Report on:

ERCOT PNNL Contract 401882: *Start Date* 3/19/2018

Development of an Integrated Transmission and Distribution Test System to Evaluate Transactive Energy Systems

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ERCOT Contract: Presentation Outline

❑ **Original Task/Milestone Schedule: M1-M3**

❑ **Updated Task/Milestone Schedule: M1-M3**

❑ **M3.2 Work to Date:** Summary of AMES V5.0 Work to Date for Milestone M3.2

❑ **M3.2 Work in Progress:** Summary of AMES V5.0 Work in Progress for Milestone M3.2

❑ **M3.2: Report on AMES V5.0 Verification Test Cases**

  ▪ Notes on AMES V5.0 Verification Test-Case Data Files

  ▪ AMES – PSST : Sequence of Events

  ▪ Summary of Previous AMES V5.0 Verification Test Cases

  ▪ Summary of Previous and Ongoing AMES V5.0 Verification Test Cases

  ▪ Total Production Cost Modeling in AMES V5.0 for SCUC/SECD operations

  ▪ Brief Summary of Planned Future AMES V5.0 Verification Test Cases

Original Task & Milestone Schedule

Milestone	Date Due	Original Description
M1	May 31, 2018	5-zone model of the old ERCOT system, posted to a web repository.
M2	Sep 30, 2018	Nodal model of the new ERCOT system, posted to a web repository.
M3	Sep 30, 2018	Submitted conference or journal paper on this work.

Updated Task & Milestone Schedule

Milestone	Date Due	Date Delivered	Fuller Descriptions of Actual Work
M1* DONE	May 31, 2018	June 5, 2018	**Development of 8-Bus ERCOT model (with nodal locational marginal pricing); grid/load/gen data posted at PNNL repository**
M2.1 DONE	Sept 30, 2018	August 1, 2018	**Basic 8-Bus ERCOT Test System, implemented via AMES V3.1, posted at https://github.com/ITDProject/ERCOTTestSystem**
M2.2 DONE	Sept 30, 2018	August 24, 2018	**8-Bus ERCOT Test System (with wind power),** implemented via AMES V3.2, **posted at https://github.com/ITDProject/ERCOTTestSystem**
M3.1 DONE	Sept 30, 2018	August 31, 2018	**200-Bus ERCOT Test System (with wind power),** implemented via AMES V3.2, **posted at https://github.com/ITDProject/ERCOTTestSystem/tree/master/ERCOT_Test_Systems/The_200Bus_ERCOT_Test_System**
M3.2**	Feb 28, 2019		**200-Bus ERCOT Test System (with wind power),** implemented via AMES V5.0, to be posted at PNNL/ISU repositories.
M3.3**	Feb 28, 2019		**Paper to be submitted** that focuses on the development of the ERCOT Test Systems

- * **M1 Modification (Ok'd by PNNL):** For M1 we have skipped the modeling of the old (zonal) ERCOT system and instead directly worked to develop an 8-bus model of the new (nodal) ERCOT system.
- ** **M3 Modification: Contract extension through Feb 28, 2019 received from PNNL on Dec 21, 2018, for completion of task M3**

Summary of AMES V5.0 Work to Date for M3.2

❑ **Extension of AMES V5.0 Capabilities for Milestone M3.2**

- [**DONE**] Coding for Daily DAM SCUC optimization

- [**DONE**] Coding for RTM SCED optimization every M minutes (M user specified).

- [**DONE**] Coding for FNCS integration to enable network co-simulation.

- [**DONE**] Detailed documentation for analytical DAM SCUC/SCED optimization in AMES V5.0

- [**DONE**] Basic documentation for AMES V5.0, including a detailed list for all parameters/flags and initial state variables that need user configuration.

- **[DONE]**

— **Modified `PSST' Code**

  ➢ To ensure correct refreshing of initial DAM/RTM conditions for multiple-day runs.

  ➢ To report DAM LMPs and GenCo Commitments back to the user.

  ➢ To read 'startup' and 'shutdown' cost components from AMES

  ➢ To produce output messages related to solver, e.g. status of the solver, termination condition of the solver

  ➢ To include the parameter 'Maximum Time Limit' – to allow the solver to terminate after the prescribed time has elapsed

— **Verification Tests Done**

  ➢ Verified 'DAM SCUC' outcomes for their correctness for simple test cases

  ➢ Verified 'RTM SCED' outcomes for their correctness for simple test cases with RTM running every five minutes (i.e., M=5)

  ➢ Verified that AMES V5.0 runs for multiple days

  ➢ Verified that all the cost components from AMES are read correctly into the SCUC formulation

Summary of Work in Progress for Milestone M3.2

- **[IN PROGRESS] Additional Verification Checks for AMES V5.0 Code**

  - Additional DAM/RTM verification test cases are being formulated and conducted.

    - *Example:* Formulation of test cases with varied generator production cost coefficients and minimum generating capacity that permit validation of production cost component modeling for the SCUC optimization

  - Need to ensure outcomes are reported properly back to the user. Additional data that need to be written to '.out' file are: RTM LMPs, RTM GenCo commitment data, DAM/RTM power flow data, LMP true costs, and generator profit/propensity data.

  - Detailed verification of PSST code for validating SCUC optimization formulation, including both objective function and constraints.

- **[IN PROGRESS] Further Cleaning Up of AMES V5.0 Code**

  - Current code includes unused functions that need to be removed.

Report on AMES V5.0 Verification Test Cases

Notes on AMES V5.0 Test-Case Data Files

➢ Input data files for verification test cases are located in the following GitHub website directory: AMES-V5.0\DATA\VerificationTestCases\

➢ Intermediary output files:

— Data files written by AMES V5.0

- ✓ ReferenceModel.dat : This is an input file for PSST that contains input data required to solve SCUC.

- ✓ RTReferenceModel.dat : This is an input file for PSST that contains input data required to solve SCUC.

- ✓ rt-unitcommitments.dat: : This is an input file for PSST that contains the unit commitment status of each generator for each M-minute period.

— SCUC output data files generated by PSST for Day-Ahead Market (DAM)

- ✓ xfertoames.dat : Contains DAM unit commitment status and dispatch schedule for each generator along with generator ID.

- ✓ DAMLMP.dat : Contains DAM LMP at each bus for each hour of a 24-hour period

— SCED output data files generated by PSST for the Real-Time Market (RTM)

- ✓ RTSCED.dat : Contains RTM LMP at each bus for each M-minute period, power dispatch scheduled for each generator for the next M-minute period, and start-up and shut-down cost details for each minute of each M-minute period.

AMES – PSST : Sequence of Events

Step 0: Initialize D = 0, H = 0, I = 0;

Step 1: AMES starts DAM operation on day 'D' for day 'D+1'.

Step 2: AMES writes 'ReferenceModel.dat' file and makes an external call to PSST to solve SCUC.

Step 3: PSST reads the input file 'ReferenceModel.dat' and performs SCUC.

Step 4: PSST writes SCUC outcomes into 'DAMLMP.dat' and 'xfertoames.dat' files.

Step 5: AMES reads 'DAMLMP.dat' and 'xfertoames.dat' and updates its DAM outcomes.

Step 6: AMES starts RTM operations for interval 'I' (duration of each interval = 'M' min).

Step 7: AMES writes 'rt-unitcommitments.dat' (contains generator unit commitments of day 'D' and 'RTReferenceModel.dat' and makes an external call to PSST to solve SCED.

Step 8: PSST reads the input files 'rt-unitcommitments.dat', 'RTReferenceModel.dat' and performs SCED.

Step 9: PSST writes SCED outcomes into 'RTSCED.dat'.

Step 10: AMES reads 'RTSCED.dat' and updates RTM outcomes.

Step 11: Increment I;

  If (I*M % 60 == 0) {

    H++;

  }

  If (H% 24 == 0) {

    increment D;

    goto Step 0;

  }

  Else goto Step 6.

Summary of Previous AMES V5.0 Verification Test Cases

❑ VerTestCaseBaseCase

– This test case produces SCUC/SCED outcomes under the following conditions:

✓ Transmission congestion is absent

✓ Minimum power generation limits are taken to be zero

✓ Start up, shut down and no-load costs are taken to be zero

✓ Minimum up-time and down-time values are taken to be 0 (hr)

✓ No ramping limits

✓ Day-ahead and real-time load forecasts are set equal

– This test case provides a base case for later comparison purposes.

❑ VerTestCaseGenMinPowerLevel

– This test case verifies a generator's minimum power level is maintained when it is committed, given the above-stated conditions (i) and (iii)-(vi).

❑ VerTestCaseUpTimeDownTime

– This test case verifies a generator's minimum up time and down time are maintained when it is committed, given the above-stated conditions (i) and (iii)-(vi).

❑ VerTestCaseMultiDayRun

– This test case verifies DAM/RTM initial conditions are refreshed appropriately when AMES V5.0 is run for multiple successive days.

Note: Files for the above test cases are uploaded at https://github.com/ITDProject/ERCOTTestSystem/tree/dev-source-code/AMES-V5.0/DATA/VerificationTestCases

- ## VerTestCaseCostComponents

  The purpose of this test case is to verify cost component aspects of the SCUC formulation under the above-stated conditions (i)-(ii) and (iv)-(vi) – i.e., to verify that the SCUC formulation correctly includes no load, start-up, dispatch, and shut-down cost components.

  - ✓ Completed
    - VerTestCaseCostComponentsNoLoad

      This test case verifies that no load cost is appropriately taken into account in SCUC/SCED formulation given the above-stated conditions (i), (ii) and (iv)-(vi).

  - ✓ To be completed
    - VerTestCaseCostComponentsStartUP
    - VerTestCaseCostComponentsShutDown

Total Production Cost Modeling in AMES V5.0 for SCUC/SCED Operations

1. For any given generator j, the user specifies a convex total production cost function

$$TPC(p) = a + bp + cp^2 ,$$

$p \in [\underline{P}, \overline{P}]$, applicable for each operating period k (e.g., hourly)

2. User then sets the number NL of power blocks, and either

i. specifies the length of each of the NL power blocks, starting at $\underline{P}$ and ending at $\overline{P}$, OR

ii. chooses "Automated Approximation Option" in which the power output range $[\underline{P}, \overline{P}]$ is simply divided into NL equal-length blocks.

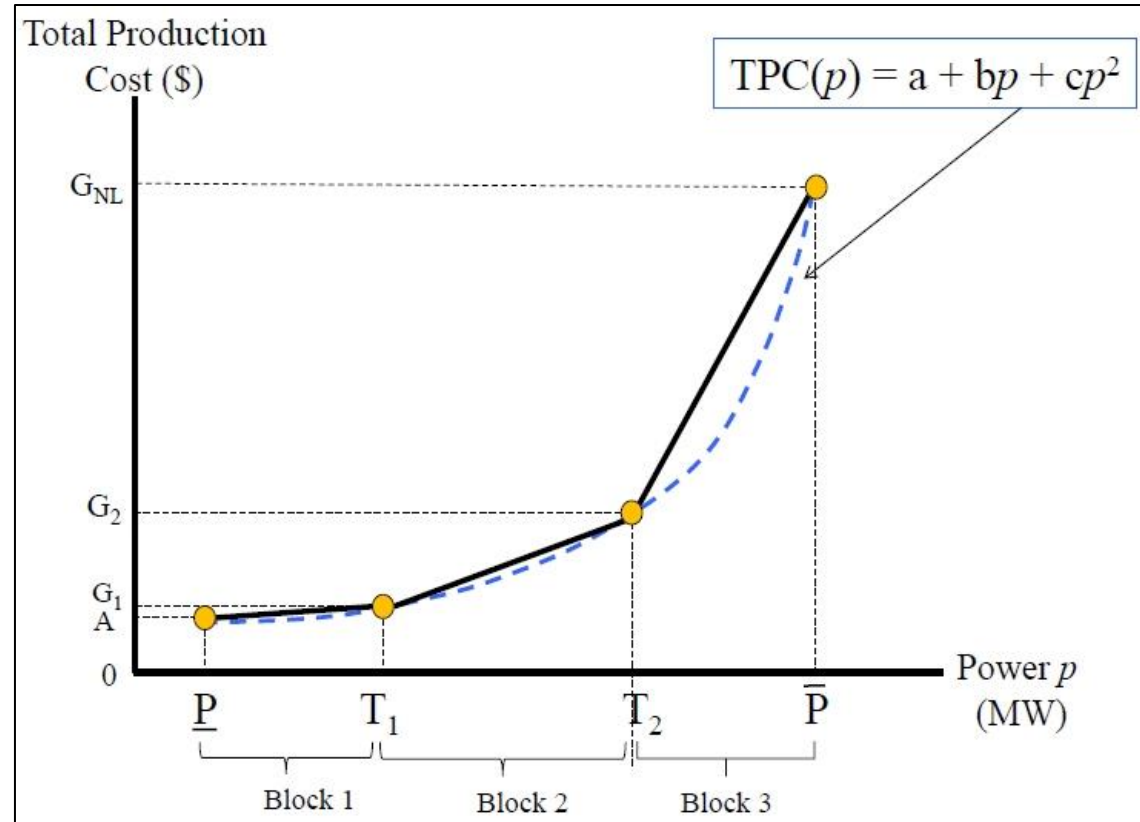3. A piecewise-linear approximation for TPC(p) is then constructed, as shown in Fig. 1.

$$TPC(p) = a + bp + cp^2$$

Fig 1. Linearized approximation for the total production cost function TPC(p) of a generator j, used for each operating period k (e.g., each hour).

NOTE: For a detailed explanation of construction 1.-3., please refer to Section 5 of "Analytical Formulation and Python Implementation for an Extended Carrion/Arroyo SCUC/SCED Optimization Formulation" at http://www2.econ.iastate.edu/tesfatsi/ECAModelAndPyomoCodeDoc.LTesfatsion.pdf"

Brief Summary of Planned Future AMES V5.0 Verification Test Cases

- ## VerTestCaseRampUpRampDown

  The purpose of this test case is to verify that ramping constraints are correctly modeled in the SCUC/SCED formulation.

- ## VerTestCaseNonDispatchableGeneration

  The purpose of this test case is to verify if non-dispatchable generation is correctly taken into account in the SCUC/SCED formulation.