POLITECNICO DI MILANO





Logical Methods:
Project on system

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System: Electric Grid

Consider the electric grid network presented in the diagram:

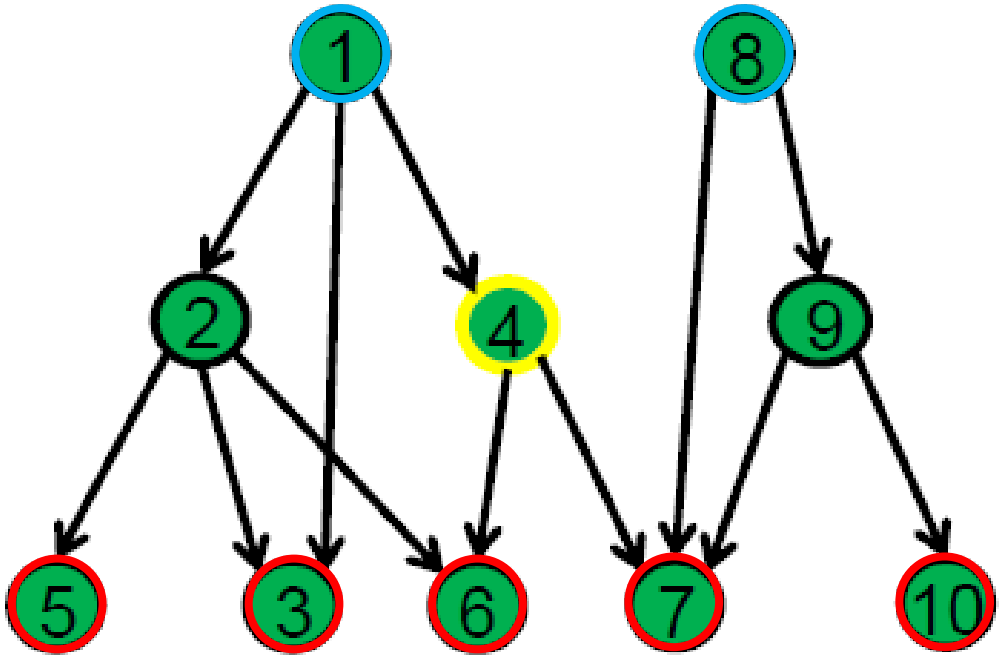
- The network consists of nodes connected by directed links, representing functional dependencies.
- Each node has two states: safe OR failed
- Redundant nodes (yellow circle) remain operational even if disruptions come from upper nodes.

Generators

Transformers

Redundancy
(e.g. presence of
diesel generators)

Consumers



Part 1: Landslide scenario and Generator vulnerability

The network under analysis includes generators that are vulnerable to natural hazards. In particular, generators at **node 1** and **8** may be damaged by a landslide, if its magnitude is sufficiently high.

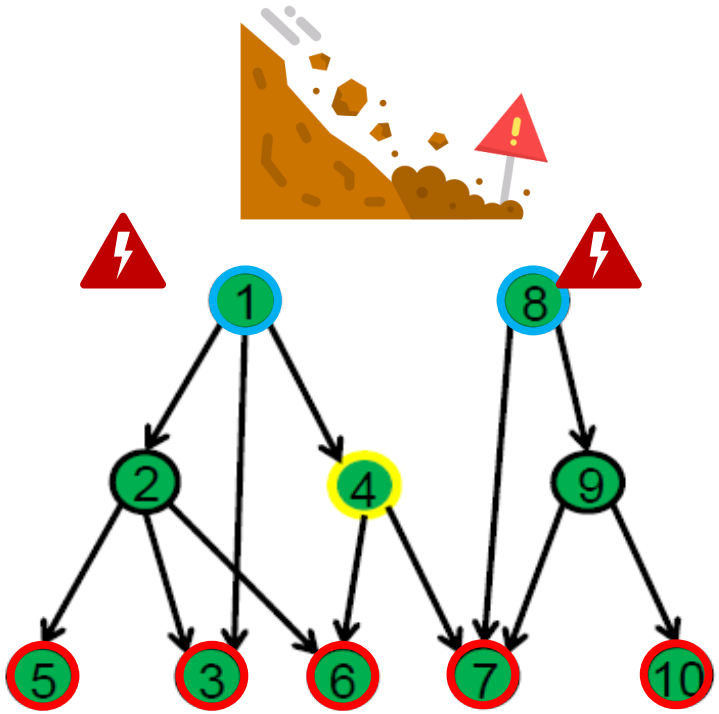
- The return period of such a landslide is 100 years
- The conditional probability of failure, given the occurrence of the landslide, is:

$$P(N1|L) = P(N8|L) = 4 \times 10^{-2}$$

Task:

Draw the ***Event Tree***, using the "landslide" as the initiating event. Identify the success scenarios in which the consumers at **node 7** are supplied with energy.

Assumption: *a node operates only if all the nodes it depends on are functioning.*



Consider the following events in the tree:

Node 8 out of service, due to the landslide	**Node 1 out of service, due to the landslide**

Part 2: Landslide scenario and Generator vulnerability

The network under analysis includes generators that are vulnerable to natural hazards. In particular, generators at **node 1** and **8** may be damaged by a landslide, if its magnitude is sufficiently high.

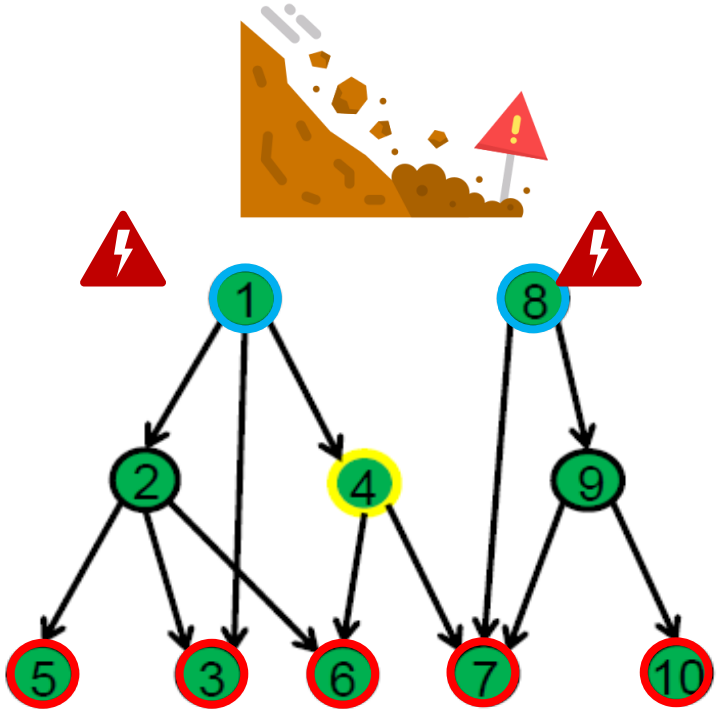
- The return period of such a landslide is 100 years
- The conditional probability of failure, given the occurrence of the landslide, is:

$$P(N1|L) = P(N8|L) = 4 \times 10^{-2}$$

Task:

Draw the ***Event Tree***, using the "landslide" as the initiating event. Identify the success scenarios in which the consumers at **node 7** are supplied with energy.

Assumption: *a node operates when at least one of the nodes it depends on is functioning well.*



Consider the following events in the tree:

Node 8 out of service, due to the landslide	**Node 1 out of service, due to the landslide**

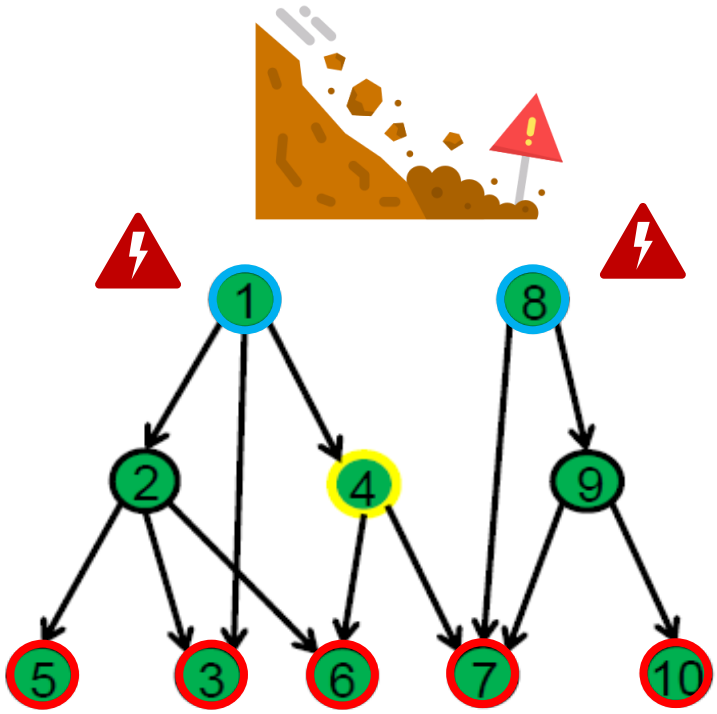
Part 3: Landslide scenario and random node degradation

The network under analysis includes generators that are vulnerable to natural hazards. In particular, generators at **node 1** and **8** may be damaged by a landslide, if its magnitude is sufficiently high.

- The return period of such a landslide is 100 years
- The conditional probability of failure, given the occurrence of the landslide, is:

$$P(N1|L) = P(N8|L) = 4 \times 10^{-2}$$

Each node (including the redundant ones) is subject to random failures, modelled by an exponential distribution with rate parameter $\lambda = 3 \times 10^{-4}\ Y^{-1}$.



Task: Draw the ***Fault Tree***, using as top event 'Consumers of **node 7** are not supplied with energy'.
Identify the **minimal cut sets** that lead to the top event.
Estimate the **probability of the top event** over a mission time of **10 years**.

Assumption: *a node operates only if all the nodes it depends on are functioning.*

Reminder: Hazard occurrence and return period

For a rare event (e.g. landslide) with return period U, the yearly probability could be estimated as:

$$p = \frac{1}{U}$$

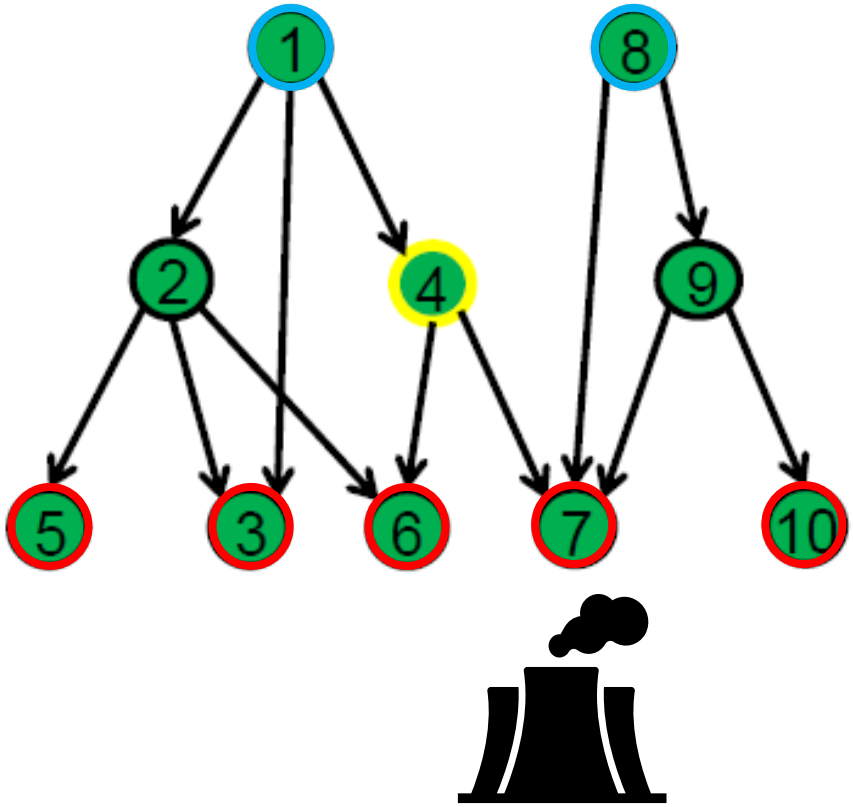
To estimate the probability of event occurs exactly in k years (i.e., after $k-1$ years without occurring), use the geometric distribution:

$$P(Y = k) = (1-p)^{k-1} * p$$

To estimate the probability that the event occurs at least within T years, use the cumulative form:

$$P(Y < K) = \sum_{k=1}^{T} (1-p)^{k-1} * p$$

Part 4: Chemical plant safety under Node 7 dependency



A chemical plant is supplied with electricity from **Node 7** of the grid. In the event of a *"Loss of Primary Containment" (LOPC),* the plant can **overheat**. To avoid this, the plant relies on **three safety layers** to interrupt the accident sequence.

Part 4: Chemical plant safety under Node 7 dependency

A chemical plant is supplied with electricity from **Node 7** of the grid. In the event of a *"Loss of Primary Containment" (LOPC),* the plant can **overheat**. To avoid this, the plant relies on **three safety layers** to interrupt the accident sequence.

First safety layer: An *automatic mechanical valve* designed to stop the injection of reagents

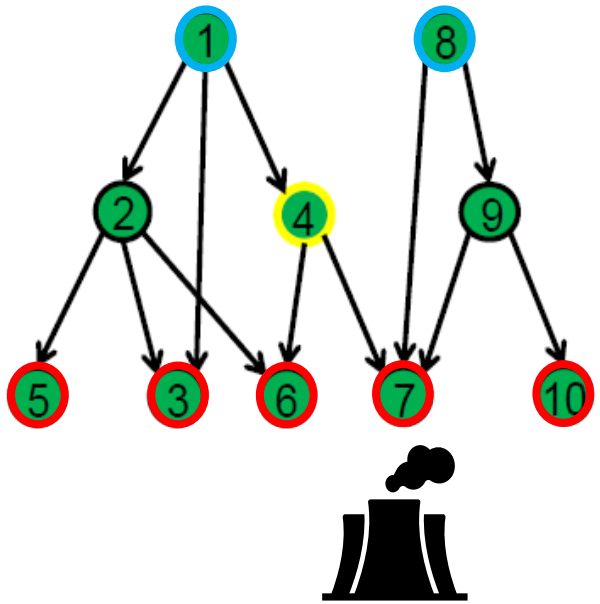
- Switch-on failure probability: $P_v = 5 \times 10^{-2}$

Second safety layer: A water reservoir used for cooling, which must be manually activated by an operator

- Probability of human error activating the reservoir: $P_r = 2 \times 10^{-2}$

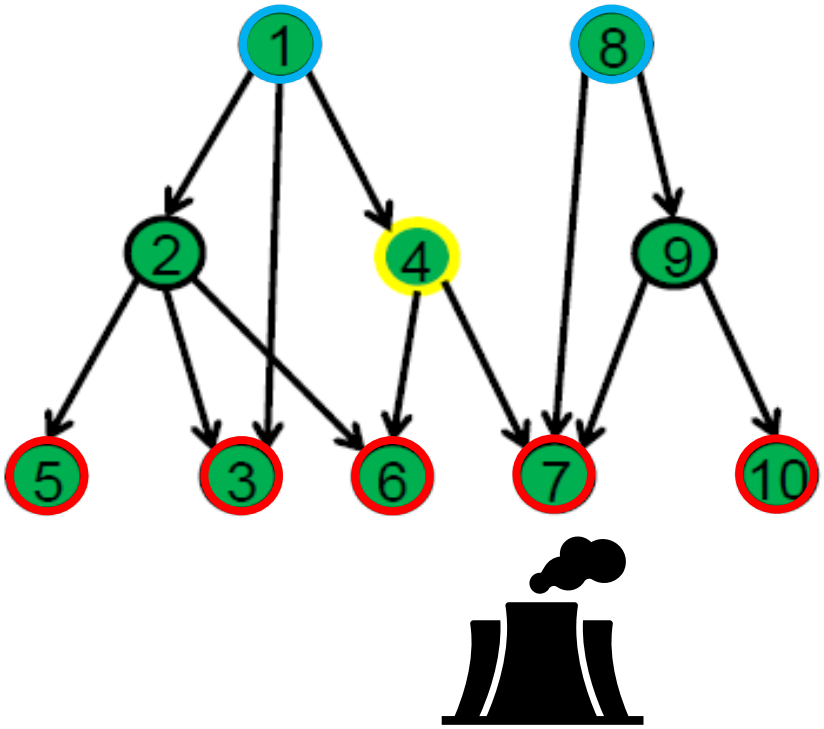
Third safety layer: An underground water pump electrically powered and activated to provide cooling

- Switch-on failure probability: $P_p = 10^{-2}$
- The pump requires power supply from Node 7 to operate,
- It must remain operational for one month to restore safe conditions



Assume that the only relevant failure mechanisms are related to the activation (switch-on) process of each layer

Part 4: Chemical plant safety under Node 7 dependency



Task:

Draw the ***Event Tree*** for the initiating event: LOPC considering the events of failures of the safety layers and the loss of supply power to the pump over 1-month due to failure of node 7 (as modelled previously by Fault Tree).