An Improved Transmission Switching Algorithm for Managing Post-(N-1) Contingencies in Electricity Networks

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INTRODUCTION

1

- **Overview**
  - Transmission Switching (TS) is a planned line outage
  - TS can aid **load shed recovery** (minimizing load shedding)
- **Cascading failures and blackouts**

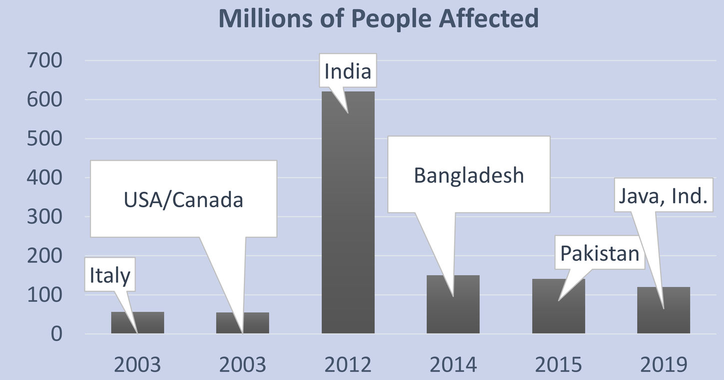
Blackouts cause N America chaos

Work has been going on through the night to restore power after massive blackouts hit major cities in the eastern United States and Canada.

The power failures caused chaos as they spread from New York to Detroit, and Toronto to Ottawa.

Many took to the streets after the power went off

http //news.bbc.co.uk/2/hi/americas/3152451.stm



https //en.wikipedia.org/wiki/List_of_major_power_outages

- **Industry Practice**
  - Redispatch generators
  - Shed load

PAST WORK AND MAJOR CHALLENGES

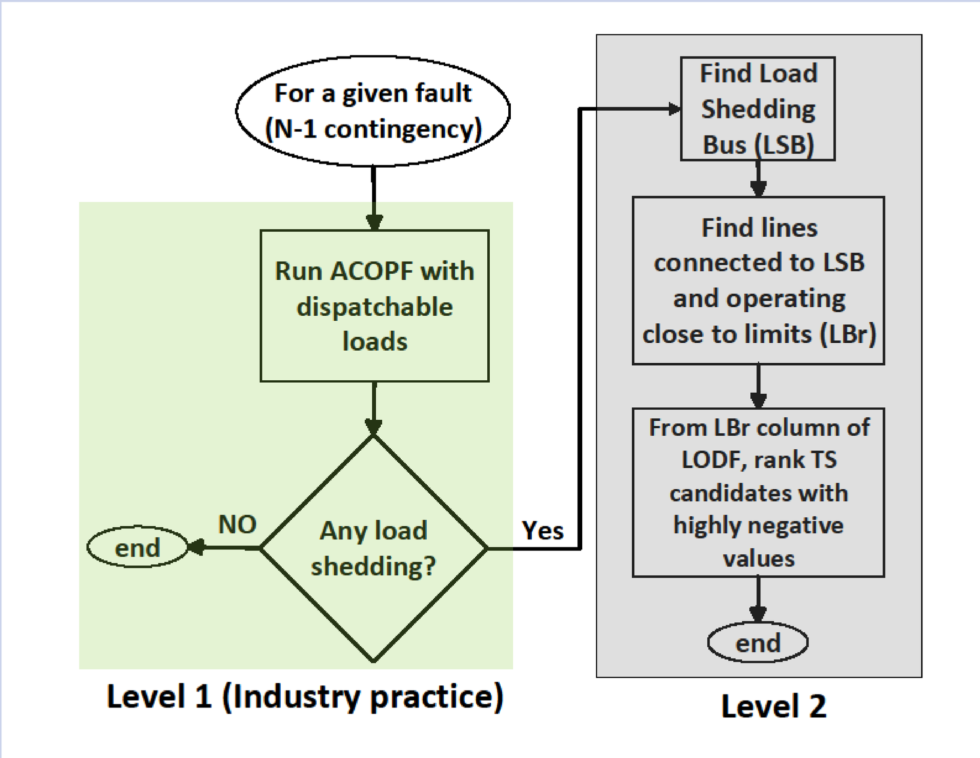
2

- **Past work**
  - TS has been used for optimal load shedding
  - Escobedo et al. [1] developed a DC Optimal Load Shed Recovery mechanism with TS (DCOLSR-TS)
    - **DCOLSR-TS is NP-hard and computationally complex**
  - TS used for reducing post contingency violations
  - Li et al. [2] developed an AC corrective TS based Real-Time Contingency Analysis (RTCA) tool
    - RTCA tool is computationally less complex
    - **does not guarantee removal of post contingency violations**
  - Sadat et al. [3] developed a system stress metric to show susceptibility to cascading failures
    - computationally less complex
    - based on **L**ine **O**utage **D**istribution **F**actor (LODF)
    - **does not guarantee removal of post contingency violations**
- **MAJOR CHALLENGES**
  - Guaranteed removal of post contingency violations with
    - manageable computational complexity
    - in polynomial time
    - impending integration of renewable energy sources to the grid

THE IMPROVED ALGORITHM

3

- **Bi-level algorithm**
  - A bi-level algorithm building on advances by [1]--[3] that
    - guarantees removal of post contingency violations
    - is computationally simple
    - can be easily adopted by industry
  - Considering renewable energy integration



- **Components of improved algorithm**
  - AC optimal power flow to incorporate renewable energy integration
  - dispatchable loads to guarantee removal of post contingency violations
  - LODF to calculate best TS candidate

RESULTS

5

Comparison with existing algorithms and industry practice

Algorithms	Load shedding (MW)	Post contingency violations	Time (sec)	Best TS candidates
CBCE [2]	0	3	0.32	NA
CBVE [2]	0	3	0.32	NA
CE [2]	0	3	1.02	NA
Industry practice	109.4	0	0.23	NA
Improved algorithm	0	0	0.23	4,6,7,11,12

No load shedding needed — No post contingency violations — Computationally viable — Multiple candidate solutions

Load shed recovery with renewable energy integration

Cases	Load shedding (MW)	Post contingency violations	Time (sec)	Best TS candidate
Industry practice	154.74	0	0.23	NA
Best Solution with CE	44.27	0	6.29	4
Improved algorithm	44.27	0	0.24	4

Matches computationally inefficient best solution — No post contingency violations — Computationally viable — Same best candidate

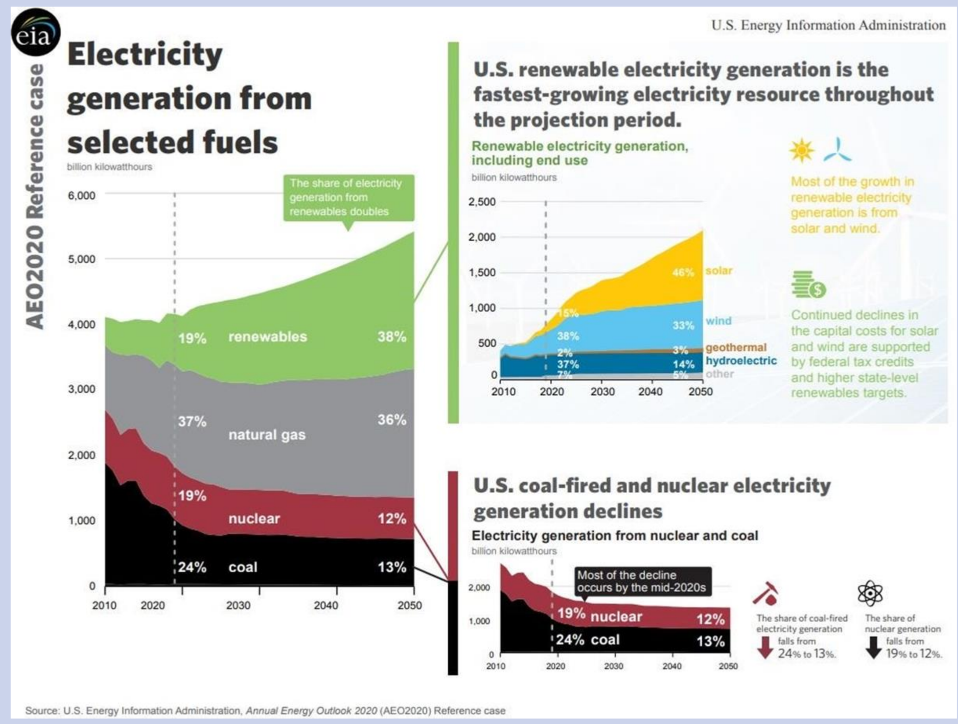
CASE STUDY

4

- **Computational environment and test systems**
  - IEEE 39-bus test system
  - Branch 35 outage i.e., between buses 21 and 22
  - 2.50 GHz windows machine with 16 GB RAM
  - Post-(N-1) contingency violations studied
- **Two case studies are performed**
  - **Comparison with existing algorithms from [2] and industry practice**
  - **Assuming 56% of generation is dispatchable** with proposed bi-level method
    - CBCE (closest branches to contingency element) [2]
    - CBVE (closest branches to violation element) [2]
    - CE (complete enumeration) i.e., removing all lines one at a time to find the best TS candidate [2]
    - load shedding with generators re-dispatch (industry practice)
    - Improved algorithm

Energy source	Generator nameplate capacity (MW)	Percentage of total	Capacity factor	Dispatchable
Coal	264,072.5	22%	53.6%	No
Petroleum	37028.5	3%	14%	Yes
Natural Gas	537292.1	45%	24%	Yes
Other Gases	2894.4	0.2%	65.4%	Yes
Nuclear	104270.2	8.7%	92.5%	No
Hydroelectric conventional	79911.6	6.7%	41.9%	Yes
Wind	94970.5	8%	34.6	No
Solar	32238.7	2.7%	25.1%	No
Pump storage	21871.3	1.8%	23.6%	Yes
Others	22165	1.9%	-	-
Total	1196487.9			56%

  - **Load shed recovery with renewable energy integration**
  - Three cases assuming **36% of dispatchable generation**
    - industry practice
    - best solution with CE
    - improved algorithm



FUTURE WORK

6

- **Future Steps**
  - implementation on large-scale/realistic power systems
  - high performance computing for computational efficiency
  - machine learning for handling large data volumes

References

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Disclaimer

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