Electricity Pricing Forecasting in Smart Grid using Python based Machine Learning tools

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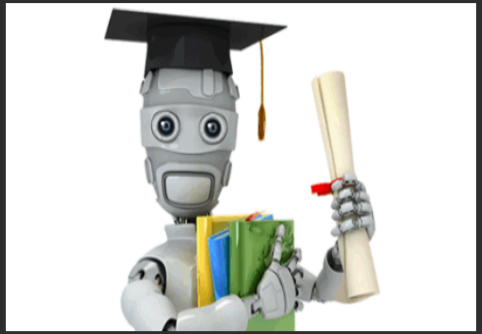
Introduction



Machine Learning

Machince learning learn from and make predictions on data

Elasticity

Elasticity demand and price play role in demand response

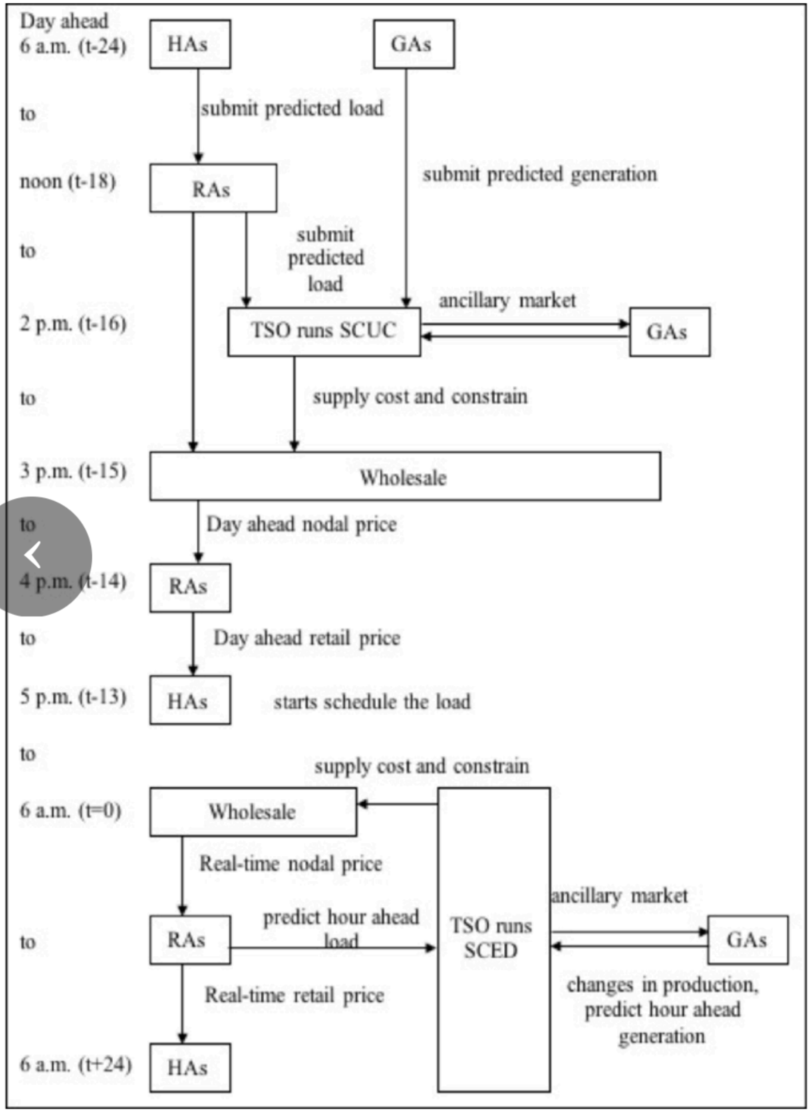
VRE

Variable renewable energy resource is non-dispatchable due to it fluctuation nature

Environmental concern

There is environmental cost to fossil fuel

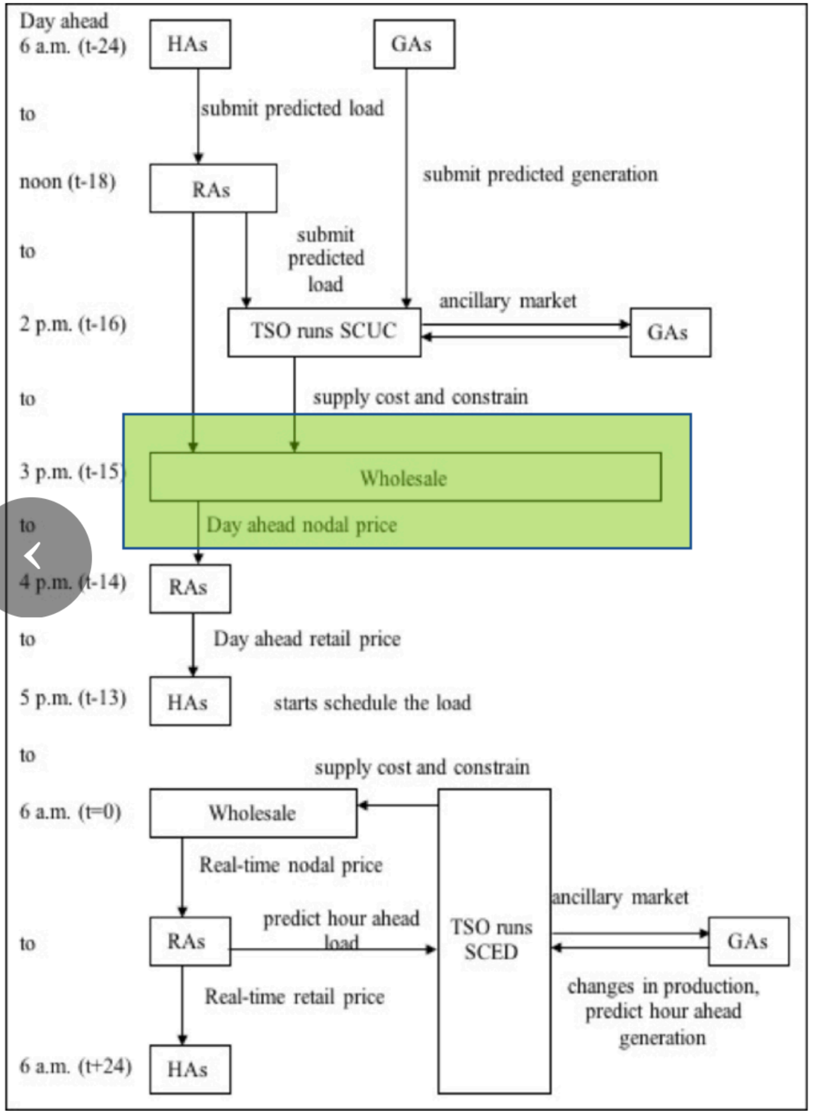
Conceptual research framework



The conceptual research framework of this study is shown in this figure. There are consisted of keys method which are

- Unit commitment
- Economic dispatch
- Nodal price calculation (LMP)
- Forecasting in demand and generation

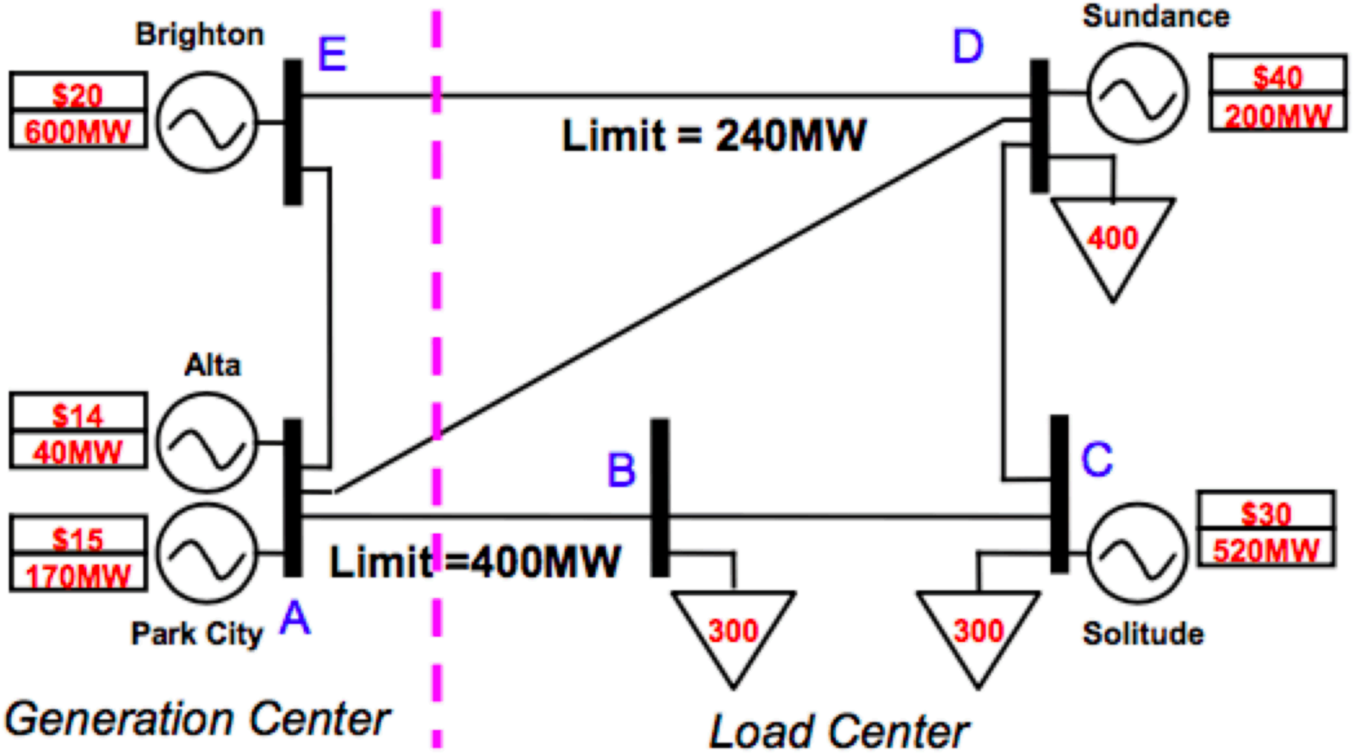
Conceptual research framework



- This progressive exam will show result on running economic dispatch to investigate locational marginal price (or called "LMP") and LMP sensitivity due to load variation from (-20% to +20%)
- The assumption of this result are forecasted load and genaration.

Test system

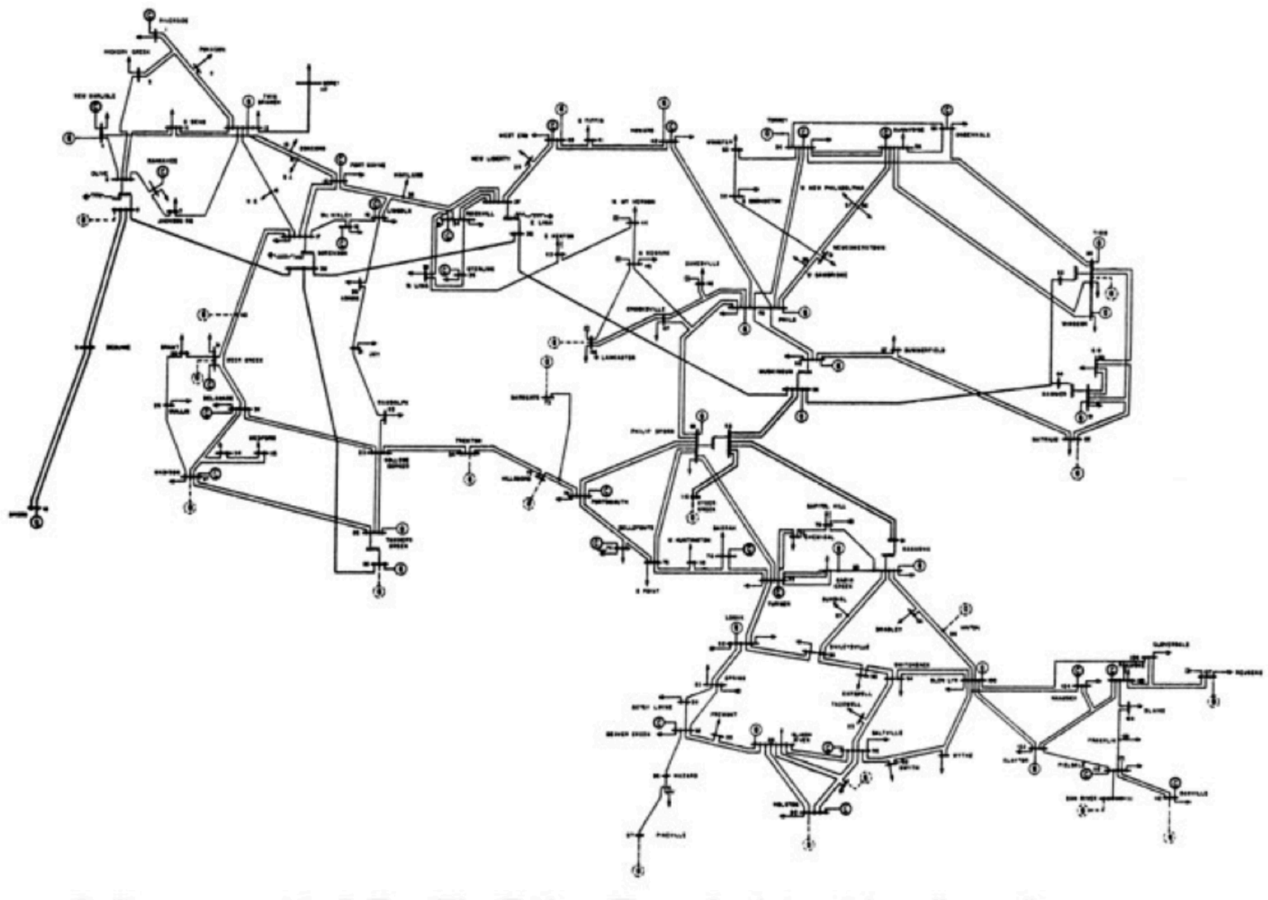
PJM 5-bus system and IEEE 118 bus system



PJM 5 bus system

Test system

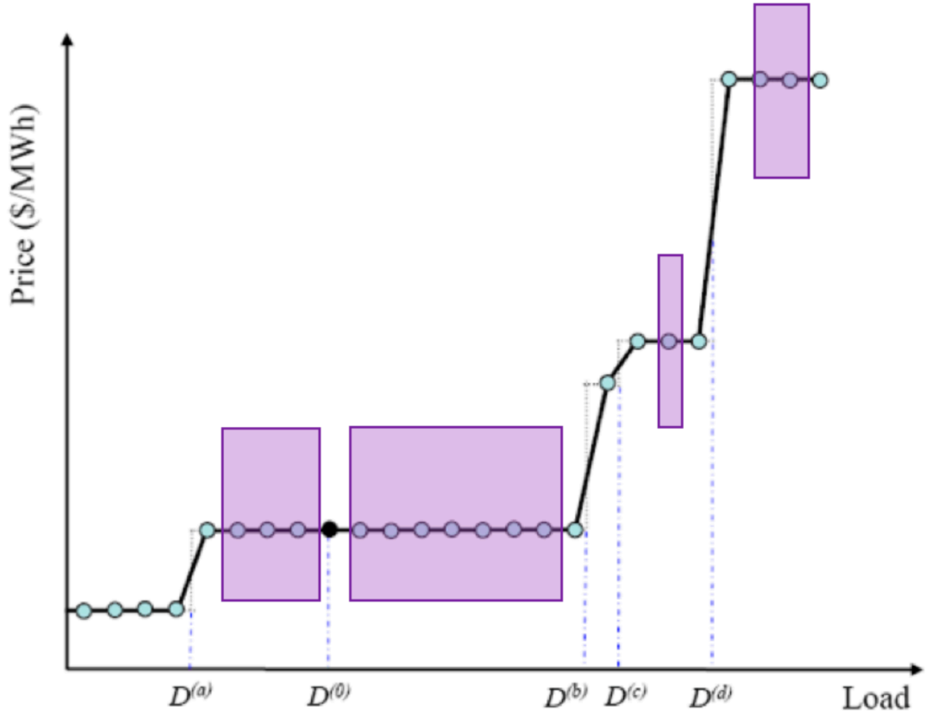
PJM 5-bus system and IEEE 118 bus system



IEEE 118 bus test system

Proposed method

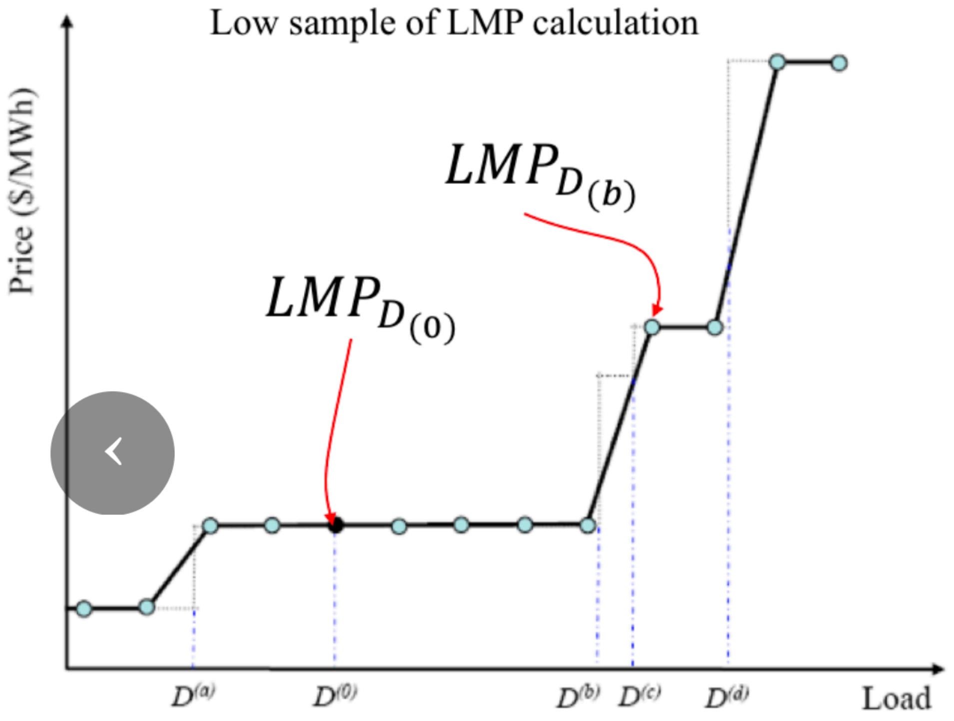
Heuristic-Brute force approach

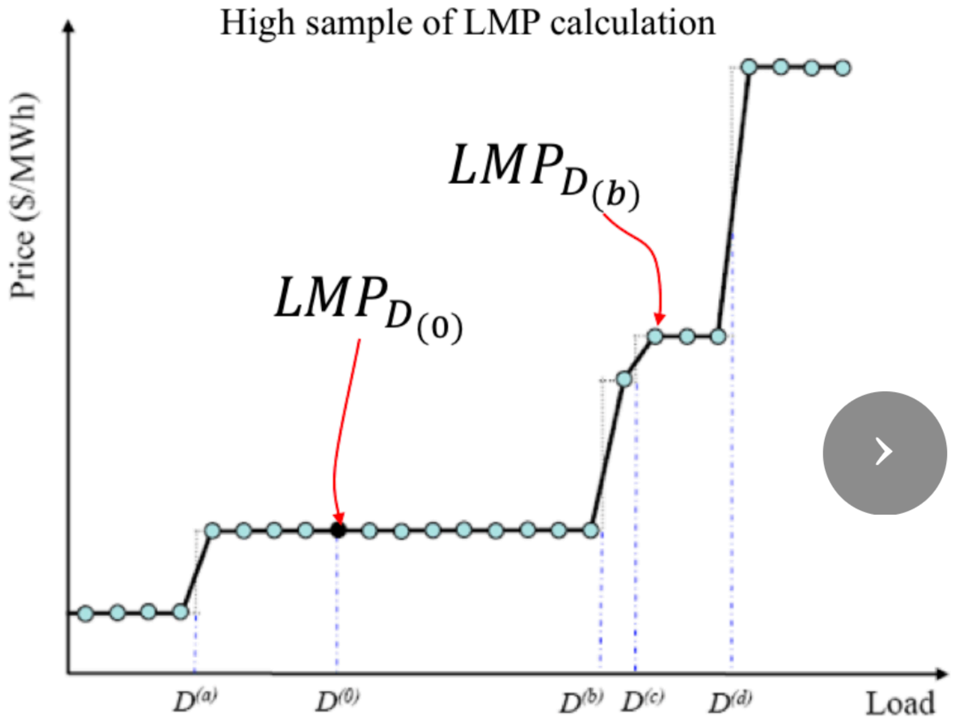


These highlighted boxes show that these iterations can be eliminated due to very small change of LMP
(0.01$ or 1 cents per MWhr for this study)

Proposed method

Heuristic-Brute force approach

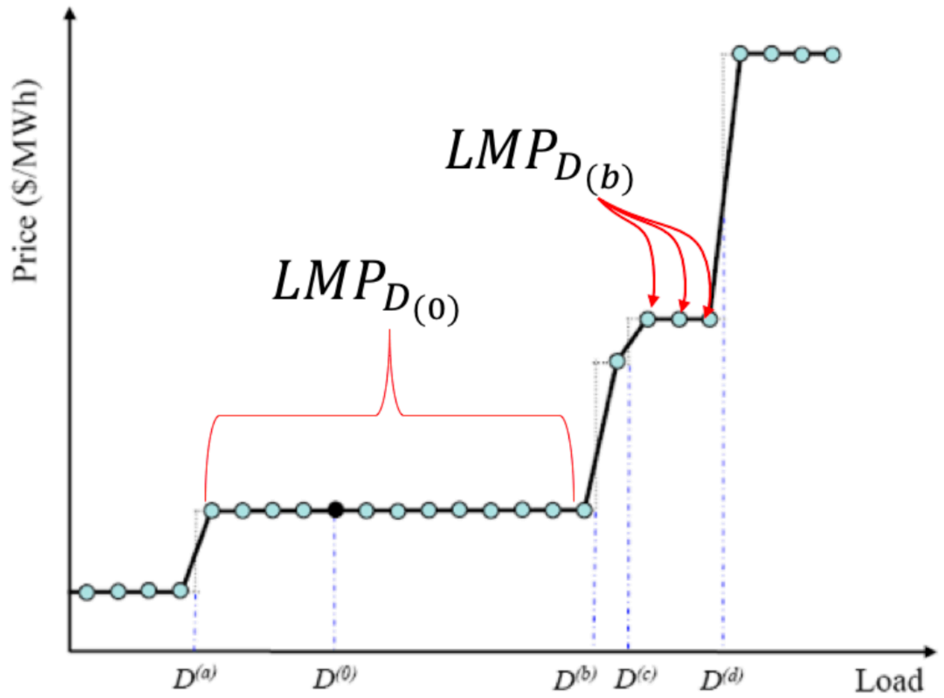




High sample of LMP calculation give more accuracy but comes with number of iteration and time consumption

Proposed method

Heuristic-Brute force approach



The LMP calculation when load changed is call LMP sensitivity due to load variation. It can be observed that when there is narrow change in load, LMP remain the same

Data: $D_0, D_{upper} = [D_{+20}, D_{+19}, ..., D_{+1}], D_{lower} = [D_{-20}, D_{-19}, ..., D_{-1}]$

Result: $LMP_{D_{-20}}, LMP_{D_{-19}}, ..., LMP_{D_{-1}}, LMP_{D_0}, LMP_{D_1}, ..., LMP_{D_{19}}, LMP_{D_{20}}$

initialization;

i=1 %for upper LMP;

j=1 %for lower LMP;

theashold = 0.01 $/MWhr;

start compute upper LMP;

while $i < 21$ **do**

  set load level at D_i;

  run ACOPF;

  get LMP_{D_i} using Equation 4.3.17;

  if $|LMP_{D-0} - LMP_{D_i}| \leq threashold$ **then**

    set LMP_{D_i} to $LMP_{D_{+1}}$ are equal to LMP_{D_0};

    i=21;

    stop compute upper LMP;

  else

    i=i+1;

  end

end

repeat for lower LMP;

Proposed method (cont')

ACOPF

In transmission system can be fomulted as minimize:

$$\sum_{i=1}^{N}(C_{G_i} \times P_{G_i}$$

Subject to:

$$P_{G_i} - P_{L_i} - P(V,\theta) = 0$$
$$Q_{Gi} - Q_{Li} - Q(V,\theta) = 0$$
$$|F_k| = F_k^{max}$$
$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max}$$
$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}$$
$$V_i^{min} \leq V_i \leq V_i^{max}$$

where:

C_{Gi} is generation cost of generator G_i ($/MWhr). P_{Gi} and Q_{Gi} are real and reactive power output of generator G_i (MW, MVar). P_{Gi}^{min} and P_{Gi}^{max} are minimum and maximum limit of P_{Gi} . Q_{Gi}^{min} and Q_{Gi}^{max} are minimum and maximum limit of Q_{Gi} . P_{Li} and Q_{Li} are real and reactive power demand of load L_i (MW, MVar). F_k and F_k^{max} are line flow and its maximum limit at bus i. V_i^{min} and V_i^{max} are minimum and maximum voltage limit at bus i.

LMP calculation

The LMP at bus i can be written as follows:

$$LMP_i = LMP^{energy} + LMP_i^{congestion} + LMP_i^{loss}$$

The LMP at any bus also be calculated in:

$$LMP_i = \sum_{j=1}^{N}(C^T \times \frac{\partial G_j}{\partial D_j})$$

Simulation result

Part I: LMP sensitivity on load variation
PJM 5 bus system

Generation Parameters

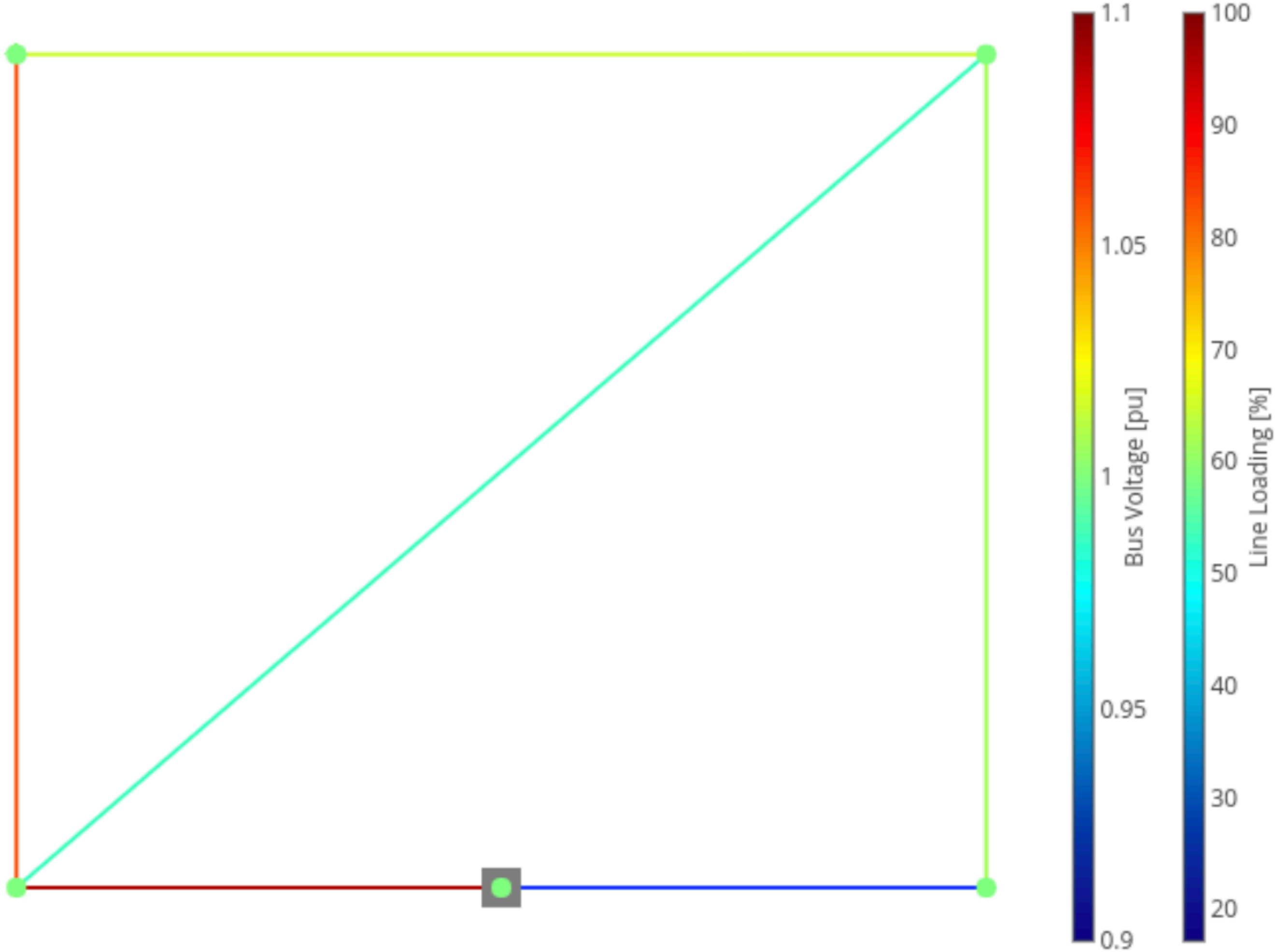
Gen. Name	Alta($/MWhr)	Park City	Solitude	Sundance	Brighton
Bus	A	A	C	D	E
Cost($/MWhr)	14	15	30	40	10
MW Limit	40	170	520	200	600
MVar Limit	+-30	+-127.5	+-390	+-150	+-450

Load data

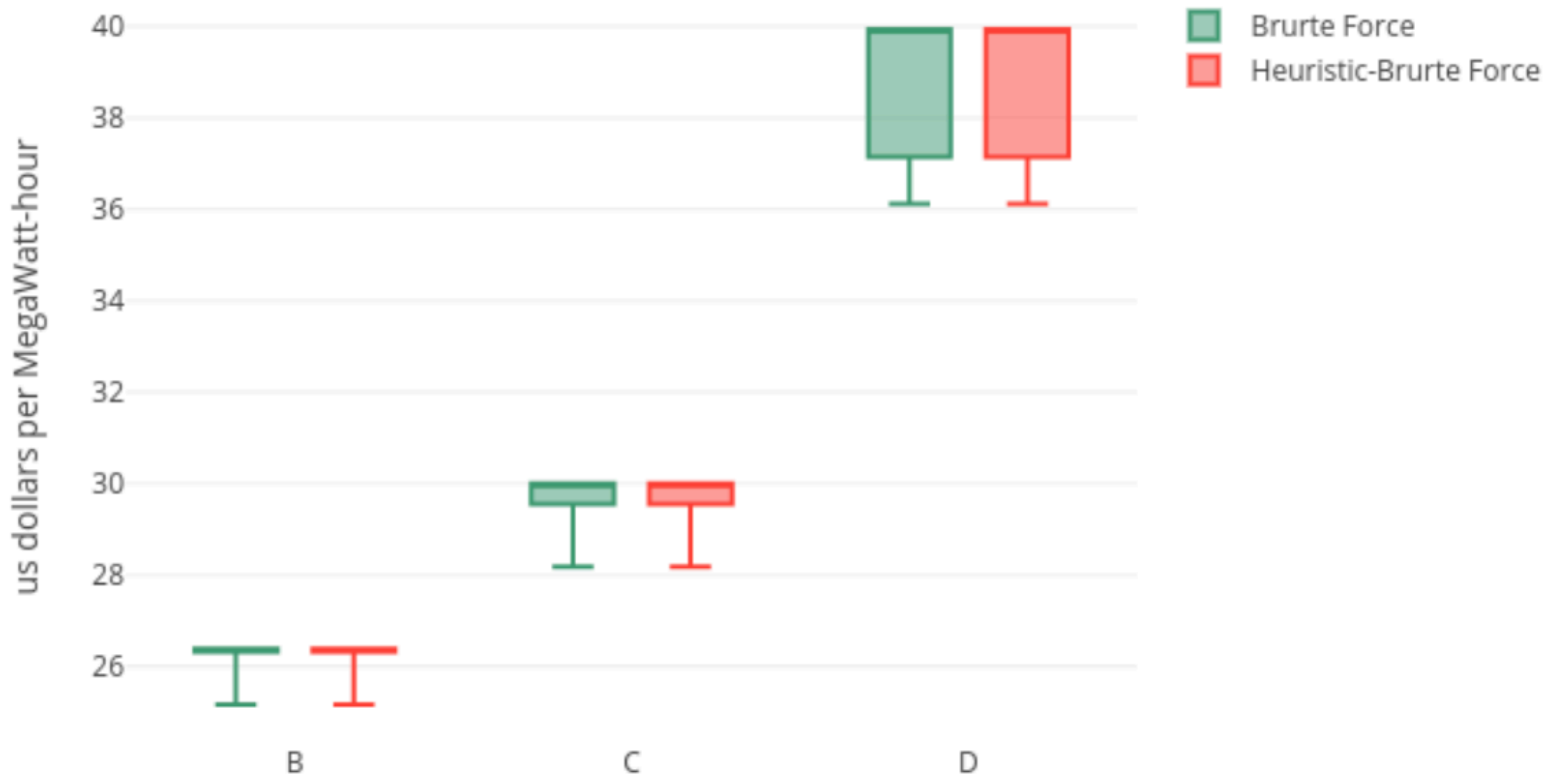
Bus	A	A	C	D	E
MW	0	300	300	400	0
MVar	0	98.61	98.61	131.47	0

Line data

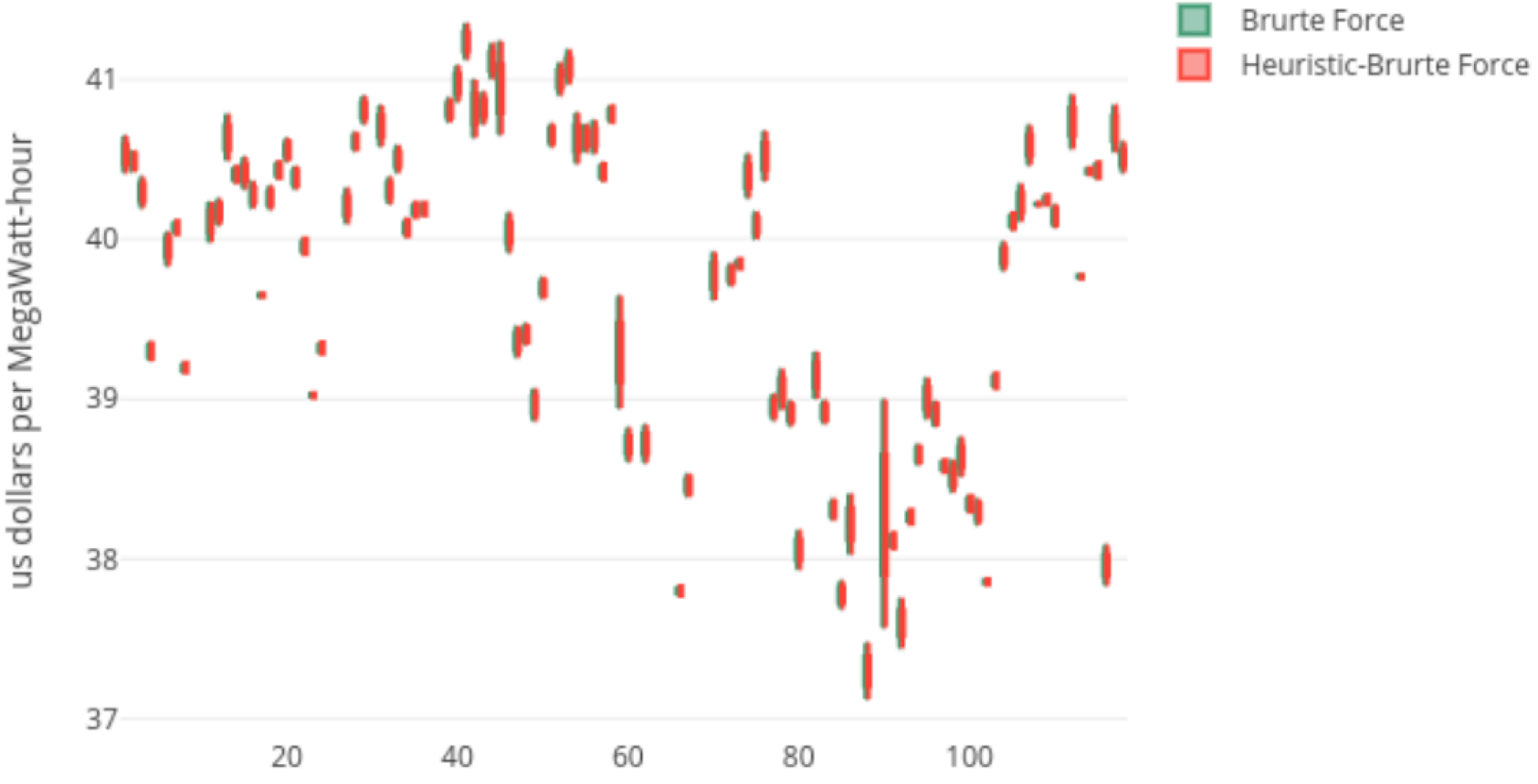
Line	AB	AD	AE	BC	CD	DE
R(%)	0.281	0.304	0.0064	0.108	0.297	0.297
X(%)	2.81	3.04	0.64	1.08	2.97	2.97
B/2(%)	3.56	3.29	15.63	9.26	3.37	3.37
Limit (MVA)	400	-	-	-	-	240



LMP at bus 2, 3 and 4 are differnced due to congestion between line A-B. The system marginal cost is 39.94 USD/MWhr



Brurte Force
Heuristic-Brurte Force
us dollars per MegaWatt-hour
40
38
36
34
32
30
28
26
B
C
D



Brurte Force
Heuristic-Brurte Force
us dollars per MegaWatt-hour
41
40
39
38
37
20
40
60
80
100

Accuracy

Comparision between results from pure brute force and combine heuristic-brute force

MAE ($/MWhr)

$$MAE = \frac{1}{N}\sum_{i=1}^{N} |p_i - \hat{p}_i|$$

$$MAPE = \frac{100}{N}\sum_{i=1}^{N} |\frac{p_i - \hat{p}_i}{p_i}|$$

where; p_i and $\hat{p}_i$ are LMP values from prue brute force and combine heuristic-brute force. N is number of LMP vlues from any quantile in every bus.

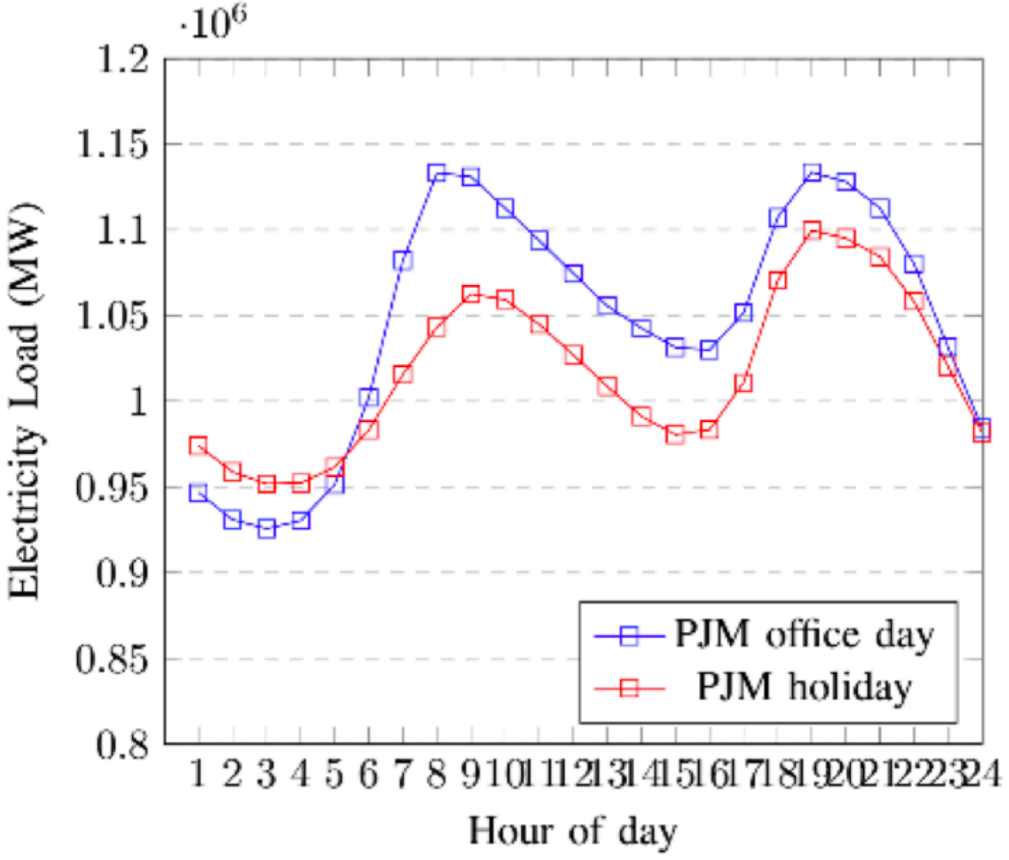
System	MAE($/MWhr)	MAPE(%)
PJM 5-bus	1.6466576417902465e-05	5.337334019974992e-05
IEEE 118-bus	0.0027926042421568546	0.00705144530541964

Speed-up performance

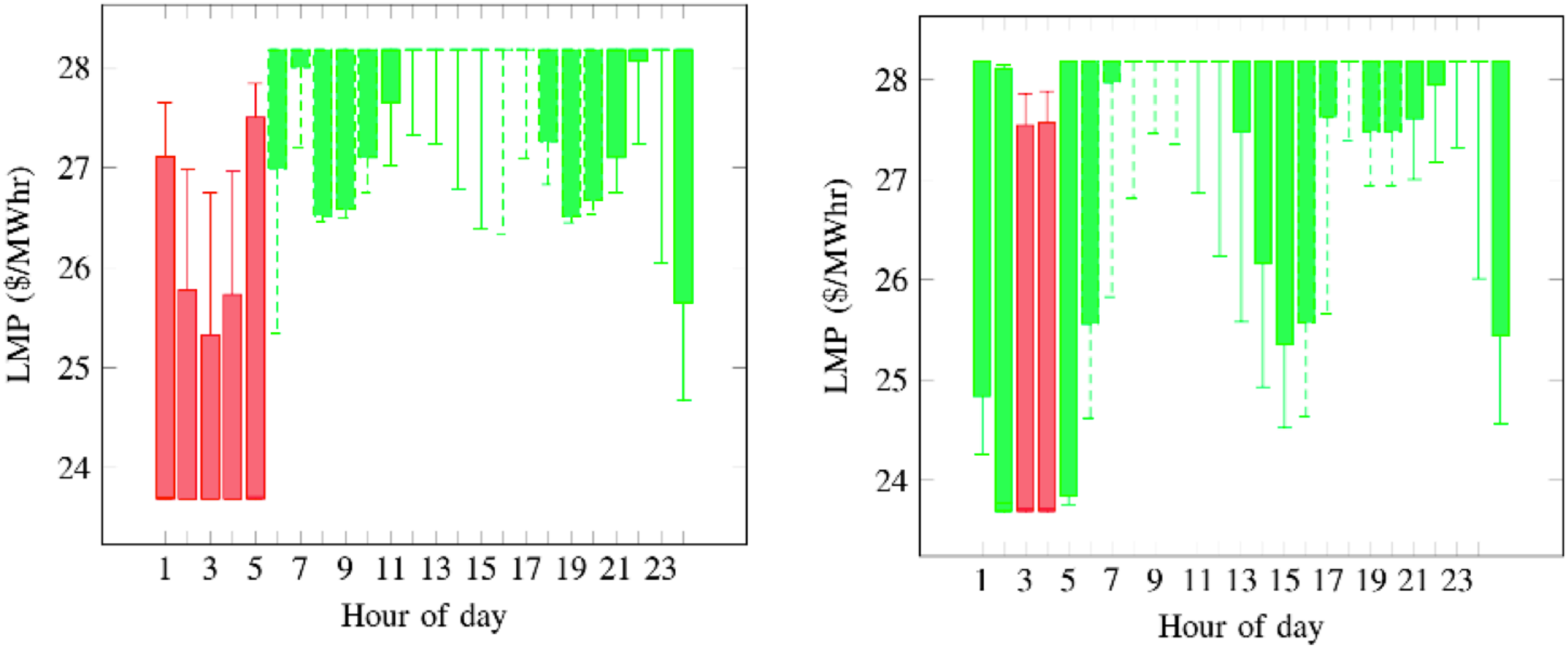
The speed-up performance shows time reduction in percentage. The base calculation time are 65.67 and 1203.06 seconds for PJM 5 bus system and IEEE 118 bus system, respectively.

System	F. Li and Bo (2009)	Purpose method
PJM 5-bus	23.14%	39.07%
IEEE 118-bus	4.29%	54.35%

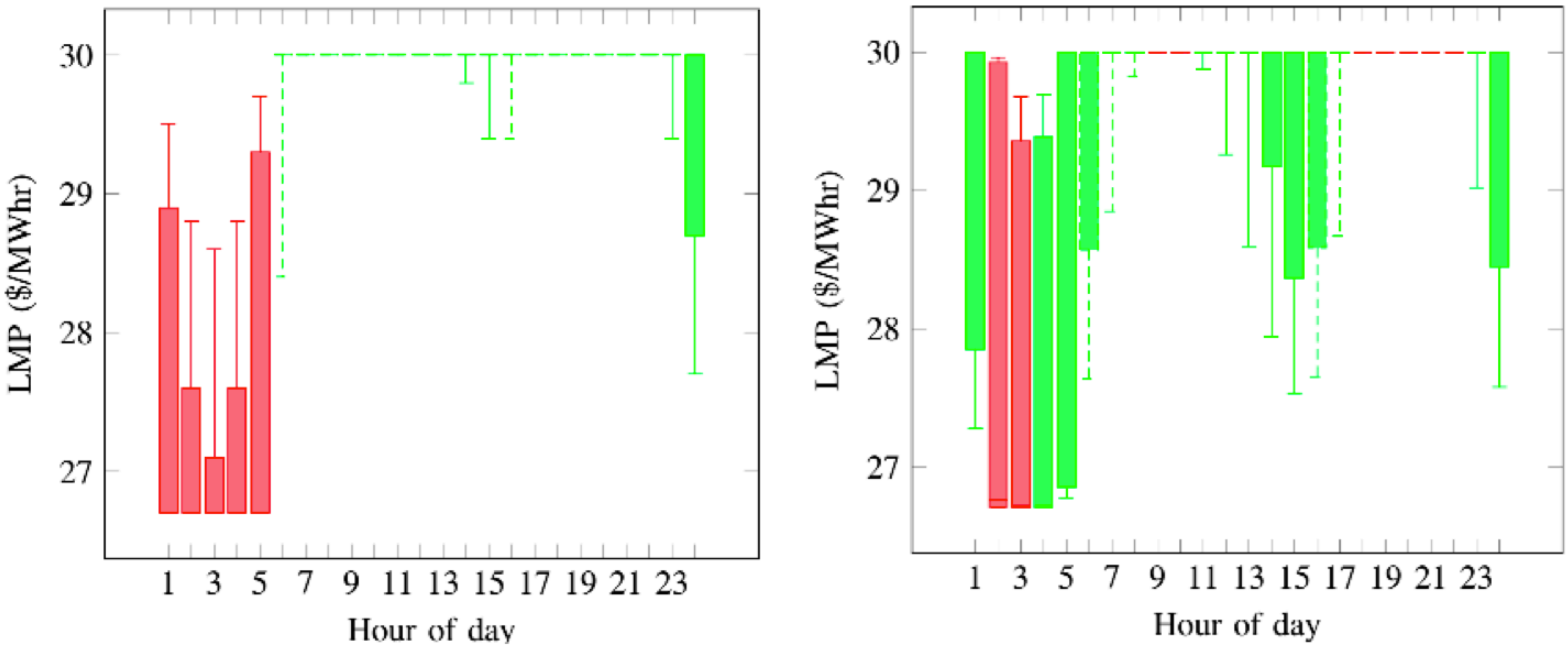
Part II: PJM dayly load (office day and holiday)



PJM 5 bus daily load

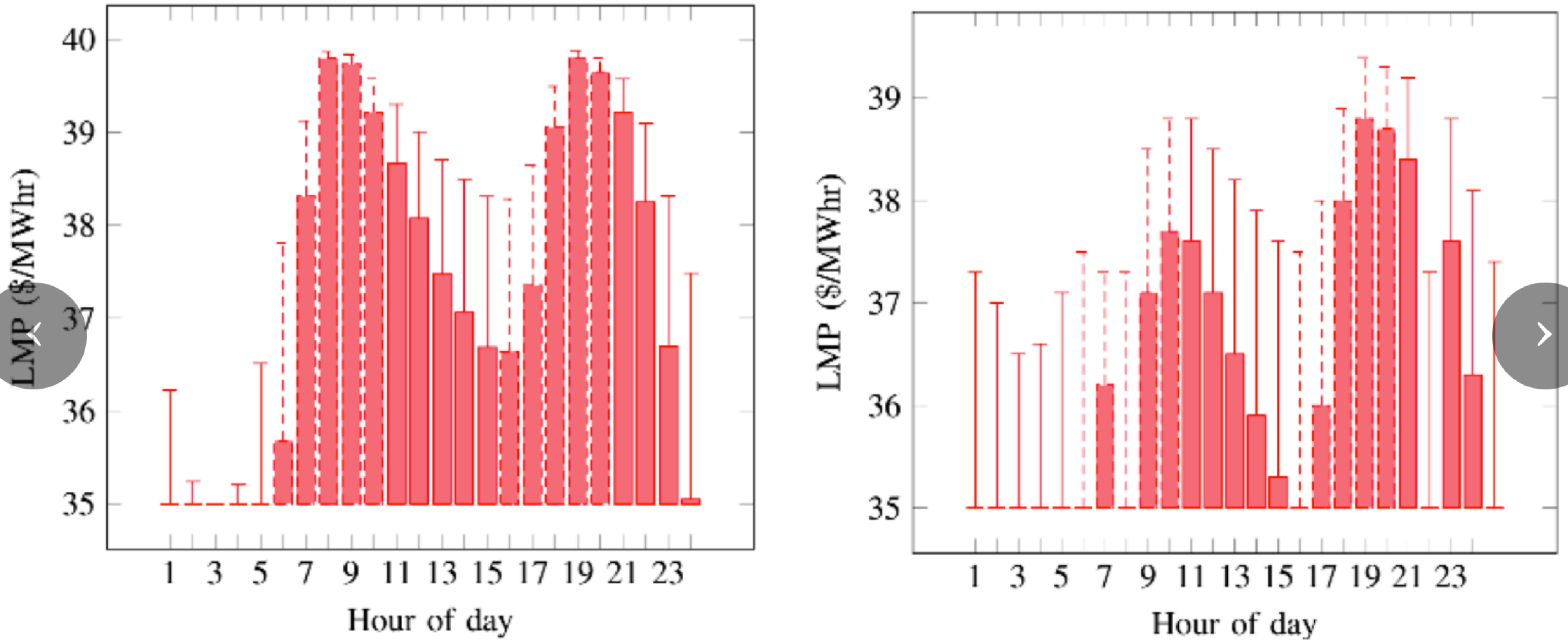


LMP sensitivity on load variation at bus B



LMP sensitivity on load variation at bus C

Part II: PJM dayly load (office day and holiday)



LMP sensitivity on load variation at bus D

Simulation result

The key points of the overall performance analysis are disscussed as below:

I. The proposed combined heuristic and brute force approach can provide similar stair case LMP curve to pure brute force approach

II. The drawback of proposed combined heuristic-brute force approach is to decrease computational time of LMP sensitivity on load variation

III. The calculated LMP and LMP sensitivity due to load variation (from -20% ti +20%) can be announced to households (home agnets) through retail agents to encourage price based or incentive based (rewards and penalty) demand response program

Future work

Forecasting in Generation

Engage Demand response program

Integrate emission cost in LMP

List of conferences and publication

Effects of High Penetration of Solar Rooftop PV on Short-Term Electricity Pricing Forecasting by using ANN-ABC Hybrid Model; Case Study of South Australia

Forecasting of monthly electricity generating for solar PV power plant by using Python based AI; case study of Thialand


End of presentation
Thank you for your attendtion
All questions are welcome