# Combined Cycle Modeling: Educational Document

## Combined Cycle Modeling - Where we are today

Combined Cycle Plants are thermal power plant units which combine the Brayton Cycle of a Gas Turbine Generator with the Rankine Cycle of a Steam Turbine Generator. A Combined Cycle Plant typically consists of one or more Gas Turbines Generators that exhaust into a Heat Recovery Steam Generators (HRSG). The steam produced by the HRSG is used to drive a Steam Turbine Generator. Combining the Brayton Cycle with the Rankine Cycle in one plant produces high efficiencies, because much of the energy in the Brayton Cycle exhaust is captured and used in the Rankine Cycle. Some Combined Cycle Plants can also operate in either the Simple Cycle (Gas Turbine Generator mode only) or the Steam Cycle only mode.

This issue concerns Combined Cycle Unit's unique incremental heat input curve. Various components of combined cycle operation are not defined clearly in Manual 15. Currently, combined cycles are modeled similarly to other unit types in PJM, but may not be the same in terms of physical parameters. Combined cycle units may be offered inconsistently by various participants due to the lack of clarity in Manual 15.

In 2005, PJM developed functionality to model Combined Cycle units in eMKT. This functionality was never used by participants. Currently, the functionality would need to be turned on and may not work with the unit commitment program. Combined Cycle plants would have the ability to be modeled as single composite unit or as multiple individual units using the Combined Cycle Model. The Combined Cycle Model allows a plant to be modeled as a combined cycle group. The individual units within the combined cycle group can have the individual physical components modeled and have all the unit constraints. Therefore, each combustion turbine (CTs) and each steam turbine (steam unit) within the combined cycle group can have its own start-up cost, minimum run time, minimum down time, offer curves. Etc. Individual availability can also be assigned to each unit component in the combined cycle group that will be factored into the commitment process. If modeled as a combined cycle group, therefore, the output of the steam turbine is a function of the output of the combustion turbines in the group.

## References to PJM Documents

PJM eMKT User Guide still refers to the Combined Cycle model that was developed in 2005. The 2005 Combined Cycle model was not used and the associated eMKT screen cannot be seen by participants. It requires that the Operating Company submit to PJM unit-specific information about a generating unit. To be modeled as a combined cycle group in the Combined

Cycle Model, the Primary Unit Characteristics of the unit must be changed to identify the unit as group. Unit modeling changes in the PJM eMKT system (unit type, aggregation level, for example), not including changes based on physical changes at the plant, can be made at the beginning of each quarter.

Once designated as a combined cycle group, participant may submit offers and unit parameters for each unit within the group. A participant can also indicate if a unit should be modeled for simple cycle operation. There is also an optional field that enforces a minimum time between startups for all combustion turbines in the combined cycle group.[1]

Operating Agreement of PJM Interconnection (OA) does not mention "Combined Cycle Modeling".

The Open Access Transmission Tariff (OATT) does not mention "Combined Cycle Modeling".

## Other RTOs

ERCOT applies the following rules specifically to Combined Cycle Power Plant[2]:

1. Verifiable Costs will only be verified for CCP configurations that are registered with ERCOT. If a Filing Entity wishes to submit Verifiable Cost data for a CCP configuration, the Filing Entity must submit costs for all units that make up that registered configuration.

2. If the Resource includes "Alternate" Units in its Resource Registration, for the purpose of determining verifiable costs for the registered configuration, ERCOT will create a composite unit by averaging the verifiable cost data of the non-Alternate Unit(s) with the verifiable cost data of the Alternate unit(s). To determine the composite unit ERCOT will weigh the data from the units using the respective HSL ratings of the units. See Equation 3 of Appendix 5 for a description of the equation used by ERCOT to determine the composite unit.

3. Filing Entities submitting Verifiable Cost data for startup or operation at LSL must submit fuel and O&M data for each configuration that has been registered. Filing

Entities submitting Verifiable Cost data for operation above LSL may submit O&M data for each configuration at which the plant will be operated.

ISO New England uses a Pseudo Combined Cycle Model option to split resources into multiple market assets[3]:

1. Single asset with "2 on 1" configuration becomes two assets
2. Each asset is an "Pseudo Combined Cycle (PCC) Generator"
3. Each asset represents one CT and a pro-rata portion of steam
4. turbine
5. Only Combined Cycle assets with two or more CTs and one
6. Steam turbine will be eligible for this option

Midwest ISO Combined Cycles are modeled as follows:

"A Combined Cycle CT is normally offered as a single (aggregate) unit; however, the component CTs and/or steam turbine (ST) with an alternate steam or thermal source may be offered as separate units (for example, when the steam turbine unit or CTs are not in service)."[4]

IESO evaluated a number of different options for modeling Combined Cycles, but also uses the Pseudo Unit Combined Cycle model.[5]

## Summary

In general, additional guidance in Manual M15 should be provided to ensure that all combined cycle units are offered consistently by participants.

[1] PJM eMKT Users Guide

[2] www.ercot.com/content/meetings/.../**Verifiable_Cost_Manual**_v021.doc

[3] http://www.iso-ne.com/pubs/pubcomm/pres_spchs/2007/psdo_cc_gen.pdf

[4] BPM 002 - Energy and Operating Reserve Markets

[5] http://www.ieso.ca/imoweb/pubs/consult/se21-edac/se21-edac-20081128-Pseudo_Units.pdf