ERCOT Project Tasks Documentation

1 Introduction to AMES

Stable Release of AMES V3.1 for Milestone M1 of ERCOT Project

The following is a brief overview of AMES V3.1 (submitted for Milestone M1):

- The AMES wholesale power market operates over an AC transmission grid for Max_Day (maximum no. of days) successive days, with each day D consisting of 24 successive hours $\mathrm{H} = 00, 01, \ldots, 23$.
- The AMES wholesale power market includes an Independent System Operator (ISO) and a collection of energy traders consisting of Load-Serving Entities (LSEs) and Generators distributed across the nodes of the transmission grid.
- AMES models fully operational two-settlement system that includes a daily 24-hour real-time market (RTM) as well as a daily day-ahead market (DAM), each separately settled by means of *locational marginal pricing*.
- The RTM is cleared by means of an ISO-managed SCED optimization, based on ISO load forecasts and Generation Company (GenCo) supply offers; it determines real-time dispatch levels and locational marginal prices (LMPs).
- The DAM is cleared by means of an ISO-managed SCED optimization; it determines a generation dispatch schedule and LMPs for next-day operations, based on Load Serving Entity (LSE) demand bids and GenCo supply offers.
- AMES is integrated with Framework for Network Co-Simulation (FNCS) in order to enable co-simulation of the Transactive Energy (TE) agents to establish and perform simulations within the Integrated Transmission and Distribution Test System (ITD v3.0)

Previous Releases of AMES

- AMES V3.0 models a fully operational two-settlement system that includes a daily 24-hour Real-Time Market (RTM) as well as a daily Day-Ahead Market (DAM), which are cleared by ISO-managed SCED optimizations
- AMES V4.0 incorporates an ISO-managed DAM Security Constrained Unit Commitment (SCUC) optimization to handle unit commitments, scheduled generation levels, and price (LMP) levels for next-day real-time operations.

Development Version of AMES V5.0

AMES V5.0 is planned to have the following capabilities in additional to the features discussed in AMES V3.1:

- Non-dispatchable generation (NDG) is added to AMES and is treated as negative load
  - Created a new agent called NDGenAgent (Non-dispatchable Generation Agent) to handle the forecast
- Storage Units can now be handled in AMES, with StorageAgent representing the relevant data/methods of Storage Units. Note: A variable called hasStorage is used to flag the storage constraints in the pyomo optimization model
- Forecasts for Net load NL = [Load-NDG] is incorporated into DAM/RTM
  - In DAM, the forecasts for load and NDG are submitted by LSEAgent and NDGenAgent respectively
  - In RTM, the forecasts for Net load (load and NDG) is submitted by ISO
- Daily DAM SCUC optimization
  - Incorporation of DAM SCUC into AMES V5.0 to handle daily generation unit commitments, LMP determination, and scheduled generation dispatch levels for next-day real-time operations
- RTM SCED that runs every M minutes (where M is user specified).
  - RTM SCED optimization is run using the SCUC optimization code, where all of the "unit commitment" (on/off) binary variables (for each minute) for day-D RTM optimization are pre-set to the DAM unit commitment binary solution values as determined in the DAM on day D-1.
  - Here, the set of time periods = {1, 2, 3, ..., M } where each time period's length is 1 'minute'. In case of DAM SCUC optimization, the set of time periods = {1, 2, 3, ..., 24 } where each time period's length is 1 'hour'.

IMPORTANT CAUTION: The above extensions need verification with test cases to check for and correct any bugs prior to public release.

2 Installation of AMES V5.0

2.1 Java Requirements

- All the versions of AMES are based on Java. Java can be downloaded from: https://java.com/en/download/.
- ANT tool is used to compile AMES
- AMES requires FNCS library in order to run the simulation

2.2 FNCS Requirement

- AMES V5.0 requires the java libraries for FNCS to be located at C:/tesp/src/java or other location where the FNCS library is installed.
- Instructions from https://tesp.readthedocs.io/en/stable/TESP_DesignDoc.html#installing-on-windows are followed to install the TESP (with FNCS as prerequisite)

2.3 Python Requirements

Since AMES V5.0 uses PSST (Power System Simulation Toolbox) which is based on python, python needs to be installed.

To install PSST:
cd C:/YourlocationtoAMES-v5.0/psst
pip install e .
Note: The pip install command contains "period" at the end.
Note: PSST has its own dependencies which are installed when the above command is passed.

3 Brief Overview of important classes in AMES

AMES GUI (AMESGUIFrame.java)

- Graphical User Interface is handled in this class to load, create, save a test case and output files as well as control the simulation
- From AMES V4.0, this class is modified to include the specification of Non-dispatchable generation and storage units parameters in the test cases
- FNCS initialization and FNCS end is called in this class (i.e., before loading the GUI and after the output of the simulation is saved into a file respectively)
- Note: As of now, NDG and storage units have to be explicitly specified in the test cases and cannot be added using GUI
- Comment: The format of the test cases used in AMES is .dat file. Previous developers have tried to support dictionary format by creating a new class called DictionaryReader under amesmarket.filereaders package

AMES Market (AMESMarket.java)

- This is the main class for running the simulation i.e., setting up various parameters read from test case, building the agents, transmission network, etc.
- The buildSchedule method is used to create a schedule with a timer (from FNCS.time_request)

- ISO operates the Day-Ahead Market and Real Time Market at specific times, which are called in iso.marketOperation(min, hour, day)

Independent System Operator (ISO.java)

- ISO handles the market operations, both Day-Ahead and Real Time Markets
- On day D, at hour = 1, the DAM is initialized with load forecast submitted by the LSEs.
- At hour = 12, ISO calls the PSST SCUC to handle SCUC optimization
- At the beginning of every M interval, RTM (in turn PSST SCED) is called to handle the SCED optimization
- At the end of day D, the unit commitments are stored for the next day's real time market
- Note: These hourly unit commitments are scaled down to every M min

Generator Agent (GenAgent.java)

- This class models a GenCo's attributes with several getter and setter methods
- Note: Several learning parameters are being read from the test cases. However learning is not turned on (with M1 set to 1 instead of 10) and therefore these parameters are not being used as of now
- Learning implementation is carry forwarded to this version with no changes

Load Serving Entity Agent (LSEAgent.java)

- This class models a Load Serving Entity's attributes with several getter and setter methods
- In Day-Ahead Market, the LSE submits a 24 hour load profile as forecast
- LSE has the ability to handle both fixed demand bid as well as price sensitive demand bid
- As of now, only fixed demand bids are being used in the Day-Ahead Market

Day Ahead Market

- At hour = 12, the DAM in ISO's market operation method writes a referencemodel.dat file with the necessary parameters required for the SCUC optimization
- PSST SCUC is called at hour = 12, with referencemodel.dat as the input file and xfertoames.dat as the output file

Real Time Market

- At the beginning of every M minute interval, the real time market operation is called to perform the SCED optimization
- ISO handles the net demand forecast for the real time market operations
- Similar to DAM SCUC, a reference file (rtreferencemodel.dat) is written in order to be given as input file to the PSST SCED optimization. Along with this file, rt-unitcommitments.dat file (containing the unit commitments over the M minute interval) is given as input.
- These unit commitment values are pre-set in the Pyomo Model. Therefore the optimization now solves for SCED

4 Detailed listing of user-specified inputs in AMES

Tables 1, 2 and 3 refer to the exogenous variables for the AMES Framework. The ERCOT test case's values corresponding to the variables in table 2 are taken from the fuel costs of the ISO New England based 8-Zone Test Case.

Table 1: Admissible Exogenous Variables for the AMES Framework - Structural Variables

Variable	Description	Admissibility Restrictions
K	Total number of transmission grid nodes	$K > 0$
N	Total number of distinct network branches	$N > 0$
I	Total number of Generators	$I > 0$
J	Total number of LSEs	$J > 0$
I_k	Set of Generators located at node k	$\text{Card}(\cup_{k=1}^{K} I_k) = I$
J_k	Set of LSEs located at node k	$\text{Card}(\cup_{k=1}^{K} J_k) = J$
S_o	Base apparent power (three-phase MVAs)	$S_o \geq 1$
V_o	Base voltage (line-to-line kVs)	$V_o > 0$
V_k	Voltage magnitude (kVs) at node k	$V_k = V_o,\ k = 1, \ldots, K$
p_{Lj}	Real power load (MWs) withdrawn by LSE j	$p_{Lj} \geq 0,\ j = 1, \ldots, J$
km	Branch connecting nodes k and m (if one exists)	$k \neq m$
BR	Set of all distinct branches km, $k < m$	$BR \neq \emptyset$
X_{km}	Reactance (ohms) for branch km	$X_{km} = X_{mk} > 0,\ km \in BR$
P^U_{km}	Thermal limit (MWs) for real power flow on km	$P^U_{km} > 0,\ km \in BR$
δ_1	Reference node 1 voltage angle (radians)	$\delta_1 = 0$
π	Soft penalty weight for voltage angle differences	$\pi > 0$

Table 3 contains the learning parameters described in [13]. For the ERCOT test cases, M1 is set to be 1 in order to turn off the learning.

Table 2: Admissible Exogenous Variables for the AMES Framework - Generator Costs

Variable	Description	Admissibility Restrictions
Money_i^o	Initial money holdings (\$) for Gen i	$\text{Money}_i^o > 0,\ i = 1, \ldots, I$
Cap_i^L	True lower production limit (MWs) for Gen i	$\text{Cap}_i^L \geq 0,\ i = 1, \ldots, I$
Cap_i^U	True upper production limit (MWs) for Gen i	$\text{Cap}_i^U > \text{Cap}_i^L,\ i = 1, \ldots, I$
a_i, b_i	True cost coefficients (\$/MWh, \$/MW^{2}h) for Gen i	$b_i > 0,\ i = 1, \ldots, I$
$\text{MC}_i(p)$	$\text{MC}_i(p) = a_i + 2b_i p =$ Gen i's true MC function	$\text{MC}_i(\text{Cap}_i^L) > 0,\ i = 1, \ldots, I$
FCost_i	Fixed costs (hourly prorated) for Gen i	$\text{FCost}_i \geq 0,\ i = 1, \ldots, I$

Table 3: Admissible Exogenous Variables for the AMES Framework - Generator Learning

Variable	Description	Admissibility Restrictions
M_i	Cardinality of the action domain AD_i for Gen i	$M_i \geq 1,\ i = 1, \ldots, I$
Mj_i	Integer-valued density-control parameter for AD_i	$\prod_{j=1}^{3} Mj_i = M_i,\ i = 1, \ldots, I$
RIMax_i^L	Range-index parameter for AD_i construction	$\text{RIMax}_i^L \in [0, 1),\ i = 1, \ldots, I$
RIMax_i^U	Range-index parameter for AD_i construction	$\text{RIMax}_i^U \in [0, 1),\ i = 1, \ldots, I$
RIMin_i^C	Range-index parameter for AD_i construction	$\text{RIMin}_i^C \in (0, 1],\ i = 1, \ldots, I$
SS_i	Slope-start control parameter for AD_i construction	$SS_i > 0,\ i = 1, \ldots, I$
$q_i(0)$	Initial propensity (learning)	Any real value, $i = 1, \ldots, I$
C_i	Cooling parameter (learning)	$C_i > 0,\ i = 1, \ldots, I$
r_i	Recency parameter (learning)	$0 \leq r_i \leq 1,\ i = 1, \ldots, I$
e_i	Experimentation parameter (learning)	$0 \leq e_i < 1,\ i = 1, \ldots, I$

Additional parameters/flags

- SCUC input data for the generators is enclosed in between #ScucInputDataStart and #ScucInputDataEnd. These values are used in DAM SCUC optimization through Pyomo Model
- Non-dispatchable generators' data can be included with the tags #NDGDataStart and #NDGDataEnd in the input test case. This is similar to the LSE Fixed Demand bid. An additional flag called 'NDGFlag' is set to 0 if Non-dispatchable generation is directly included in the fixed demand bids, else it is set to 1 to include the NDG data explicitly from the test case.
- In case of storage units, a variable called 'StorageFlag' is used to determine if storage is used or not.
- Load Serving Entities can submit price sensitive demand bids. However it is currently not considered in the ERCOT test cases. This is turned off by setting the LSE Data Hybrid Demand flags to 1.

5 Introduction to the Construction of Reduced-Order Model of ERCOT Transmission System

The specific task of this project is to build a reduced order model (8-bus and then later on 200-bus) of the ERCOT Transmission System to enable power system studies like transmission planning, contingency analysis, etc. Building a reduced-order model of the transmission network could become an empirical anchor to the Integrated Transmission & Distribution Systems. Previous work by Overbye et al. [2, 3, 4, 5, 6, 7] has addressed the problem of building synthetic test cases to enable power system studies. However, these synthetic test cases are built for specific purposes like geomagnetic disturbance analysis, voltage stability, AC power flow, etc. We have approached the problem of developing synthetic test cases along the lines of Overbye et al.'s work with hybrid economic control studies as the objective.

In the next section, the synthetic test case construction for the ERCOT region is described. Several steps such as obtaining the publicly available data, clustering the nodes, building the topology of the network and assigning physical parameters to the network are discussed in detail.

6 ERCOT Synthetic Test Case Construction

6.1 ERCOT Data

Generator Data

The generator data (2016) is obtained from the U.S. Energy Information Administration (EIA) [12]. The data files obtained from the EIA contains various generators, utilities and plants information in the US. This vast data is then processed to obtain the generators which are located in the ERCOT region of Texas for our purposes. The following is a brief summary of the data obtained from EIA as of 2016:

- There are 1040 generators in Texas state, of which 834 generators are located in the ERCOT region
- Each generator has a location (latitude and longitude) associated with it, along with the nameplate capacity and the fuel type
- The generation capacity proportions by fuel type in ERCOT is shown in the figure 1
- Of 834 generators, there are 630 generators with the following major fuel types (by percentage):
  1. Natural Gas Fired Combined Cycle - 37.3%
  2. Natural Gas Steam Turbine - 13.25%
  3. Natural Gas Fired Combustion Turbine - 6.8%
  4. Natural Gas Internal Combustion Engine - 0.5%
  5. Conventional Steam Coal - 20.37%
  6. Onshore Wind Turbine - 15.15%
  7. Nuclear - 4.77%
  8. Solar Photovoltaic - 0.53%
  9. Conventional Hydroelectric - 0.5%
- The thermal generation is approximately 83% of the total generation
- Non-dispatchable generation can be considered as negative load in the test case construction i.e., Net load = Load - Non-dispatchable Generation

The dispatch cost function for each generator g is modeled as follows:

$$C_{P,g} = a_g p_g + b_g [p_g]^2 \tag{1}$$

The cost coefficients a_g and b_g were derived from Dheepak et al.'s [8] work on 8-bus test system for ISO-NE.

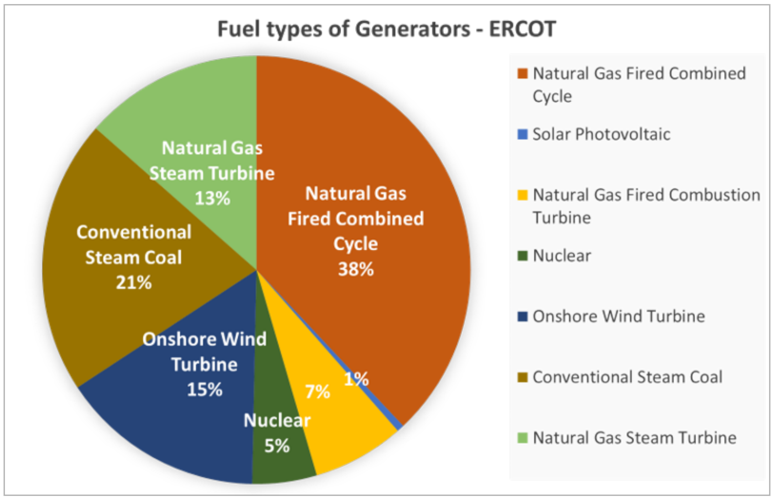

Figure 1: Generation Capacity proportions by fuel type in ERCOT

Load Data

Load data is constructed approximately based on the historical load profiles (available by weather zones) [10] and the population information obtained from the 2010 U.S. Census data [11]. An average (over the year) per capita load consumption is calculated for the eight weather zones of ERCOT as shown in Table 4. Initially, each ZIP Code is considered to be a load node. Load at each ZIP Code is therefore computed by multiplying the population of the ZIP Code with the per Capita load consumption of the corresponding weather zone.

Table 4: Power Consumption Per Capita by Weather Zone

Weather Zone	Per-capita consumption (kW)	Weather Zone	Per-capita consumption (kW)
COAST	2.362	NORTH	1.859
EAST	1.563	SCENT	2.045
FWEST	1.854	SOUTH	1.843
NCENT	2.438	WEST	2.368

The Figure 2 depicts the data collected for generator nodes and the data computed for the load type nodes. Here red circles represent the load nodes and the other color circles represent the generator nodes with different fuel types.

6.2 Clustering Algorithm

Algorithm description. A modified hierarchical clustering algorithm is used to cluster the Generation and Load Nodes into three types i.e., load cluster, generation cluster, and Hybrid Cluster.

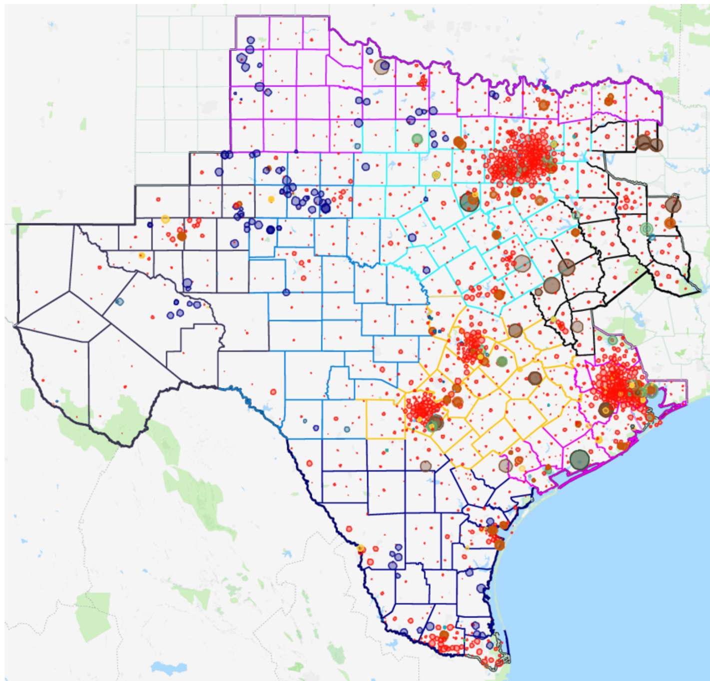

Figure 2: Load and Generation nodes in ERCOT

Algorithm 1: `Modified Hierarchical Clustering Algorithm`

1. Start with N = $N_g + N_l$ clusters (c_1, c_2, ... c_N) each consisting of either a single generator or a single load
2. Combine a pair of clusters c_i and c_j with minimum distance amongst all pairwise distances to form a new cluster c_{ij}
3. Update the coordinates of cluster c_{ij} as weighted (by generation capacities) average of the coordinates of its members
4. Update total generation capacity of cluster c_{ij} as sum of the generation capacities of its members
5. Remove the clusters c_i and c_j. Update the pairwise distances between the reduced number of clusters
6. Repeat 2-5 until the required number of generator clusters are formed

In the above clustering algorithm, note that the generators and load nodes are clustered together without any constraints and therefore are allowed to form hybrid clusters (i.e., both generation and load cluster).

6.3 Transmission Line

6.3.1 Transmission Line Topology

For the 8 bus transmission system, in theory there could be 23 transmission lines to completely connect the transmission system (i.e., 23 edges to complete the 8 node graph). However, from statistical analysis of the number of transmission lines, it is found to be a constant multiple of the number of nodes/buses in the network. Therefore, not all lines are needed to build the synthetic network.

Delaunay triangulation is one of the triangulation methods known to be close to give the lines that are highly overlapped with that of the real transmission lines according to Birchfield et al. For a simple test case like 8 bus case for ERCOT, it can be adopted without using any additional algorithms from graph theory. We have therefore chosen the transmission lines from the Delaunay triangulation to build the topology of the 8-bus transmission system.

6.3.2 Transmission Line Parameters

For the 8-bus ERCOT test case, only 345 kV transmission lines are used. Therefore, the transmission line parameters are chosen according to this voltage level. The line impedance per mile is taken to be 0.584 ohm (by considering a Cardinal conductor with 2 conductor bundling with conductor spacing of 1.5 ft. per bundle).These parameters are taken from [2].

6.4 8-Bus Transmission System for ERCOT

For N = 8, the load and generator nodes are clustered using the clustered algorithm mentioned in Algorithm 1. After the nodes/buses are obtained, delaunay triangulation is applied to build the topology for the 8-bus transmission system. The resultant transmission system is depicted in the figures 3 and 4.

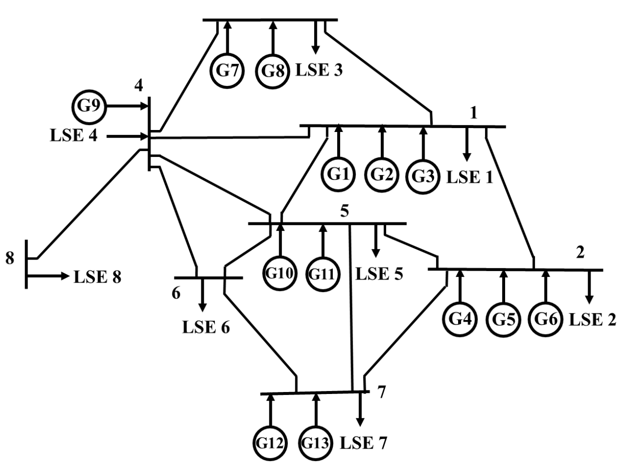

Figure 3: 8-Bus Transmission Grid

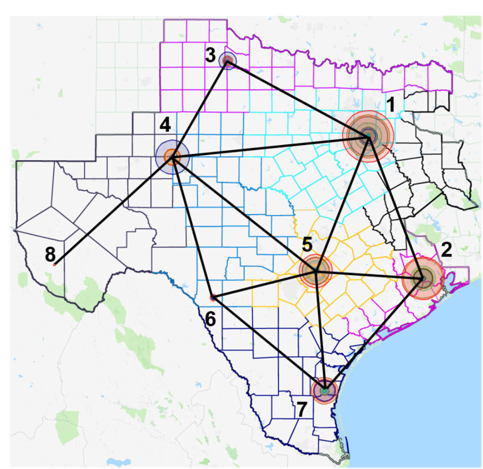

Figure 4: 8 Bus Test Case of ERCOT

6.4.1 GenCo and LSE Data

GenCo

- For the 8-bus test case, only thermal generation (83%) is considered. Although the non-dispatchable generation could be modeled as negative load, AMES is not capable of handling negative net load at the LSE's.
- The generator cost curves' coefficients are taken to be as shown in the Table 5
- In total, there are 13 GenCos in ERCOT (each with a different fuel type at a bus) with their locations, capacities and their cost coefficients as shown in Table 6

Table 5: Generator Cost-Curves for the 8-Bus Test Case

Generator Fuel Type	a ($/MWh)	b($/$MW^2h$)
Natural Gas	40	0.005
Coal	19	0.005
Nuclear	8	0.00019

Table 6: Generator Data for the 8-Bus Test Case

Name	At Bus	Generator Type	a	b	Cap^L	Cap^U
GenCo1	1	Natural Gas	40	0.005	0	19,978.8
GenCo2	1	Coal	19	0.005	0	11664.8
GenCo3	1	Nuclear	8	0.00019	0	2430.0
GenCo4	2	Natural Gas	40	0.005	0	20,761.69
GenCo5	2	Coal	19	0.005	0	3190.3
GenCo6	2	Nuclear	8	0.00019	0	2708.6
GenCo7	3	Natural Gas	40	0.005	0	80
GenCo8	3	Coal	19	0.005	0	720
GenCo9	4	Natural Gas	40	0.005	0	3438.2
GenCo10	5	Natural Gas	40	0.005	0	10589.7
GenCo11	5	Coal	19	0.005	0	5728.1
GenCo12	7	Natural Gas	40	0.005	0	7385.0
GenCo13	7	Coal	19	0.005	0	622.4

LSE Data

- Each bus in the 8-bus transmission system is considered to have an LSE entity, representing the load consumption
- Each LSE can submit a 24-hour Day-Ahead Market demand bids in either Fixed Demand bid or Price-Sensitive Demand bid or both
- For the 8-bus test case, each LSE is assumed to submit a fixed demand bid for the DAM operations
- Historical load profiles dated 04/28/2018 are considered as the load profile data for the LSEs to make a forecast on the following day i.e., on 04/29/2018

Table 7: LSE Fixed Demand Bid (Without Non-dispatchable Generation)

Name	Bus	H-00	H-01	H-02	H-03	H-04	H-05	H-06	H-07
LSE1	1	10168.91	9560.41	9162.96	8951.62	8966.74	9243.79	9707.37	10200.05
LSE2	2	10609.49	10130.78	9823.78	9669.55	9574.93	9668.12	9928.59	10158.56
LSE3	3	252.21	243.71	239.88	240.38	242.88	249.87	256.78	266.58
LSE4	4	3067.03	3004.96	2979.83	2971.99	2956.48	2974.59	3012.23	3034.82
LSE5	5	5122.12	4779.23	4600.74	4481.19	4451.58	4510.64	4720.72	4878.95
LSE6	6	329.36	315.95	308.06	303.93	301.28	305.23	312.44	319.34
LSE7	7	4371.46	4137.38	3982.46	3906.68	3856.37	3896.78	4007.57	4081.97
LSE8	8	99.59	97.91	97.30	97.24	96.72	97.00	97.97	98.10
Name	Bus	H-08	H-09	H-10	H-11	H-12	H-13	H-14	H-15
LSE1	1	10930.74	11502.83	11990.15	12392.66	12783.36	13233.04	13799.71	14379.07
LSE2	2	10686.87	11282.58	11928.66	12497.71	13031.79	13618.55	14177.62	14643.48
LSE3	3	276.83	283.88	286.93	290.47	294.47	301.39	309.22	318.62
LSE4	4	3099.12	3155.68	3222.93	3299.02	3343.73	3409.14	3488.62	3533.64
LSE5	5	5236.73	5604.26	5947.02	6231.92	6502.99	6767.29	7065.99	7308.35
LSE6	6	332.88	345.71	360.26	372.45	382.97	393.83	405.15	415.88
LSE7	7	4286.84	4511.23	4757.32	4959.20	5116.37	5256.40	5393.67	5533.11
LSE8	8	99.65	101.14	102.94	105.27	106.26	107.95	110.14	110.95
Name	Bus	H-16	H-17	H-18	H-19	H-20	H-21	H-22	H-23
LSE1	1	14911.46	15167.50	14967.62	14421.21	14115.51	13649.33	12682.31	11671.62
LSE2	2	14874.98	14847.61	14462.77	13809.82	13539.55	13120.42	12423.70	11605.80
LSE3	3	326.55	331.57	331.62	321.10	317.11	312.21	294.56	274.56
LSE4	4	3611.84	3633.37	3634.41	3576.88	3514.78	3484.40	3382.54	3271.74
LSE5	5	7520.95	7603.62	7500.91	7233.92	7045.46	6780.70	6340.00	5820.73
LSE6	6	424.66	427.50	422.80	409.43	403.35	394.25	375.51	354.10
LSE7	7	5624.90	5645.97	5531.89	5313.97	5277.70	5142.94	4912.60	4618.83
LSE8	8	113.26	113.78	113.96	112.57	110.81	110.33	107.98	105.33

6.4.2 Input variables considered for the 8-bus test case

The following variables are considered as inputs for the 8-bus test case:

- Base Voltage, Power
- Max_Day (is set to be 3)
- Node Data, Penalty Weight
- Branch Data with max capacity, reactances
- Generator Data with FCost (ignored, initialized with 0), a, b, cap^L, cap^U, InitMoney
- LSE Fixed Demand Data
- LSE Price Sensitive Data (Not being used, added to avoid exception)
- LSE Hybrid Demand Flags - These are set to 1, which implies that only fixed demand data is considered
- Generator learning parameters are set to default. However, all M1 and M2 variables need to be set to 1 to turn off the learning
- StorageFlag and NDGFlag are set to 0 i.e., no storage unit is used and non-dispatchable generation is being considered as negative load at the LSE's bus locations

6.4.3 Transmission Line Parameters

The following Table 8 refers to the transmission line parameters of the 8-bus test case: Refer section 6.3.2 for the transmission line parameters (per-unit values) of the 8-bus test case

Table 8: 8-Bus Test Case - Branch Data

Branch From	To	lineCap	X(ohms)	Length (Miles)
1	2	1000.0	122.3124	209.4390
1	3	1000.0	125.6020	215.0720
1	4	1000.0	156.4805	267.9461
1	5	1000.0	116.1924	198.9595
2	5	1000.0	87.7518	150.2599
2	7	1000.0	123.4350	211.3613
3	4	1000.0	87.2334	149.3723
4	5	1000.0	147.8132	253.1047
4	6	1000.0	118.7483	203.3361
4	8	1000.0	126.8891	217.2758
5	6	1000.0	84.1587	144.1073
5	7	1000.0	98.6619	168.9416
6	7	1000.0	118.0990	202.2244

References

[1] http://www2.econ.iastate.edu/tesfatsi/AMESMarketHome.htm

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