RESILIENCE OF CRITICAL INFRASTRUCTURES PROJECT

[redacted] – Tommaso Giorgeschi

Part 1

In the part 1 of the PDF you can find the Event tree in which we had two heading events (failure of node 8 and node 1).
In this part, we were asked to analyze the situation in which node 7, in order to work, requires that **all the nodes it depends on are working.**

From the diagram you can see that if node 8 fails, then node 7 cannot supply energy to its consumers.
Otherwise if generator 8 does not fail:

- if generator 1 fails, then node 7 will provide energy to its consumers since node 4 works as a backup (*assuming node 4 is working properly*)
- if generator 1 does not fail, then consumers underlying node 7 will be supplied with energy

Probabilities explanation:

- P1 is simply the failure probability of generator 8
- P2 is computed as (1-P1) * P1
- P3 is computed as (1-P1) * (1-P1)

Part 2

In the part 2 of the PDF you can find the Event tree in which we had two heading events (failure of node 8 and node 1).
In this part, we were asked to analyze the situation in which node 7, in order to work, requires **at least 1 node it depends on is working.**

From the diagram you can see that if node 8 works properly, then node 7 supplies energy to its consumers.
Otherwise if generator 8 fails:

- if generator 1 fails, then node 7 will provide energy to its consumers since node 4 works as a backup (*assuming node 4 is working properly*)
- if generator 1 does not fail, then consumers underlying node 7 will be supplied with energy

Probabilities explanation:

- P1 is computed as the product between the failure of the 2 generators
- P2 is computed as P1 * (1-P1)
- P3 is computed as 1-P1

Part 3.a

In the part 3.a of the PDF you can find the Fault tree for the top event "*Consumers of node 7 not supplied with energy*".
In this part, we were asked to analyze the situation in which node 7, in order to work, requires that **all the nodes it depends on are working.**

From the diagram you can see that node 7 can fail in the following situations:

1. Node 9 fails to deliver energy
   1. Node 9 fails OR
   2. Node 8 fails
2. Node 7 fails OR
3. Node 8 fails OR
4. Node 4 fails to supply energy
   1. Node 4 fails OR
   2. Node 4 fails to deliver energy
      1. Node 1 fails AND
      2. node 4 fails

Part 3.a

Minimal cutsets (specified as points in the previous slide):

- M1 -- 1.2 (or alternatively 3)
- M2 -- 1.1
- M3 -- 2
- M4 -- 4.1
- M5 -- 4.2.1 AND 4.2.2

Probabilities calculations:

- Failure probability for M2, M3 and M4 is computed as $1 - e^{-\lambda t}$ with t = 10 years
- Failure probability for the 2 generators if a landslide occurs is calculated as P(N1|L) * P(Y < 10) with N1 as G1 or G8 and P(Y<10) = 0.0956
- The probability for M5 is P(N1|L) * P(Y < 10) * probability of node failure (computed in the first bullet point)
- The final probability for the top event is M1 + M2 + M3 + M4 + M5

Part 3.b

In the part 3.b of the PDF you can find the Goal tree Success tree for the top event "*Consumers of node 7 are supplied with energy*".

From the diagram you can see that node 7, in order to supply energy to consumers, needs BOTH the following points to be true:

- (G1 **OR** N4) **AND** G8
- N4 **AND** N7 **AND** N9

Probabilities calculations:

- G1 **OR** N4 **AND** G8 = {{[1 – P(failure of G1)] + [1 - P(failure of N4)]} – {[1 – P(failure of G1)] * [1 - P(failure of N4)]}} * [1 – P(failure of G1)]
- N4 **AND** N7 **AND** N9 = [1 – P(failure of N4)] * [1 – P(failure of N7)] * [1 – P(failure of N9)]
- P(Top event) = Product of the 2 previous bullet points

* failure probabilities are the ones computed in the previous slide

Part 4

In the part 4 of the PDF you can find the Event tree with, as headings, valve failure, reservoir failure, pump failure and failure to supply energy to pump from node 7.

From the diagram you can see that:

- Valve **does not fail** with probability $1 – P_v$ → NO Overheating
- If Valve **fails**, then:
  - if Reservoir **does not fail** with probability $P_v * (1 – P_r)$ → NO Overheating
  - otherwise if Reservoir **fails**, then:
    - if Pump **fails** with probability $P_v * P_r * P_p$ → Overheating
    - otherwise if pump **does not fail**:
      - if energy to pump is **not supplied** with probability $Pv * P_r * (1 – P_p) * P_7$ → Overheating
      - otherwise if energy to pump **is supplied** with probability $Pv * P_r * (1 – P_p) * (1 - P_7)$ → NO Overheating

The final failure probability is given by the sum of the 2 overheating conditions probabilities = $1.0107*10^{-5}$

Part 5

In the part 5 of the PDF you can find the 4 Centralities for the node 4

- Degree centrality:

  It is divided into ingoing degree centrality and outgoing degree centrality just because the graph is directed. They are computed by counting the number of arcs (entering and going out from node 4) divided by N - 1.

- Closeness centrality:

  It is equal to 0 because at the denominator there is the sum of the distances from node 4 to all the other nodes. Since there are nodes to which node 4 is not connected, distance is equal to ∞ → $\frac{N-1}{\infty} = 0$

Part 5

- Betweenness centrality:

  It is computed by counting all the shortest paths from each node to every other node (except for node 4) which pass through node 4, divided by the total number of shortest paths between all the possibe couples of nodes. It is the normalized dividing by (N – 1) * (N – 2).

- Information centrality:

  It is computed by calculating the efficiency of the network with and without the node 4.
  In order to calculate the efficiency, there is the need to sum the inverse of the distances between all the couples of nodes. As in the previous cases, if two nodes are not reachable, efficiency is equal to 0

Thanks for your attention