Exercise session: Fault Trees and Event Trees

Course: Resilience and Security of Critical Infrastructures

Maria Valentina Clavijo Mesa

- Electrical pump
- Communication station
- Simple network system
- Power distribution system

- A computational tool useful for FTA

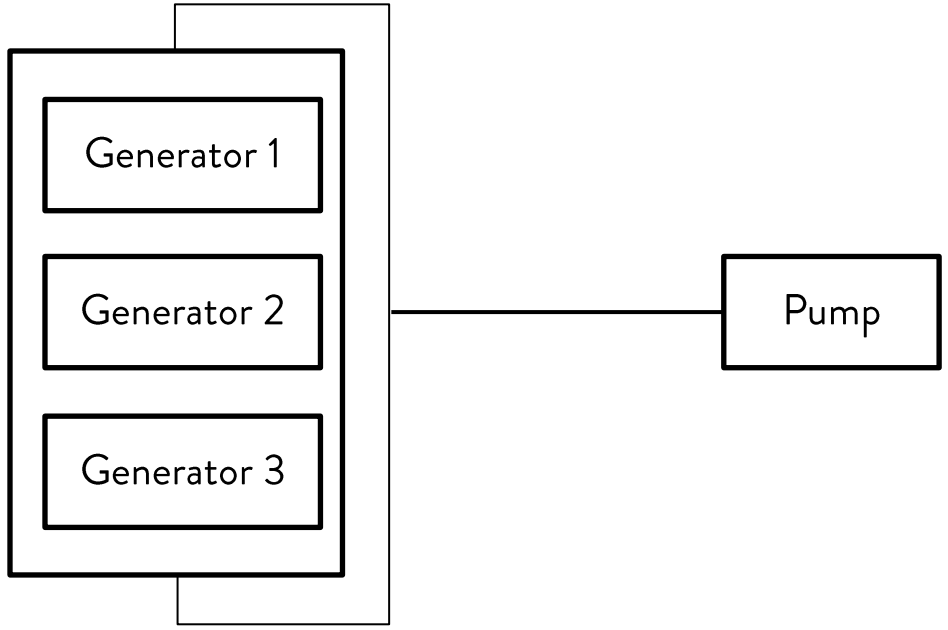
Electrical pump system

An electrical pump (P) is powered by a group of three electric generators (G). Due to the high-power demand of the pump, at least two of the generators must be in operation.

Design the ET to calculate the probability of system operation, following the structure in the header event table. Use the given reliability data for quantification:

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

P	G1	G2	G3



Communication station

A remote communication station requires continuous power to operate.
Under normal conditions, the station is powered by the external power grid. In the event of a grid failure, a control system is responsible for switching to two backup options: a *UPS* (uninterruptible power supply) and a *diesel generator*.

The *UPS* is an independent battery-based system capable of supplying power instantly. The *diesel generator* can also maintain power to the station but requires a functional *fuel pump* to operate.

The system is considered to have failed when power cannot be delivered to the station.

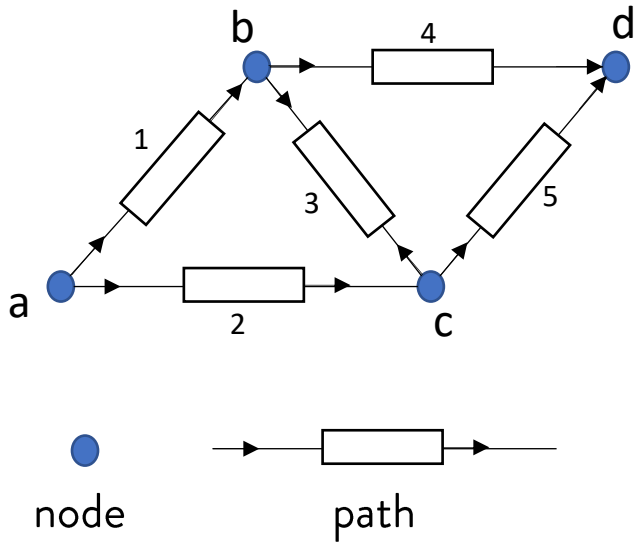
Assume that all component failures are independent and their time to failure follow exponential distribution (i.e., constant failure rate)

- Draw the FT for the top event: 'Loss of power supply to the station'
- Identify the minimal cut sets of the system
- Assume the values of the failure rates in the Table and compute the reliability of the system at 1500 hours

Component	Failure rate λ (failures/hour)
Power grid	2×10^{-5}
Generator	3×10^{-4}
Fuel pump	1×10^{-3}
UPS	5×10^{-4}
Control system	4×10^{-5}

Simple network system

Consider the following network system. All components have an equal failure rate of $\lambda = 10^{-4} days^{-1}$. The system fails when there is no connection between node a and node d.



3.A. Simple network system

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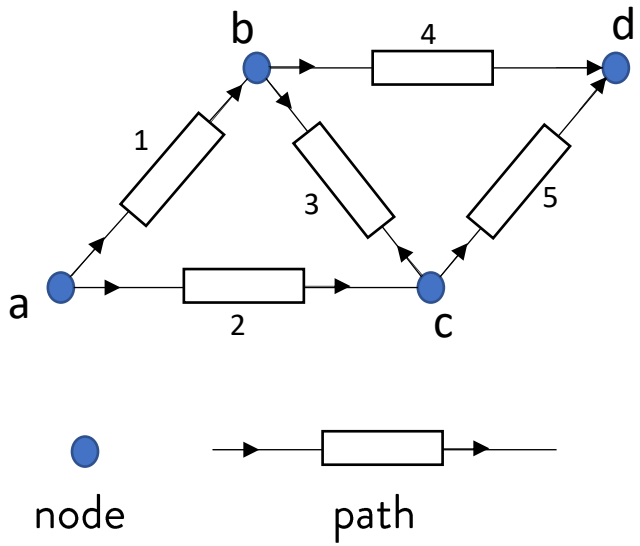
- Assuming the nodes are perfect (i.e., they cannot fail), develop a Fault Tree (FT) for the event *'No signal at D given a signal at A'*.
- Identify the *minimal cut-sets* of the network system.
- Evaluate *the system unreliability for a mission time of 1 year*.



3.B. Simple network system

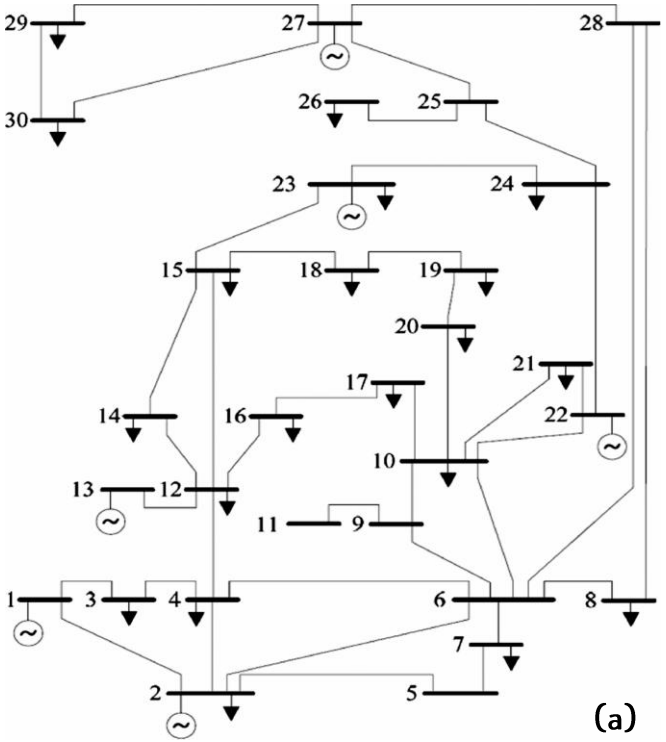
Exercise session: Fault Trees and Event Trees

- Assuming the nodes are perfect (i.e., they cannot fail), build *the ET to calculate the probability of network operation*, starting from an initiating event and following the given header events.

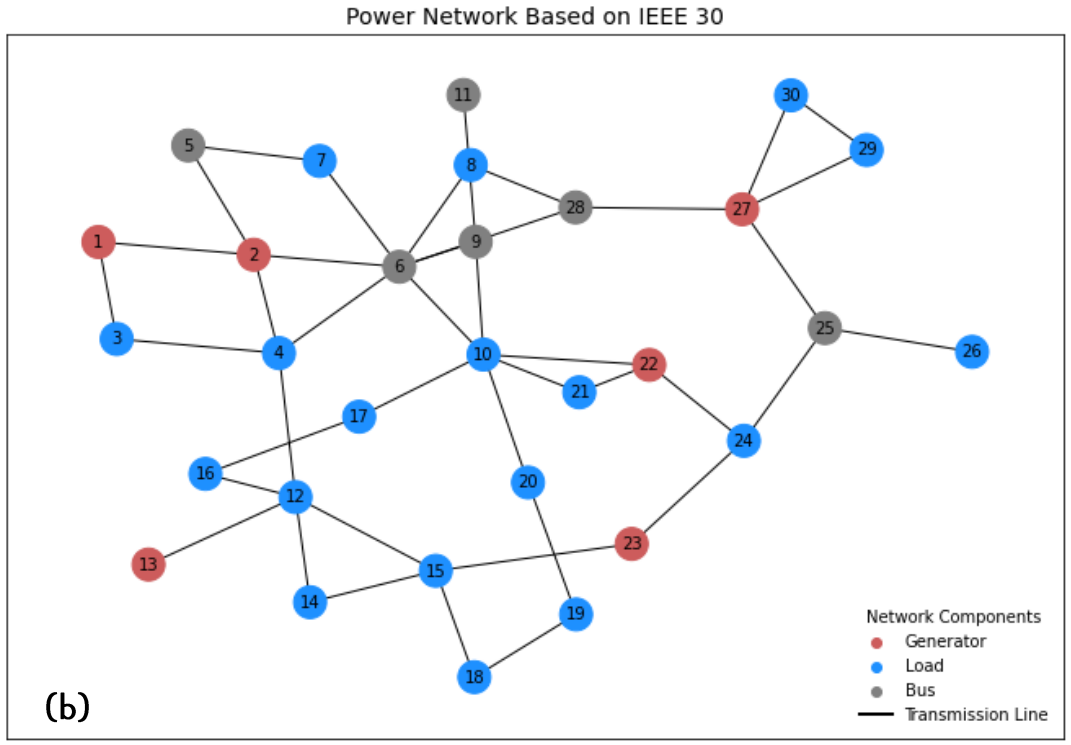
1	2	3	4	5

Power distribution system

The standard IEEE 30-bus power distribution system is shown in Figure (a). Only the major components are considered: 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)

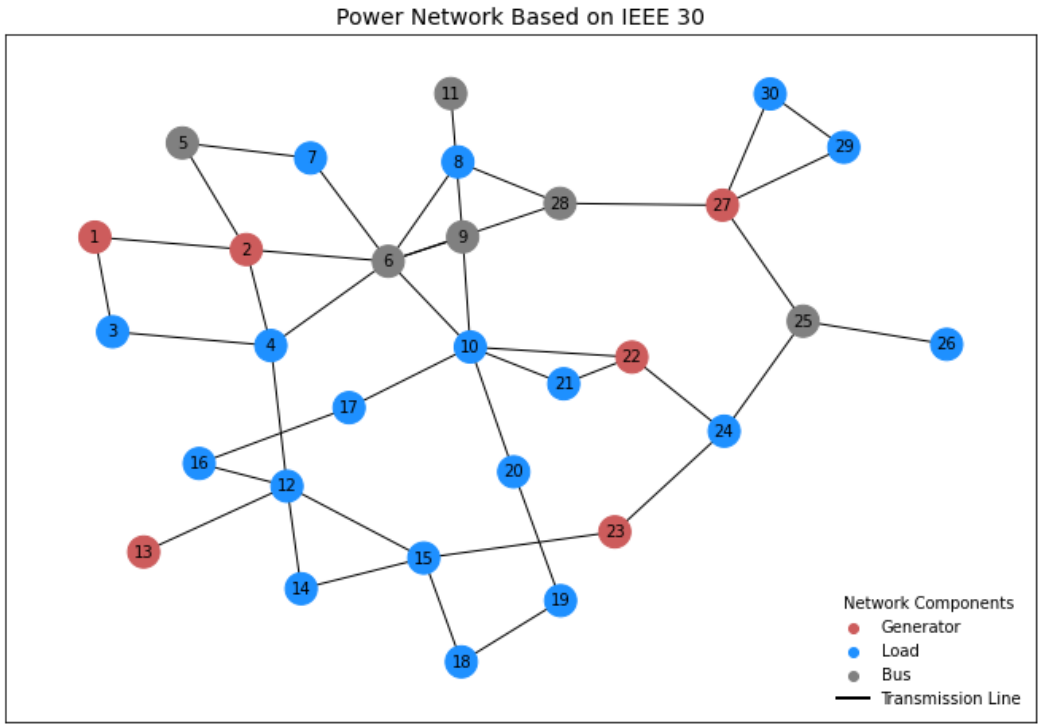


(a)

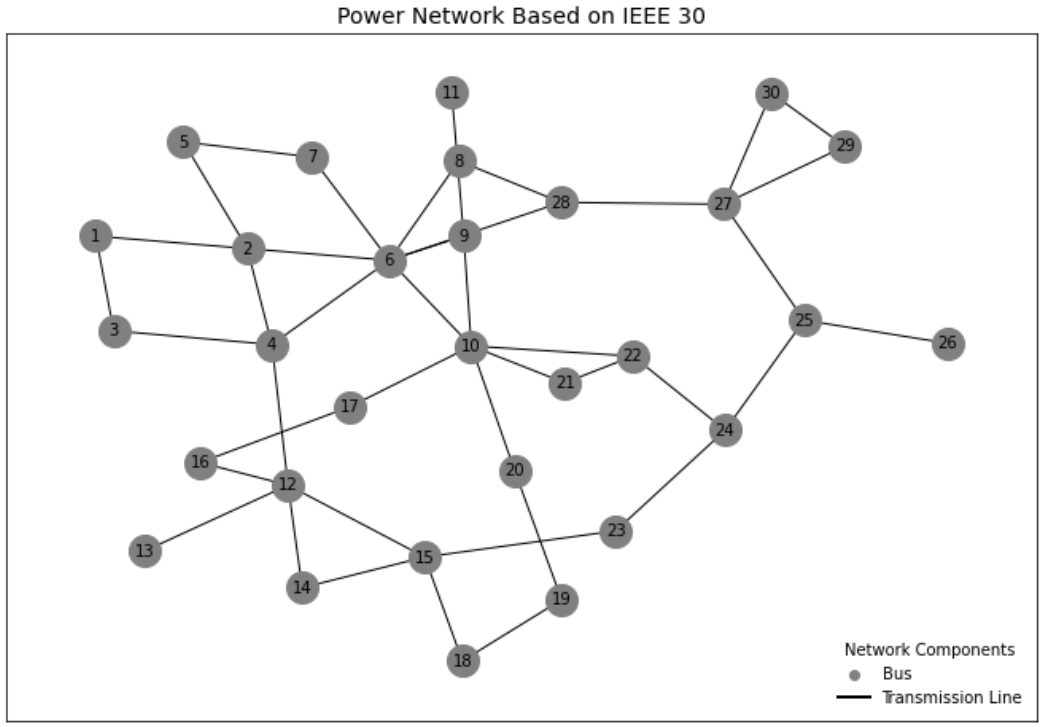


(b)

Power distribution system: IEEE 30-bus power distribution system



A load is a power consumer that does not fail but can be disconnected due to upstream failures



All nodes have buses that act as hubs where electrical power is either injected (from generators), withdrawn (by loads), or transferred across the network. If a bus fails, the corresponding node becomes inoperable

4.A. Power Distribution System

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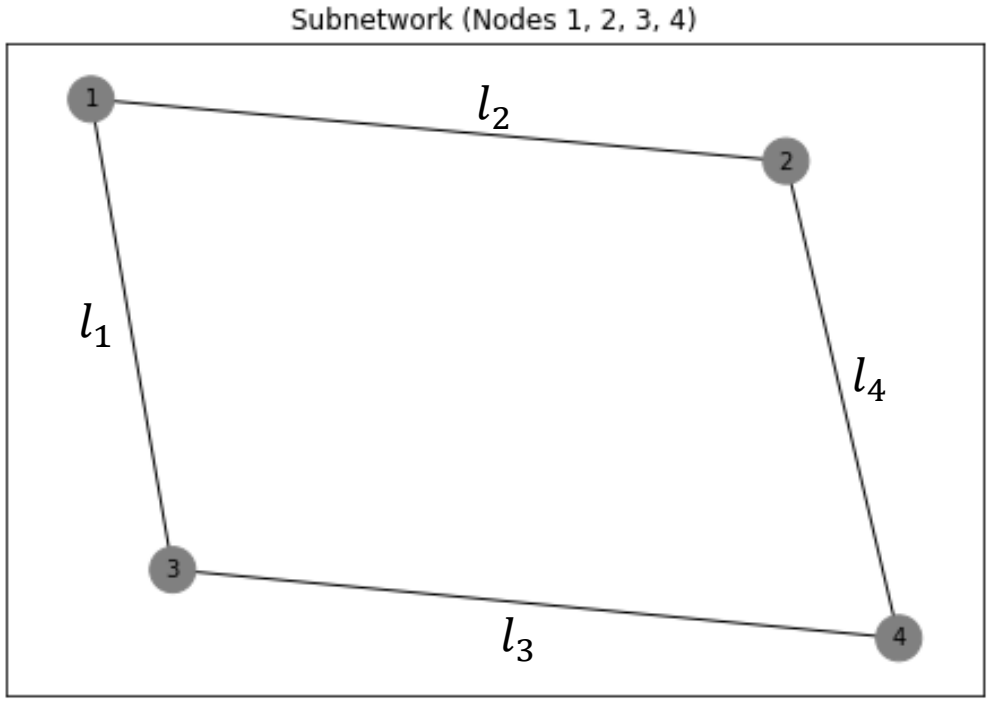
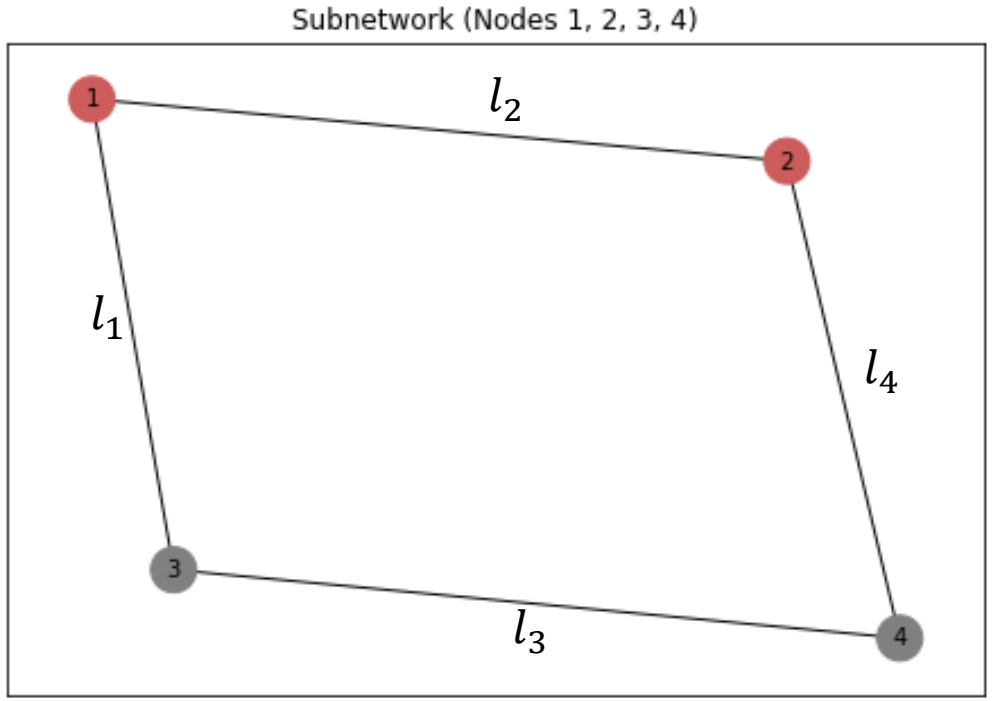
- Draw a FT for the failure of the system to *supply power to the load demand at Bus 4 (load 4).*
- Identify the *minimal cut-sets* and calculate the probability of the top event, assuming each element has a failure probability of 0.01





- Draw an ET for *the failure of the system to supply power to the load demand at bus 4 (load 4),* starting form an initiating event and following the given header events. Then, calculate the probability of network failure

G1	B1	L1	B3	L3	L2	G2	B2	L5	B4

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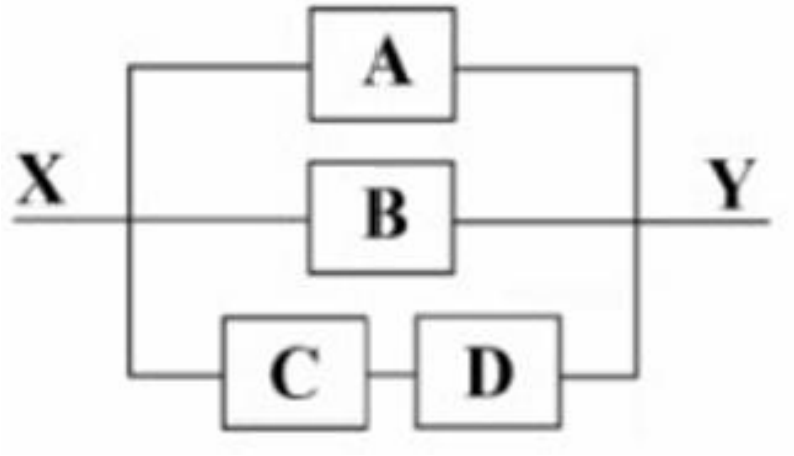

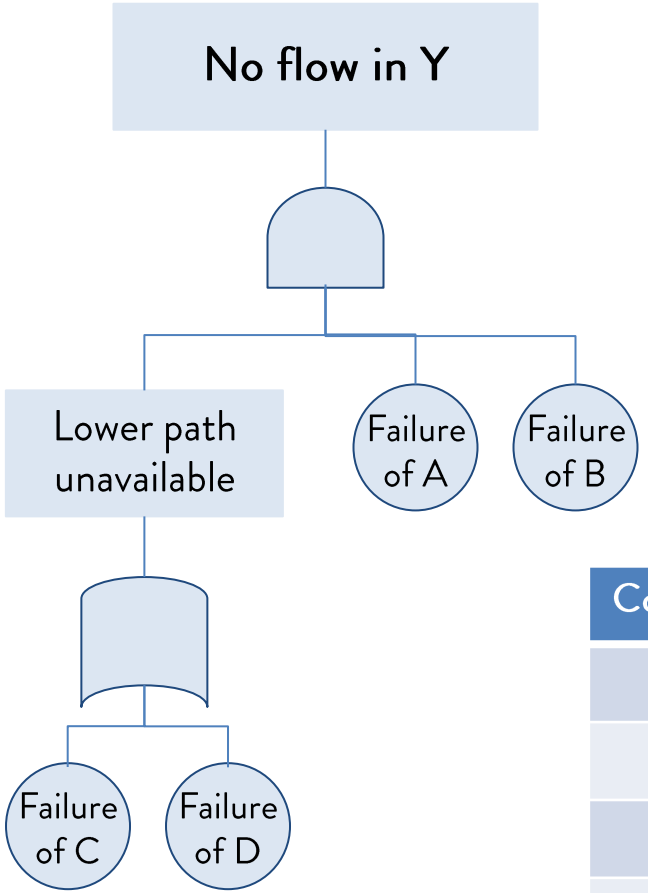

Component	Probability of failure
A	0.1
B	0.1
C	0.1
D	0.2

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```
# Install and load the FaultTree package
install.packages("FaultTree", repos="http://cran.us.r-project.org")
library(FaultTree)
```

Main functions in the FaultTree package

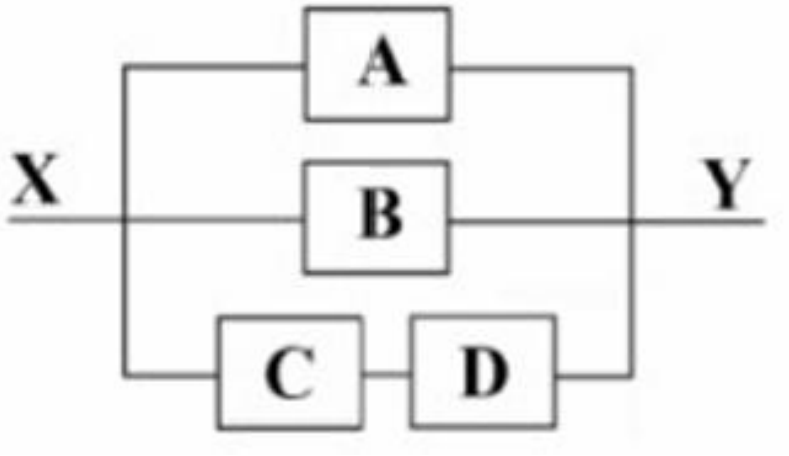
Function	Description
ftree.make()	Initializes a **new fault tree** with a **top event**
ftree.calc()	Performs **step-by-step calculations** from bottom to top
addLogic()	Introduces **intermediate events** that connect failure causes
addProbability()	Represents a **basic component failure** with an assigned probability
addDuplicate()	Used to **reuse events** without redefining them

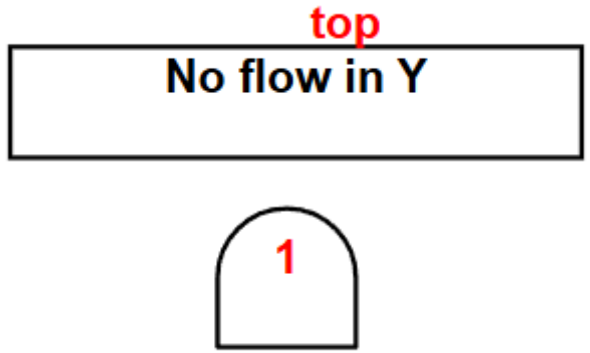
Install and load the FaultTree package

```
install.packages("FaultTree", repos="http://cran.us.r-project.org")
library(FaultTree)
```

Create the Fault Tree

```
system <- ftree.make(type="and", name="No flow in Y")
```

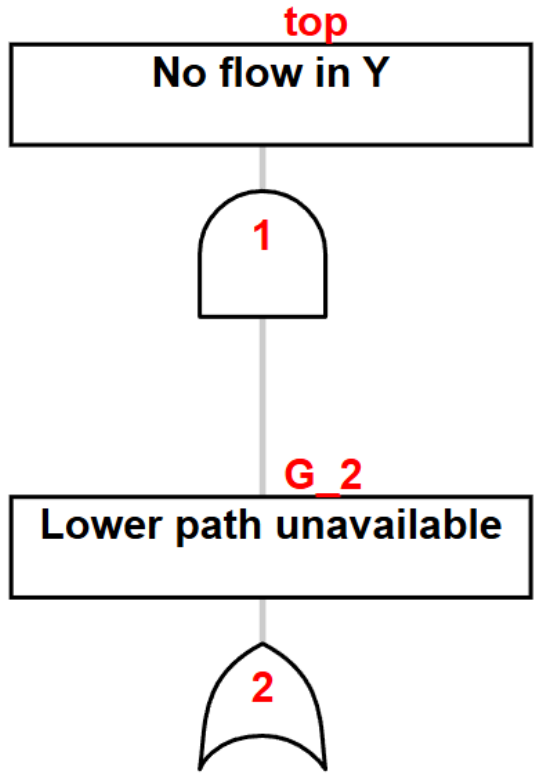




Visualize the FT

```
ftree2html(system, write_file = TRUE)
browseURL("system.html")
```

```
# Add a logical OR gate for path failure
system <- addLogic(system, at=1, type="or", name="Lower path unavailable")
```

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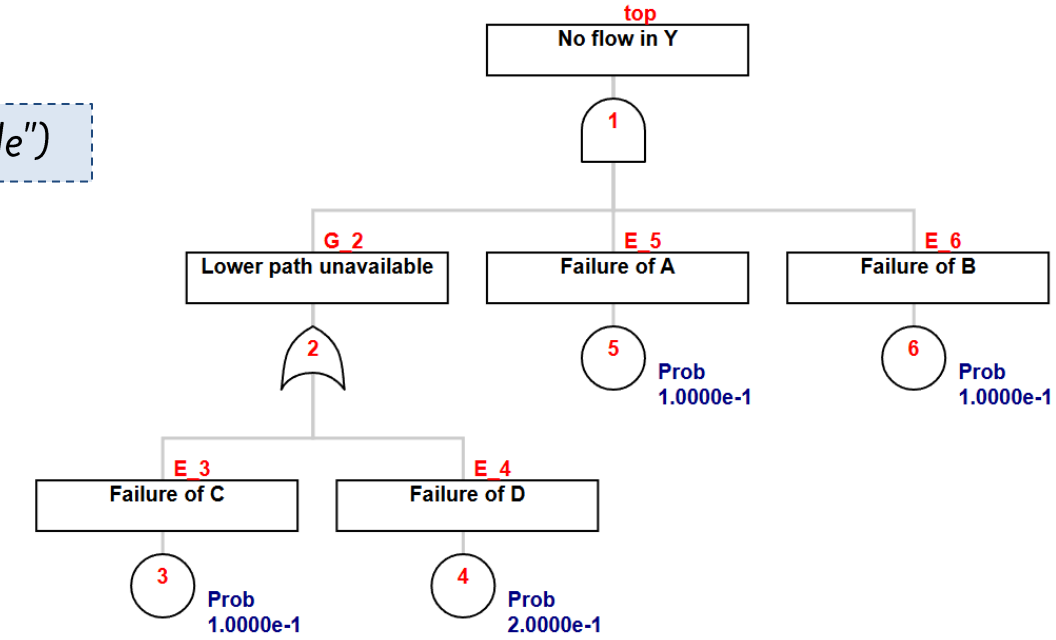
 # Add a logical OR gate for path failure

```
system <- addLogic(system, at=1, type="or", name="Lower path unavailable")
```

 # Add basic failure probabilities

```
system <- addProbability(system, at=2, prob=0.1, name="Failure of C")
system <- addProbability(system, at=2, prob=0.2, name="Failure of D")
system <- addProbability(system, at=1, prob=0.1, name="Failure of A")
system <- addProbability(system, at=1, prob=0.1, name="Failure of B")
```



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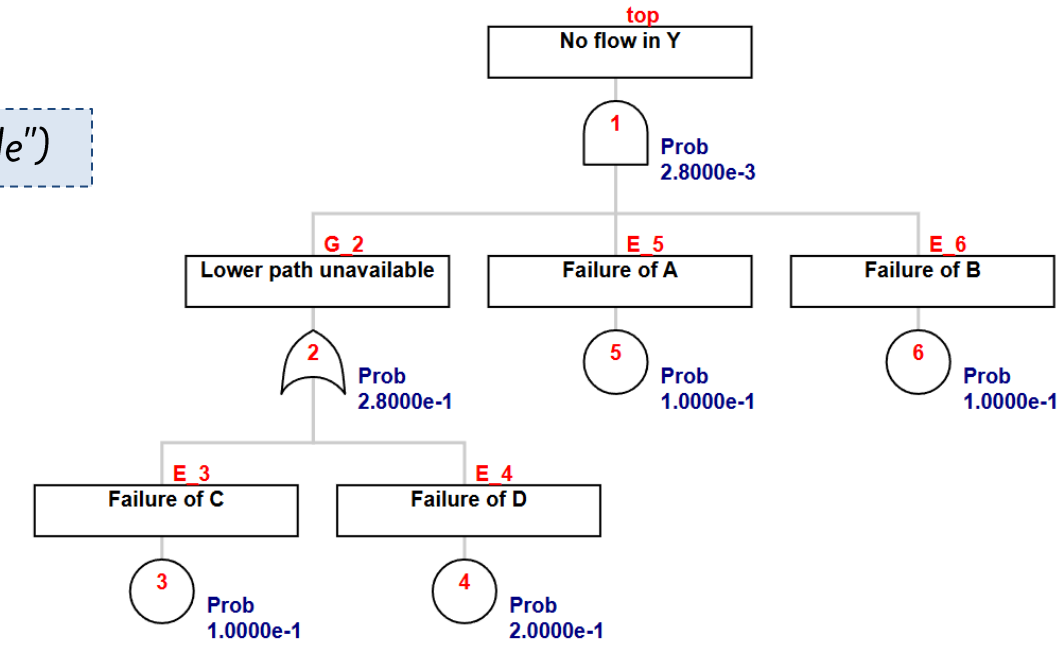
system <- addProbability(system, at=2, prob=0.2, name="Failure of D")
system <- addProbability(system, at=1, prob=0.1, name="Failure of A")
system <- addProbability(system, at=1, prob=0.1, name="Failure of B")
```

 # Compute fault tree probabilities

```
system <- ftree.calc(system)
```



Visualize the FT

```
ftree2html(system, write_file = TRUE)
browseURL("system.html")
```

THANKS

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