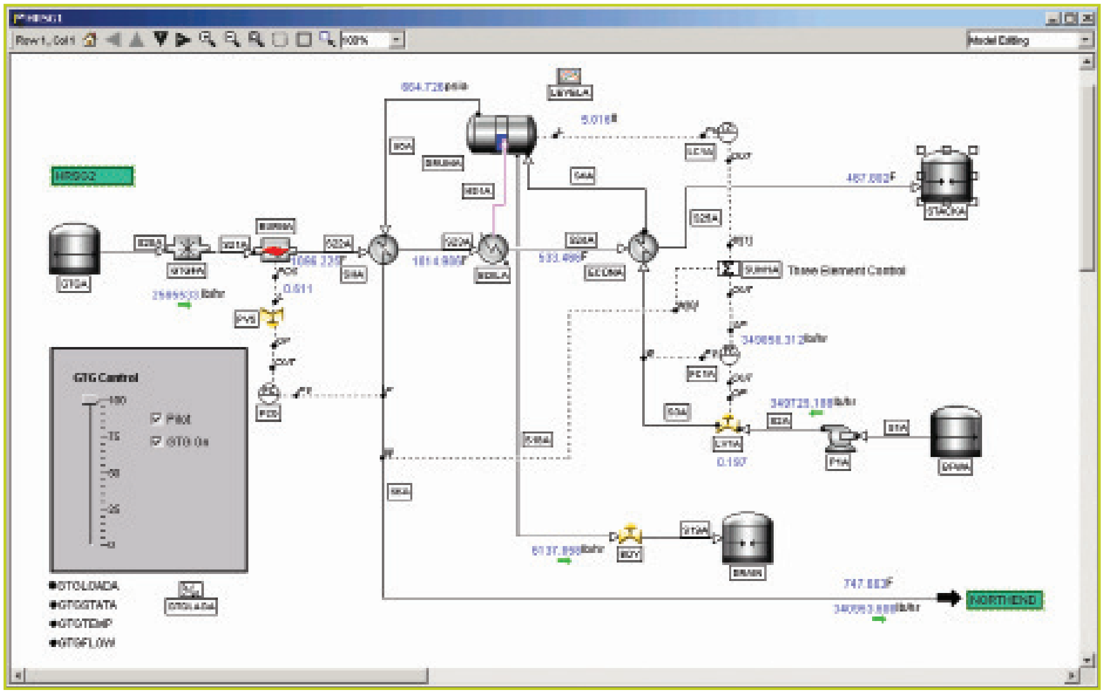

Figure 1: GTG/HRSG Train A

Figure 2 shows the refinery steam distribution system consisting of High Pressure (HP) steam at 600 psig, Medium Pressure (MP) steam at 300 psig, and Low Pressure (LP) steam at 150 psig. There are let down valves from HP to MP and MP to LP. A back pressure turbine lets steam down from HP to MP with a condensing turbine from MP steam. Refinery units on the north end of the refinery consume MP and LP steam. Steam flows to the south end of the refinery where there are HP, MP, and LP steam users. The south end flow sheet is not shown.

Excess steam is routed through the steam turbine generators (STG) to generate electricity. The refinery develops more power from the GTGs and STGs than it can consume internally. The excess power is sold to the local power utility.

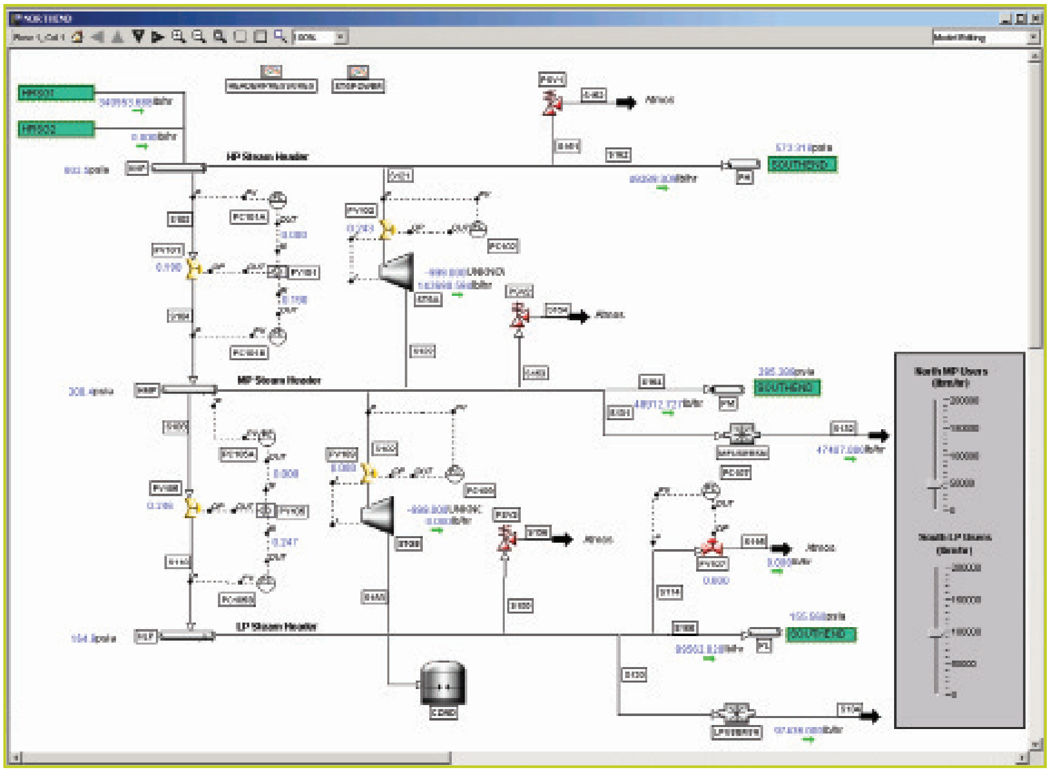

Figure 2: Refinery Steam System – North End

In the event of low steam supply, steam can be diverted away from the condensing turbines to provide more steam to the refinery. In addition, natural gas can be burned directly in the HRSG supplemental burners to produce additional steam.

The following assumptions were made in the development of this model:

- The gas turbine is modeled with an exhaust temperature and flow based on user defined correlations.
- If a gas turbine is tripped, the flow and temperature are assumed to decay with a 10-second time constant.
- Refinery steam users are modeled as constant flows of steam. In reality, steam consumption is reduced as the steam header pressure decreases. From the point of view of a dynamic simulation study to observe the impact of steam header pressure, it is conservative to assume constant steam flow to the refinery units.
- HRSG metal masses and fluid volumes must be appropriately estimated so that the response time of the HRSG is correct.

CASE EXECUTION AND RESULTS

A DYNSIM Scenario was created to easily run the simulation cases repeatedly while doing initial trial runs. The scenario was set up to load a steady state initial condition, wait five minutes, and then trip the gas turbine in Train B.

Case 1: GTG Trip with feedback control to supplemental burner

Figure 3 shows the HP steam pressure drops to 440 psig when GTG B is tripped. Supplemental firing is ramped up by automatic pressure control over 10 minutes after the event. Increasing the tuning constants to speed up on the supplement burner pressure controller is not effective as this leads to oscillatory behavior during normal operation.

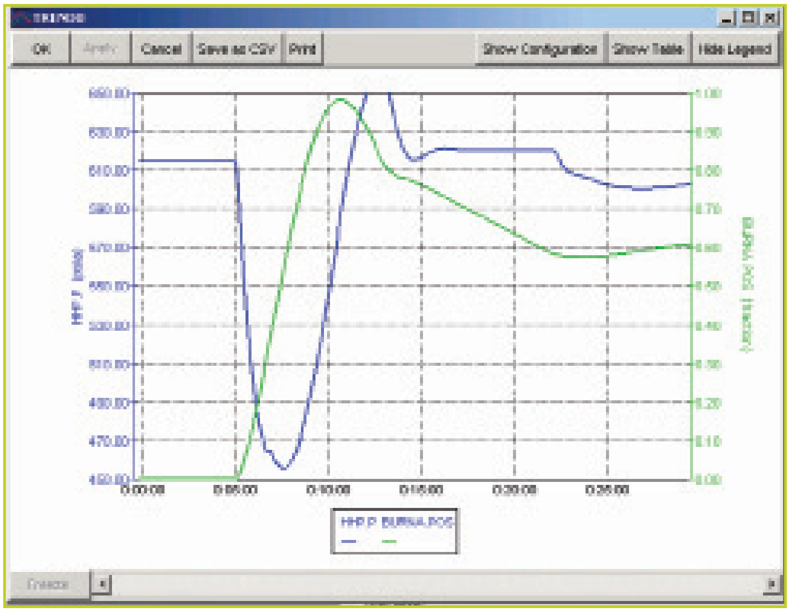

Figure 3: HP Steam Pressure (Blue) and Supplemental Firing Response (Green)
without supplemental firing feed forward control signal

Case 2: GTG with feed forward control to supplemental burner

Figure 4 shows the HP steam pressure response with a feed forward signal to the supplemental burners. The pressure drops to 520 psig when GTG B is tripped. For no delays in the regulatory controls supplemental firing, a feed forward system detects the loss of GTG B and automatically increases duct burning at the maximum ramp rate.

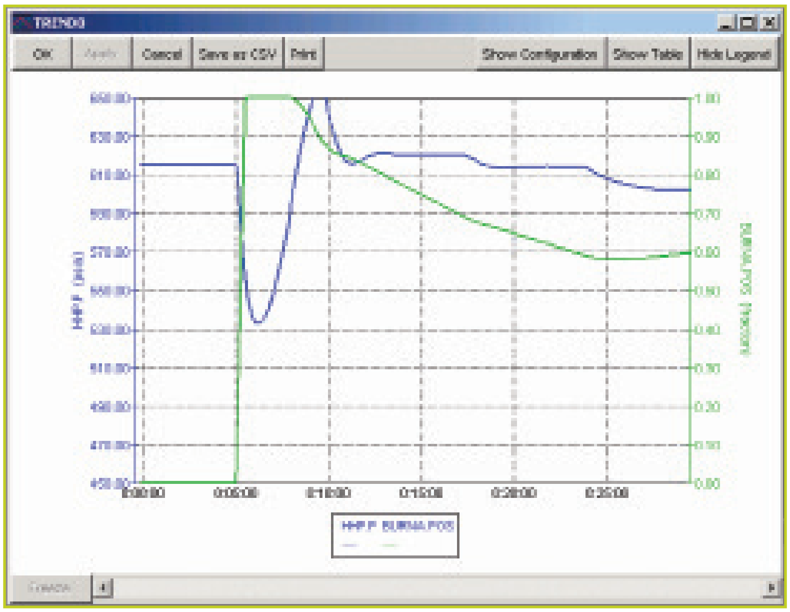

Figure 4: HP Steam Pressure (Blue) and Supplemental Firing Response (Green)
with supplemental firing feed forward control signal

Case 3: GTG with feed forward control to supplemental burner and trip of condensing turbine

Figure 5 shows the HP steam pressure response with a feed forward signal to the supplemental burners and a trip of the condensing steam turbine. The pressure drops to 555 psig when GTG B is tripped. In addition to a feed forward signal to the supplemental burners, the MP to condensing steam turbine is tripped providing fewer medium stream requirements. High-pressure steam pressure is maintained at an elevated pressure as it does not to be reduced to supply medium pressure steam.

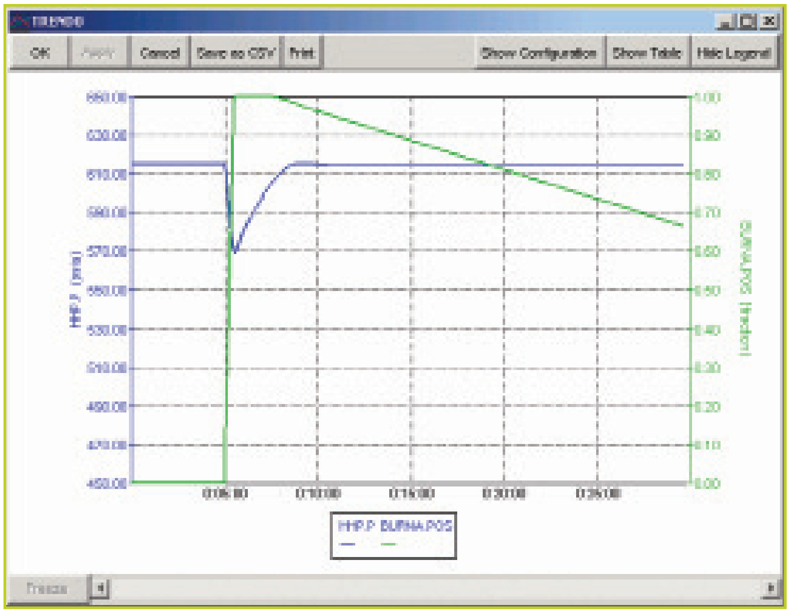

Figure 5: HP Steam Pressure (Blue) and Supplemental Firing Response (Green)
with supplemental firing feed forward control signal and trip of condensing steam turbine

Additional Study Work

Other cases can be investigated with the same simulation model:

- GTG B trip cases considering purposely over firing the supplemental burners so there is excess steam generation to produce electricity. In the event of the GTG trip, additional steam would be available. This is not economical from an electrical sales perspective; supplying backup steam to the refinery is a more critical concern.
- Islanding — refinery's electrical tie line with the local power grid is lost. This places a constraint on the system that electrical power and steam production must both match refinery demand.
- Develop a steam load shedding strategy to keep critical process units on line during steam shortages.
- Simulate an STG trip to be sure normal controls work properly so that safety valves are not lifted.
- Step loss in refinery steam consumption due to the trip of largest steam user.
- Ramp GTG up and down at maximum rate.

Additional Model Refinements

Some additional model modifications can be made for a more thorough analysis.

- Include gas turbine rate limits.
- Develop more detailed gas turbine curves for exhaust flow and temperature, as a function of gas turbine load.
- Develop a more realistic steam distribution model. The current model only has pressure calculations at the north end and south end as though all steam consumption came from one point in each end. A more realistic model includes multiple headers for each subsection of the refinery to more precisely calculate header pressures at different locations throughout the steam distribution system.
- Include steam desuperheaters after HRSG superheaters and on letdown stations.

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Rev. 01/15 PN SE-0128