Combined Cycle Modeling In MRTU – The Challenges

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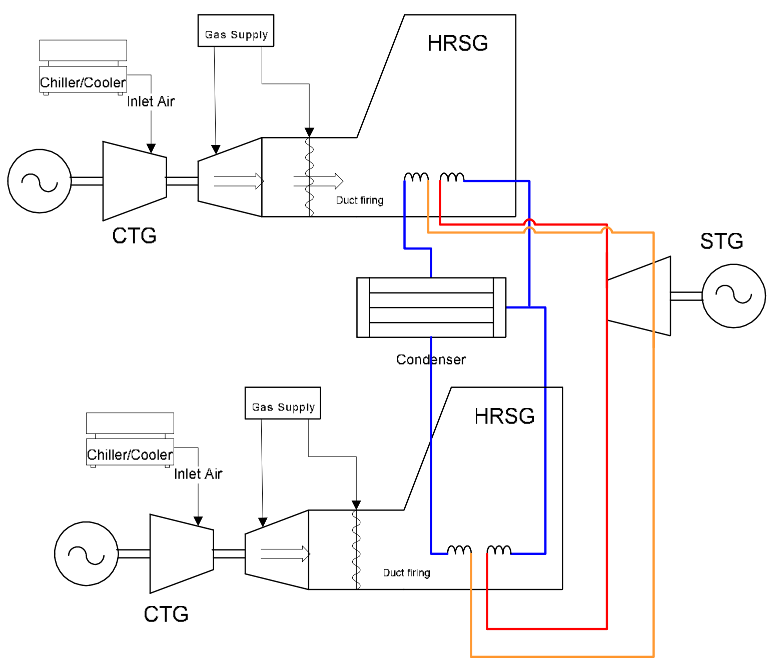
Background:

The preferred incremental source of baseload and intermediate generation in California has been, and in large part is likely to remain, the combined-cycle, natural-gas fired, power plant. This preference has emerged from their high thermal efficiency, relatively low cost, flexibility in output and their relatively low GHG emissions. Indeed, 20 percent of California's generation fleet is combined-cycle generation. New construction of several plants is underway. See Figure 1 for a typical configuration.

A combined-cycle generating station consists of one or more combustion turbines (CT) and one or more steam turbines. Each of the CTs is a single-shaft generator that is generally in the 150 to 180 MW range. They may, or may not, be capable of independent operation depending on environmental permitting as well as downstream exhaust and steam system design

FIGURE 1[1]

Typical Component and Process Diagram



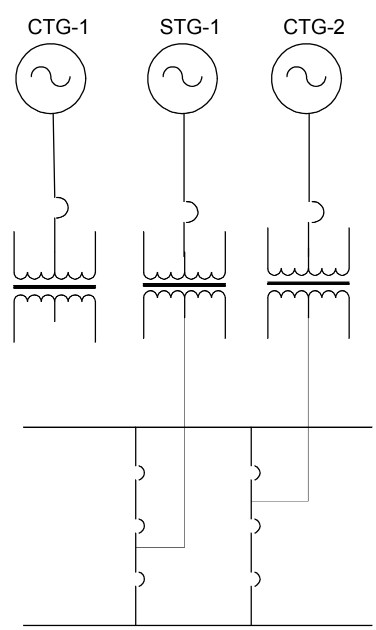
[1] Figures lifted *without* permission from the very helpful, but dense ERCOT paper on the issue. http://nodal.ercot.com/docs/pd/ida/wp/cc/18a1 IDA003 Combined Cycle Whitepaper v.91 .doc

Each CT is connected to a high volume, multistage boiler – a heat recovery steam generator (HRSG) – which is typically in 150 to 250 MW range. Most plants have the capability of directly firing natural gas into the HRSG (duct firing) which can boost output of each HRSG (albeit at a high heat rate) by the equivalent of 20 to 30 MW. Steam produced by each HRSG is subsequently used to drive one or more steam turbines (ST). Each steam turbine and each combustion turbine have an electrical generator that produces electric power (CTG and STG).

The typical configuration in California combines two CTs with one ST (Figures 1 and 2) commonly referred to as a two-by-one (2X1) combined cycle. Other configurations exist in California, including 1X1 and 3X1. Sometimes, multiple power blocks are located on one site (e.g. Calpine's Pastoria plant has a 1X1 and 2X1 behind a single meter.)

FIGURE 2

Typical Interconnection Single Line Diagram



Most combined-cycle plants can be operated in one of several configurations depending on the anticipated generation demand and market pricing. Indeed, a 2X1 CCGT could have as many as 7 configurations (CT1, CT2, CT1XST, CT2XST, (CT1and CT2)XST and two duct burners) Once in a stable configuration (for instance, both CTs and the ST in operation) the plant will have a finite operating range (e.g. a typical CC plant in 2X1 configuration will have an operating range of 350 to 520 MW.)

Transitions between generation configurations are significant events. Indeed, these transitions require either the start of the shut down of a generator, and therefore require minimum start times, minimum down times, slow ramp rates and transitions, or forbidden zones of output where generation levels cannot be maintained.

MRTU Structure and Bidding:

The nodal design anticipated in MRTU implicitly contemplates a single generator for each meter/resource ID. The SC is allowed to submit a single three-part bid for each resource. The three parts are:

1. Start-Up – the costs to take a unit from off-line to min load
2. Minimum Load – the cost to hold a unit at Pmin
3. Energy bid curve – a monotonically non-decreasing price/quantity curve that extends from Pmin to Pmax.

In addition, a generator is allowed to submit information to the CAISO on the operating characteristics of the resource. These so called “Master File” entries identify the ramp rates (MW/min) for the entire range of output, the minimum start times, minimum run times, minimum down times and many other factors. Many of these characteristics are further qualified by the status of the machine (e.g., start time will vary depending on whether the machine is “hot” or “cold.”)

The MRTU optimization takes all of these variables into consideration before dispatching a plant on, or changing its output level. In addition, rules have been established in settlement to ensure that once dispatched, a generator will absolutely recover – at a minimum – its start, no load and variable costs of operation either through market revenues or through the “Bid Cost Recovery” uplift.

Difficulties Associated with Bidding CCGTs in MRTU:

The implicit assumption that a single resource ID represents a single generator is antithetical to the bidding, design and structure of combined cycle plants.

1. Operating Characteristics: It is not possible with one set of Master File characteristics to reflect multiple generators behind one resource ID (embedded generators). It is difficult, or not possible to:
    a. Enforce warranty or insurance limitations on minimum start, minimum run and minimum down times.
    b. Protect forbidden dispatch regions (particularly when combined with limitations on ramp rates.)
2. Bid Structure: It is difficult and substantially misleading to create a continuous, monotonically non-decreasing bid curve that represents the full range of configurations the embedded generators of a CCGT.
3. Bid Cost Recovery: It is not possible to ensure bid cost recovery for embedded generators.

Problems That Arise:

The inability to model CCGT complexities into MRTU results in several distinct and unfortunate results.

1. Avoidance of CAISO Dispatch: The overarching goal of the MRTU design -- security constrained economic dispatch -- will be frustrated as CCGT owners avoid CAISO infeasible and risk-laden dispatch. The risks of infeasible dispatch – imbalances, unrecovered costs, etc. – will encourage CCGT owners to self-dispatch their units (e.g. by bidding very low to their preferred configuration.)

2. Lack of flexibility: Once in the preferred and stable configuration, a CCGT owner will be encouraged to manually adjust the CASIO dispatch range (raise Pmin, or SLIC down Pmax) in order to eliminate the possibility that the CAISO would dispatch between configurations.

3. Distraction from Reliability Function: In order to prevent the CAISO from infeasible dispatch, real-time operators at both the generator and at the CASIO will be distracted from their primary reliability function while they manually adjust dispatch ranges, as in 2, above.

4. Increased Costs to the Market: The sub-optimal dispatch results will result in higher market prices than would be available if CCGTs could be modeled and dispatched by the CASIO.

5. Increased Bids From the Generator: The exposure to infeasible dispatch, the likely costs of imbalance charges and continuous disputes all must logically be built into risk-adjusted generator bid curves.

6. Absence of Solutions: The CAISO has already experienced – in market simulations – an inability for the optimization to find a solution causing pricing lock-outs. These problems may be resolved by the application of the 10:1 ramp limitation rule. However, this ramp rate limitation will further aggravate items 1-4 above.

7. Unfounded Curiosity by Market Monitors: The inability of the CCGT owner to respond to infeasible dispatches may bring the unnecessary and unfounded attention of the market monitors.

Solutions:

Each of the other organized markets have faced and resolved the modeling of CCGT plants. Calpine will not prejudge any of the particular solutions chosen by the other markets. Rather, we will work cooperatively with the CASIO to explore all options and to drive to an implementation of CCGT modeling within 6 months of start-up.