

# RESILIENCE OF CRITICAL INFRASTRUCTURES PROJECT

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**Abstract:** This exercise will include the analysis (both topological and with logical methods) of a system representing an electric grid.

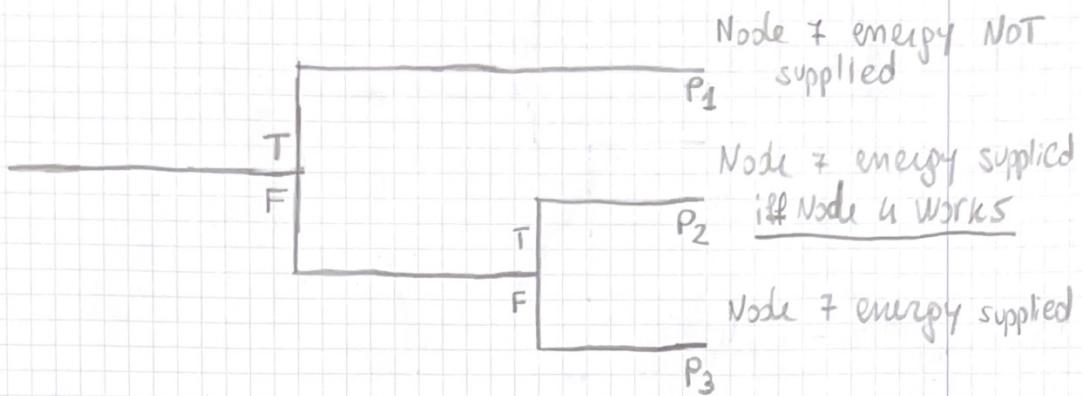
From the next page you will find the results of the analysis.

In the powerpoint presentation you will also find the description on what we have done and on the decisions taken.

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## Part 4

landslide      H1      H2  
"                 "          "  
IE                Node 8 Failure    Node 1 failure



$$P_1 = \frac{4}{100} = 0.04$$

$$\rho_2 = \frac{96}{100} \cdot \frac{4}{100} = 0,0384$$

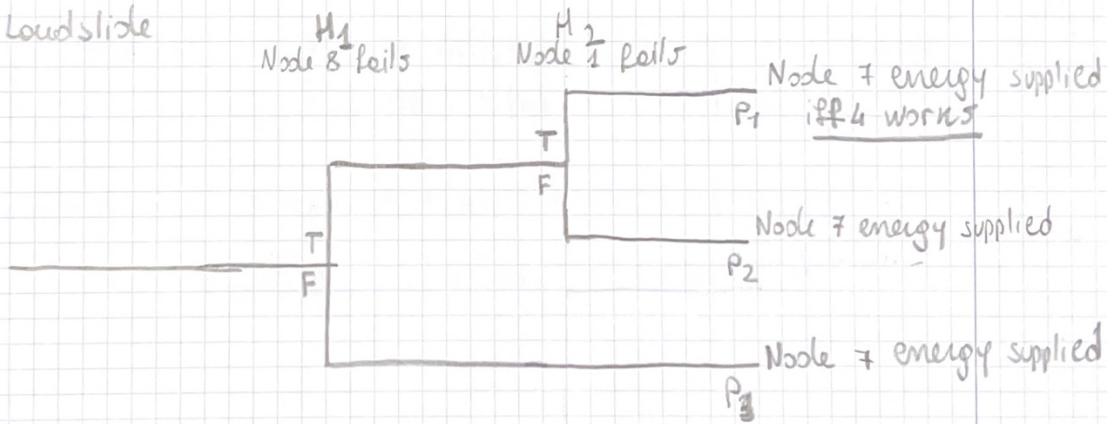
$$P_3 = \frac{36}{100} \cdot \frac{36}{100} = 0.9216$$

## PART 2

Loudslide

$H_1$   
Node 8 fails

Node 1 Pairs

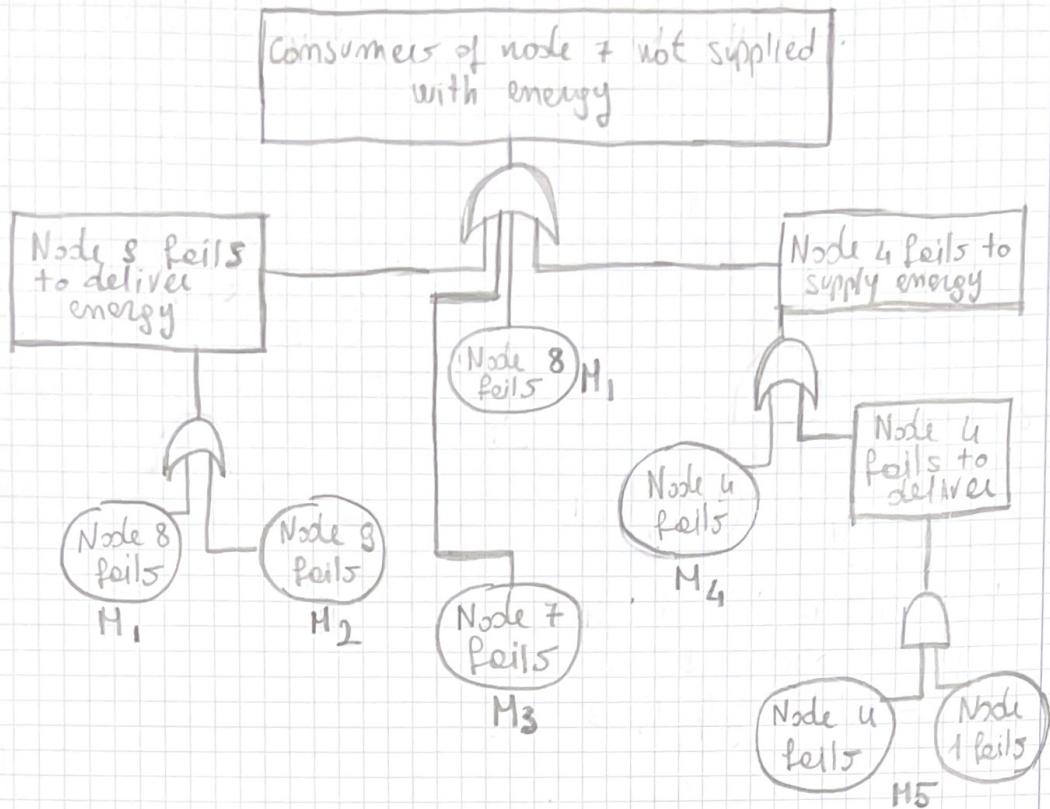


$$P_1 = \frac{4}{100} \cdot \frac{4}{100} = 0.0016$$

$$P_2 = \frac{6}{100} \cdot \frac{86}{100} > 0.0384$$

$$P_3 = \frac{96}{128} = 0.75$$

PART 3.a



$$MCS: \{G_8\}, \{N_9\}, \{N_{10}\}, \{N_4, G_1\}, \{N_7\}$$

$$\text{Node random failure prob.} = 1 - e^{-\lambda t} = 1 - e^{-3 \cdot 10^{-4} \cdot 10} = 0.002985$$

$$\begin{aligned} &\text{Generator } X \text{ fails if landslide occurs} \\ &= P(N_X \mid L) \cdot P(L \leq 10) = 3.824 \cdot 10^{-5} \end{aligned}$$

$$\begin{aligned} P(\text{Node 7 fails}) &= P(G_8) + P(N_9) + P(N_{10}) + P(N_4, G_1) + P(N_7) \\ &= 1.145 \cdot 10^{-5} + \dots = 9.0223 \cdot 10^{-3} \end{aligned}$$

## PART 3.b

Consumers of coal + oil supplied  
with energy

Generators  
work

Transformers  
work

G1

N4

N9

G8

N7

$$G_1 \parallel N_4 = 0.3333$$

$$G_8 \parallel N_9 \parallel N_7 = 0.99996$$

$$N_1 \parallel N_4 \parallel N_7 = 0.99104$$

$$P(\text{top-event}) = 0.991$$

## PART 4

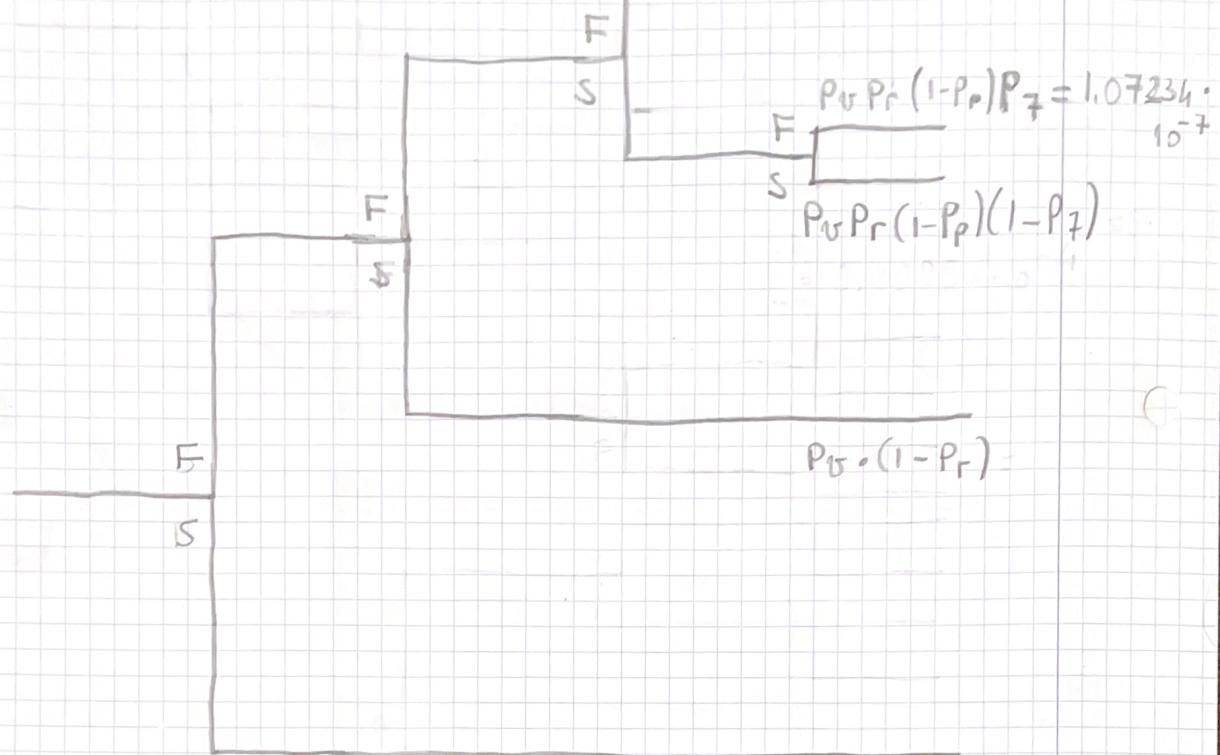
VALVE

RESERVOIR

PUMP

ENERGY  
TO PUMP

$$P_V, P_r, P_p = 10^{-5}$$



$$P_V \cdot (1 - P_r)$$

$$P_V P_r (1 - P_p) P_7 = 1.07234 \cdot 10^{-7}$$

$$P_V P_r (1 - P_p) (1 - P_7)$$

$$\text{Overheating probability} = \sum_{\text{failure conditions}}^{1 - P_V} = 1.0107 \cdot 10^{-5}$$

## PART 5

$$C_4^{\text{IN}} = \frac{\sum_{i \neq 4} a_{i4}}{N-1} = \frac{1}{3}$$

$$C_4^{\text{OUT}} = \frac{\sum_{j \neq 4} a_{4j}}{N-1} = \frac{2}{3}$$

$$C_4^C = \frac{N-1}{\sum_{j \neq 4} d_{4j}} = \emptyset$$

because we have to consider distance to all nodes and some nodes are not reachable

$$C_4^B = \frac{1}{(N-1)(N-2)} \sum_{j,k} \frac{n_{jk}^{(i)}}{m_{jk}} = \frac{3/2}{7/2} = 0.0208$$

$$C_4^I = \frac{\Delta E(h)}{E} = \frac{14 - 10.5}{14} = 0.25$$

$$D = \begin{bmatrix} 0 & 1 & 1 & 1 & 2 & 2 & 2 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & - & - & - & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \\ 1 & 0 & 1 & 1 & 2 & 2 & 2 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & - & - & - & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \end{bmatrix}$$

$$D^{-1} = \begin{bmatrix} 0 & 1 & 4 & -2 & 2 & - & - & - & - & - \\ 0 & 1 & 1 & 1 & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \\ 1 & 0 & 1 & 2 & - & - & - & - & - & - \\ 1 & 0 & 1 & 1 & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \\ 0 & - & - & - & - & - & - & - & - & - \end{bmatrix}$$

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## References

- [1] Slides of the course
- [2] Probability slides of professor Zio