POLITECNICO DI MILANO

Resilience of critical infrastructure exercises

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Emergency cooling system

The following system is designed to deliver emergency cooling to a nuclear reactor.

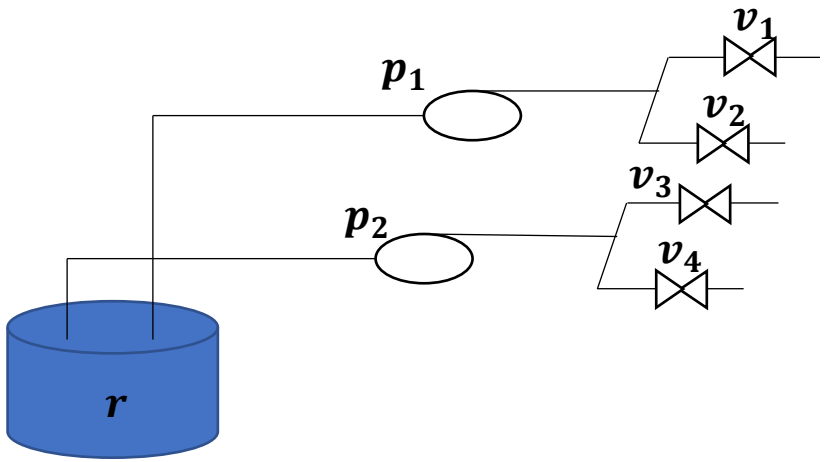
In the event of an accident the protection system delivers an actuation signal to the two identical pumps and the four identical valves. The pumps then start up, the valves open, and liquid coolant is delivered to the reactor. The following failure probabilities are found to be significant:

Probability that the **protection system** (ps) will not deliver signal, P_{ps}=0.05

Probability that a **pump** (p) fail, P_p=0.1

Probability that a **valve** (v) fail, P_v=0.02

Probability that the **reservoir** (r) will be empty, P_r=0.08



Exercise 1-A
Fault Tree

- Draw a Fault Tree (FT) for the failure of the system to deliver cooling to the nuclear reactor.
- Identify the minimal cut-sets of the system.
- Compute the probability of the top event.

Exercise 1-B
Event Tree

- Draw an Event Tree (EV) for the failure of the system to deliver cooling to the to the nuclear reactor assuming an initiating event and the following header events, then calculate the probability of operation of the system.

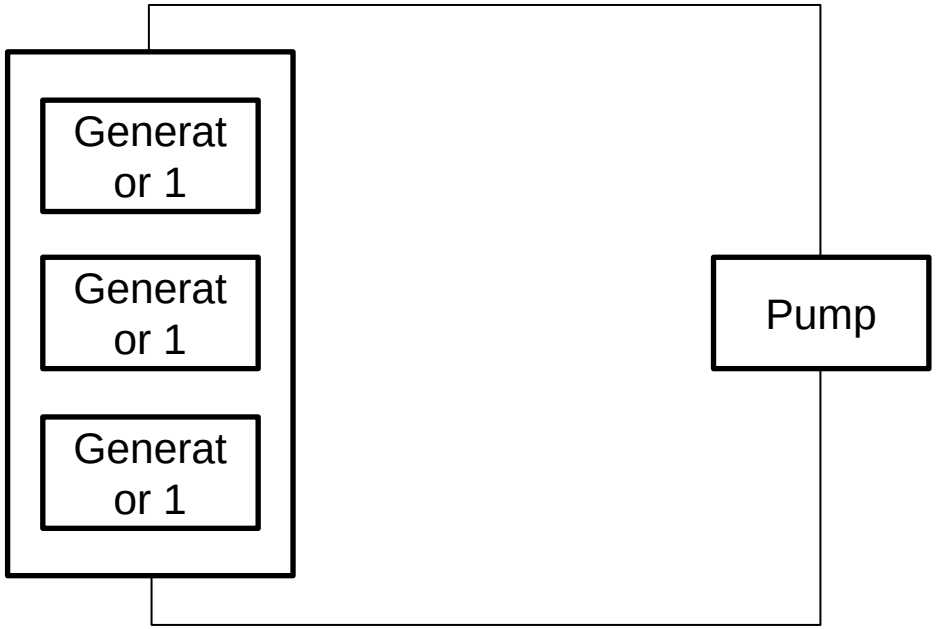
ps	r	p1	v1	v2	p2	v3	v4

Exercise 1-C
GTST-MLD

- Draw the Goal Tree Success Tree for the top goal “safety injection system works successfully”.
- Compute the probability of the top goal.

Exercise 2
Event Tree

An electrical pump (P) is fed by a group of three electric generators (G). Given the high power requested by the pump, it is necessary that <u>at least two</u> of the generators be in operation.



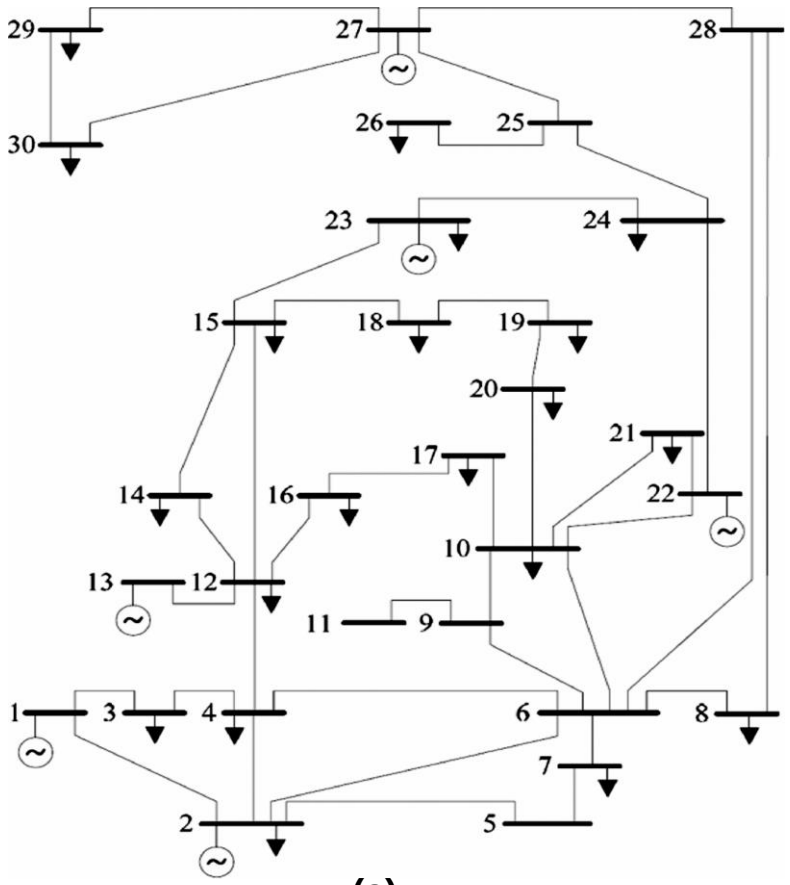
Build the event tree to calculate the probability of operation of the system that starts with an initiating event and the following header events and considering the following data:

$R_P = 0.9, \qquad R_{G1} = R_{G2} = R_{G3} = 0.85$

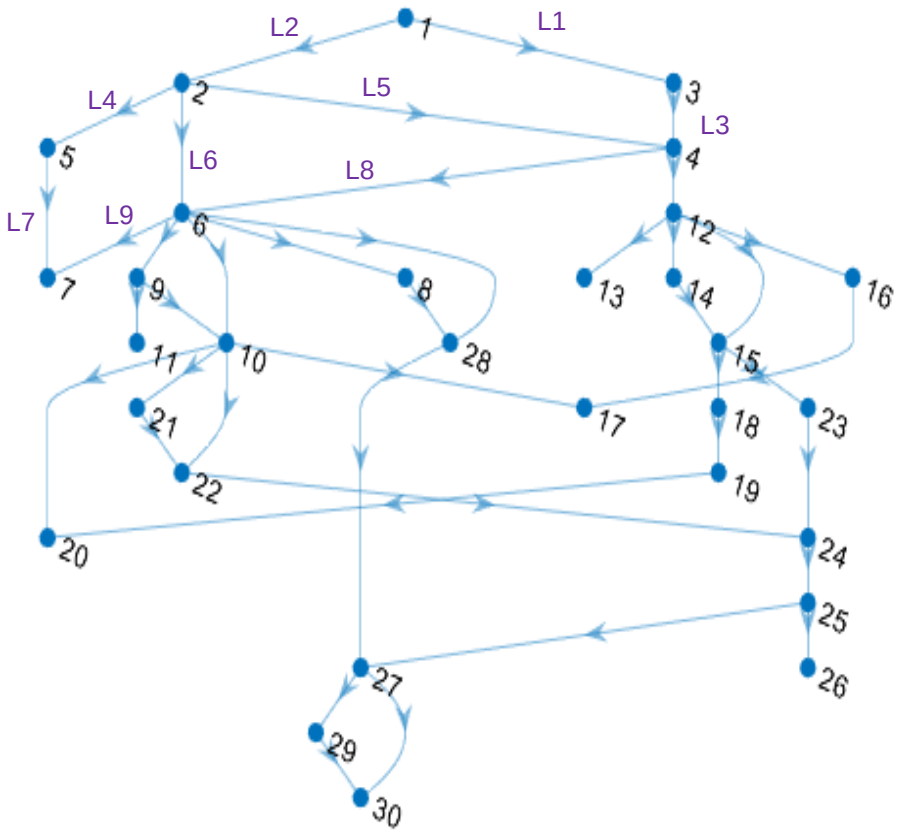
P	G1	G2	G3

IEEE30 Bus Power Distribution System

The standard IEEE30 power distribution system is shown in the figure (a). Only the major components are to be considered: the Generators (6 generators), Loads (20 loads) and power delivery paths consisting of lines (L) and buses (B). The stochastic network is shown in figure (b).



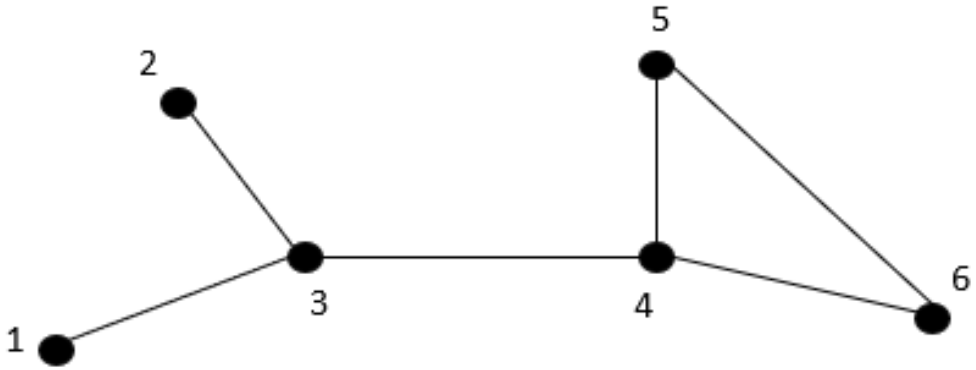
(a)



(b)

Exercise 3-A
Fault Tree

- Draw a Fault Tree (FT) for the failure of the system to supply power to the load demand at bus 4 (Load4).
- Find the minimal cut sets and the probability of the top event if probability of each element's failure is equal to 0.01.

Exercise 4
Centrality Measures

In the following network, find the topological centrality measurements (C_i^D, C_i^C, C_i^B and C_i^I) of node 3.