Transmission Contingency Modeling

Transmission vs. Gen Contingency

With lossless linear OPF models:

- Generator contingencies cause supply-demand imbalance
  - Must respond with change in production
- Transmission contingencies cause no supply-demand imbalance (non-radial lines, not including intertie lines that may change imports/exports)
  - No change in supply, demand, losses
  - Flows redistribute
  - Allows to structure a pre-contingency dispatch setpoint plan that is secure for both the pre-contingency and post-contingency topology, *without generation redispatch*

Line Outage Distribution Factors

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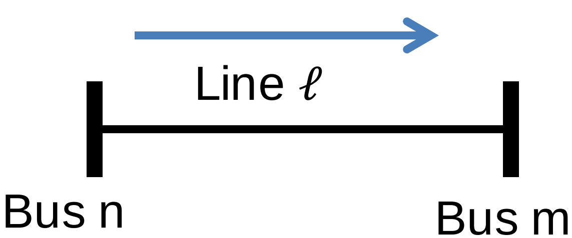
- An LODF allows you to determine the resulting flow on a particular line due to the loss of a different line
- When monitoring line *k*, what is the new flow on line *k* after you lose line ℓ

0 represents state 0, the base case, the pre-contingency state

$$P_k^{new} = P_k^0 + LODF_{k,\ell} P^0{}_{\ell}$$

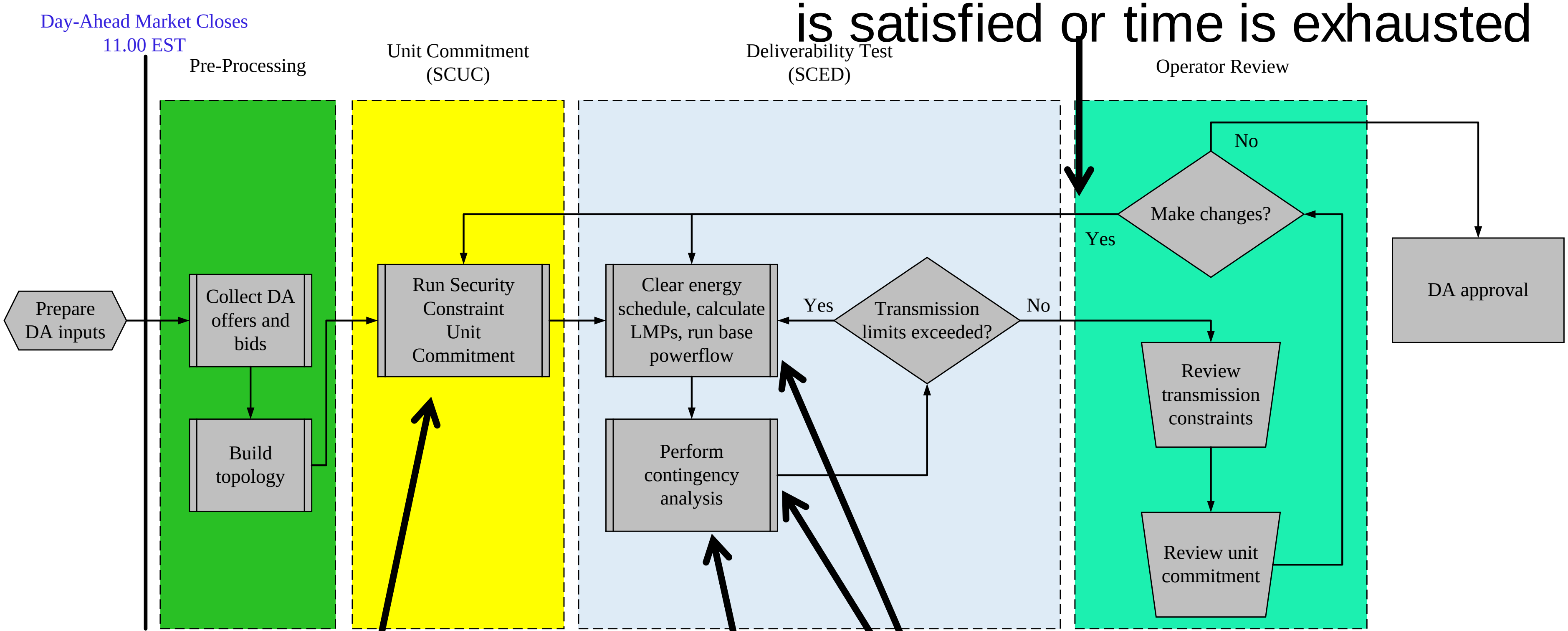
$$LODF_{k,\ell} = PTDF_{n,k}^{m} \left(\frac{1}{1 - PTDF_{n,\ell}^{m}} \right)$$



SCED/SCUC:
A Decomposition Approach to Capture Transmission Outages with LODFs

Day-Ahead Scheduling in Midcontinent Independent System Operator (MISO)

Iterative process until operator is satisfied or time is exhausted



Mixed integer linear program

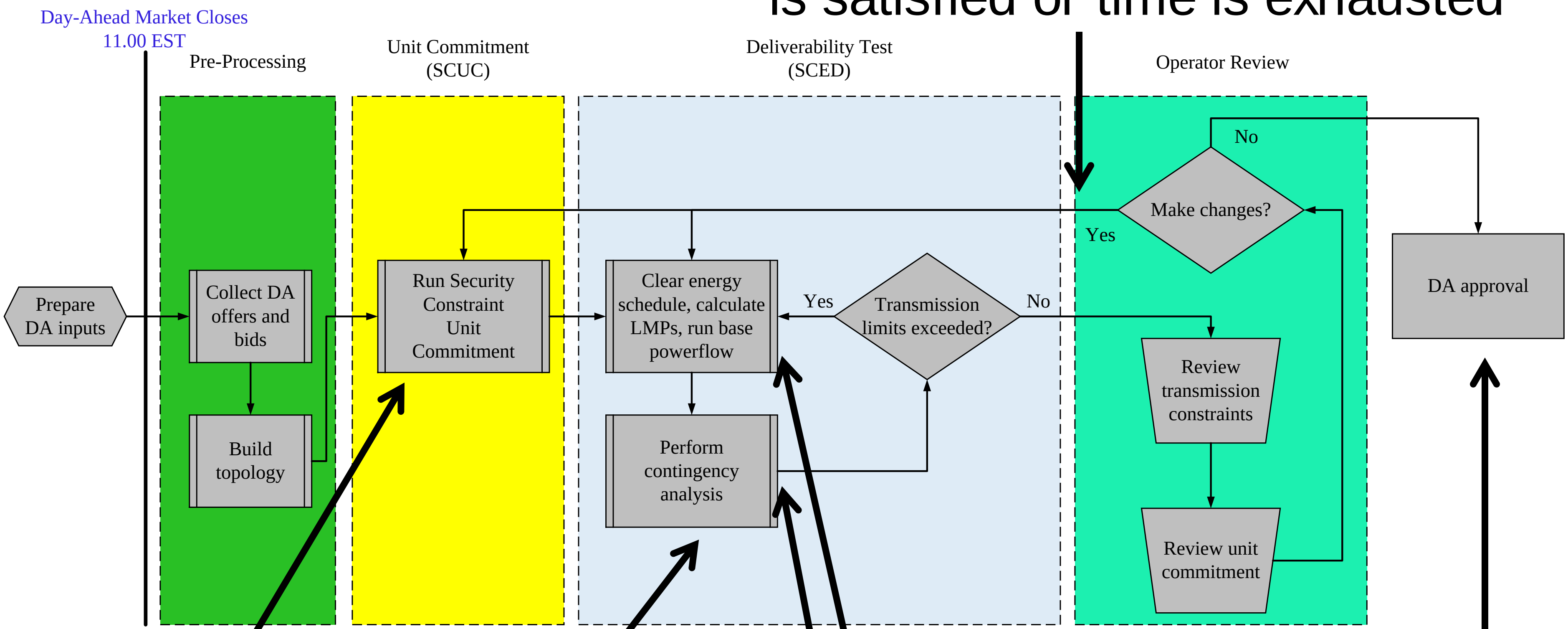
Reliability assessment

Linear program

MISO Day-Ahead Scheduling Procedure
[1] Aaron Casto, "Overview of MISO day-ahead markets," *Midwest ISO*, [Online]. Available: http://www.atcllc.com/oasis/Customer_Notices/NCM_MISO_DayAhead111507.pdf.

Day-Ahead Scheduling in Midcontinent Independent System Operator (MISO)

Iterative process until operator is satisfied or time is exhausted



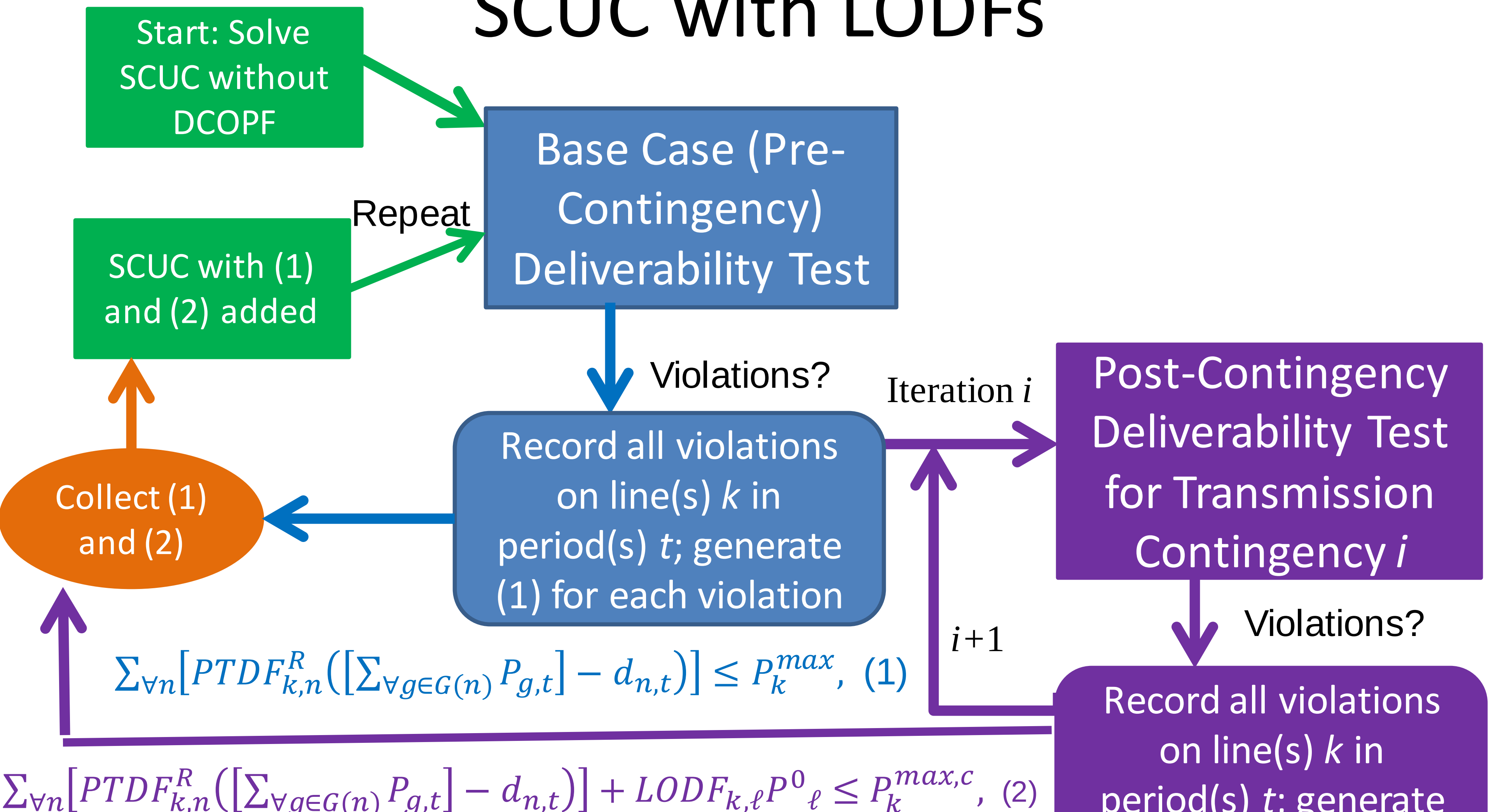
Interface limits
Nomograms

Subset of contingencies

DC Approximate, not AC; limited iterations

Final Day-Ahead Market Solution

Flowchart: Decomposition Based SCUC with LODFs



Where:

$LODF_{k,\ell}$: LODF for monitoring like k when there is an outage on line ℓ

P_{ℓ}^{0}: Base case flow for line ℓ (before contingency on line ℓ).

Decomposition Example

- Suppose you solve a SCUC without an OPF
- Then run a base-case (pre-contingency) DCOPF
  - For period 16 only, overloads on lines 5 and 7
- Then check transmission contingency 1 (assume only for period 16)
  - Overloads on lines 5 and 8
- Check contingency 2, no overloads; Check all other critical transmission contingencies, record violations…
- Add constraints:
- Re-solve SCUC & repeat

$$\sum_{\forall n}\left[PTDF_{k,n}^{R}\left(\left[\sum_{\forall g\in G(n)} P_{g,t}\right]-d_{n,t}\right)\right] \leq P_{k}^{max}, k=5,7; t=16 \quad (1)$$

$$\sum_{\forall n}\left[PTDF_{k,n}^{R}\left(\left[\sum_{\forall g\in G(n)} P_{g,t}\right]-d_{n,t}\right)\right] + LODF_{k,\ell}P^{0}{}_{\ell} \leq P_{k}^{max,c}, k=5,8; t=16; \ell=1 \quad (2)$$

Line Outage Distribution Factors

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$$P_k^{new} = P_k^0 + LODF_{k,\ell} P^0{}_\ell$$

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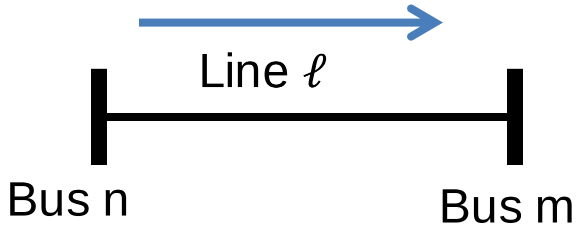

Break

Transmission Contingency Modeling

PTDF: Change in Ref Bus

- $PTDF_{n,k}^{r}$: Shift factor for an injection at n (sending) to reference bus r (receiving), for line k
- $PTDF_{m,k}^{r}$: Shift factor for an injection at m (sending) to reference bus r (receiving), for line k
- $PTDF_{n,k}^{m}$: Shift factor for an injection at n (sending) to bus m (receiving), for line k
- How to determine $PTDF_{n,k}^{m}$??

PTDF: Change in Ref Bus

- $PTDF_{n,k}^{m}$: Shift factor for an injection at n (sending) to bus m (receiving), for line k
- How to determine $PTDF_{n,k}^{m}$??
- Sending from n (injection) receiving at m (withdrawal) **is equivalent to (*same quantity*)** sending from n (injection) receiving at r (withdrawal) **plus** sending from r (injection) receiving at m (withdrawal)
  - The net injection at r is zero. The injection is at n and withdrawal is at m
  - $PTDF_{n,k}^{m} = PTDF_{n,k}^{r} + PTDF_{r,k}^{m}$

PTDF: Change in Ref Bus

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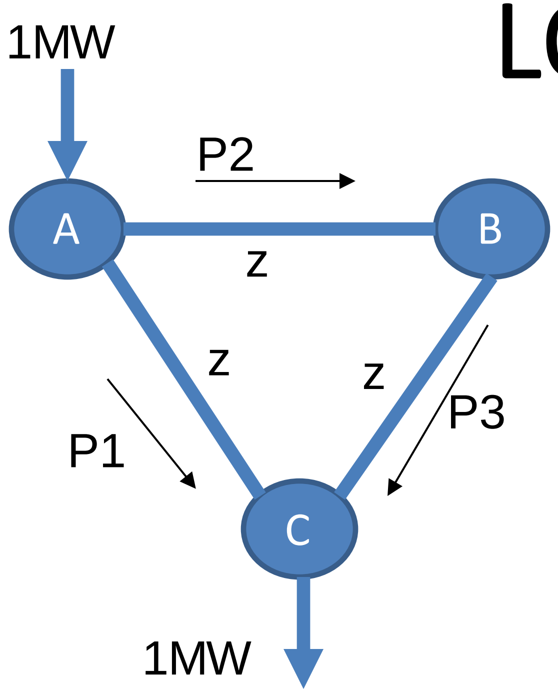
- Sending from n (injection) receiving at m (withdrawal) **<u>is equivalent to (*same quantity*)</u>** sending from n (injection) receiving at r (withdrawal) **minus** sending from m (injection) receiving at r (withdrawal)
  - $PTDF_{n,k}^{m} = PTDF_{n,k}^{r} - PTDF_{m,k}^{r}$
  - $PTDF_{n,k}^{m}(1) = PTDF_{n,k}^{r}(1) + PTDF_{m,k}^{r}(-1) = PTDF_{n,k}^{m}(1) = PTDF_{n,k}^{r}(1) - PTDF_{m,k}^{r}(1)$

Break

Transmission Contingency Modeling

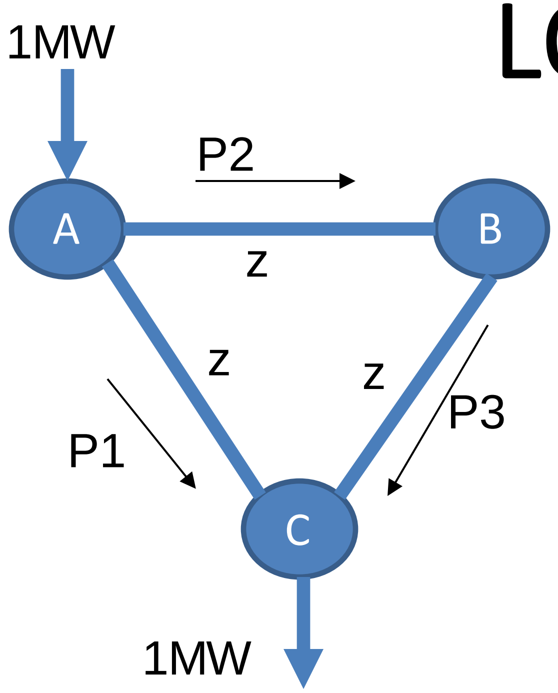
LODF Example



Determine the following:

PTDFs	P1	P2	P3
A to C			
B to C			
A to B			

LODF Example



$PTDF_{A,P1}^{C} = 2/3$ $PTDF_{B,P1}^{C} = 1/3$

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$PTDF_{A,P3}^{C} = 1/3$ $PTDF_{B,P3}^{C} = 2/3$

$$PTDF_{A,P1}^{B} = \frac{2}{3} - \frac{1}{3} = \frac{1}{3}$$

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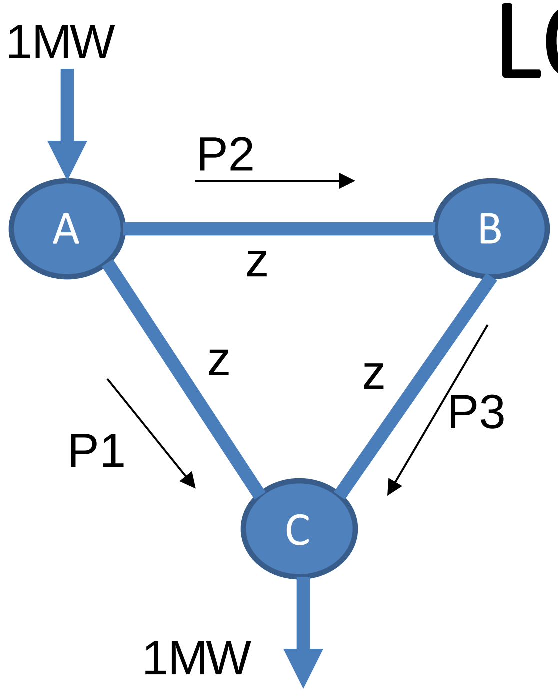
LODF Example



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P1 = 2/3, P2 = 1/3, P3 = 1/3

LODF for loss of line 2, impact on line 1?

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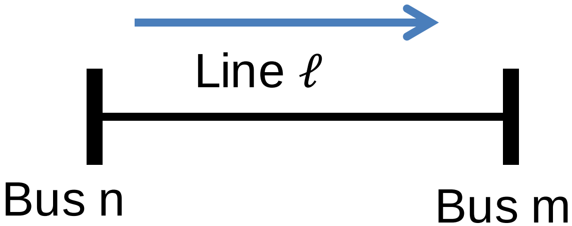
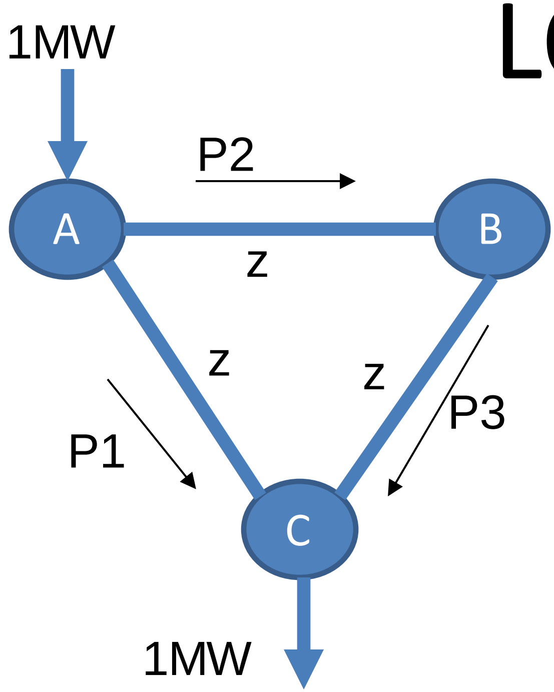


LODF Example



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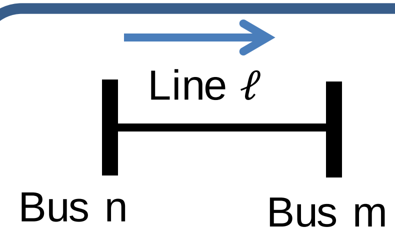
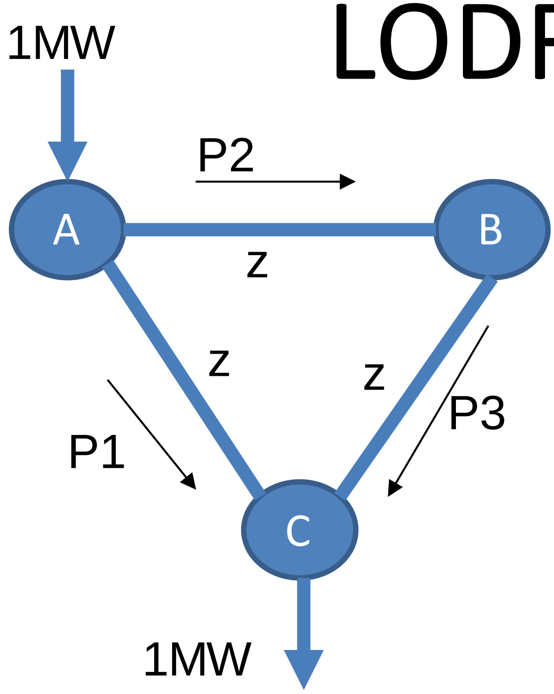


$$LODF_{k,\ell} = PTDF_{n,k}^{m}\left(\frac{1}{1 - PTDF_{n,\ell}^{m}}\right)$$

Determine the following:

$LODF_{k,\ell}$: $k = 1$ (monitored), $\ell = 2$ (lost line)	$LODF_{k,\ell}$: $k = 3$ (monitored), $\ell = 2$ (lost line)	$LODF_{k,\ell}$: $k = 2$ (monitored), $\ell = 1$ (lost line)

LODF Example Cont'd



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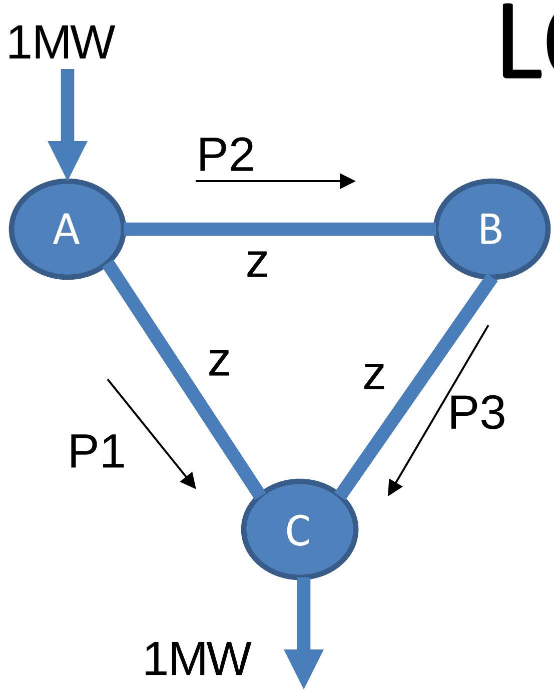
LODF for loss of line 2, impact on line 1?

LODF

$$P1^{new} = P1^{old} + PTDF_{A,P1}^{B}\left(\frac{1}{1 - PTDF_{A,P2}^{B}}\right)P2^{old}$$

$$P1^{new} = 2/3 + 1/3\left(\frac{1}{1-2/3}\right)\left(\frac{1}{3}\right) = 1$$

LODF Example



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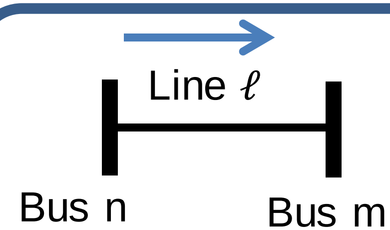

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(1/3)[1/(1-2/3)] = 1	(-1/3)[1/(1-2/3)] = -1	(1/3)[1/(1-2/3)] = 1