Estimating the Initiating Event Frequency by Monte Carlo Simulation

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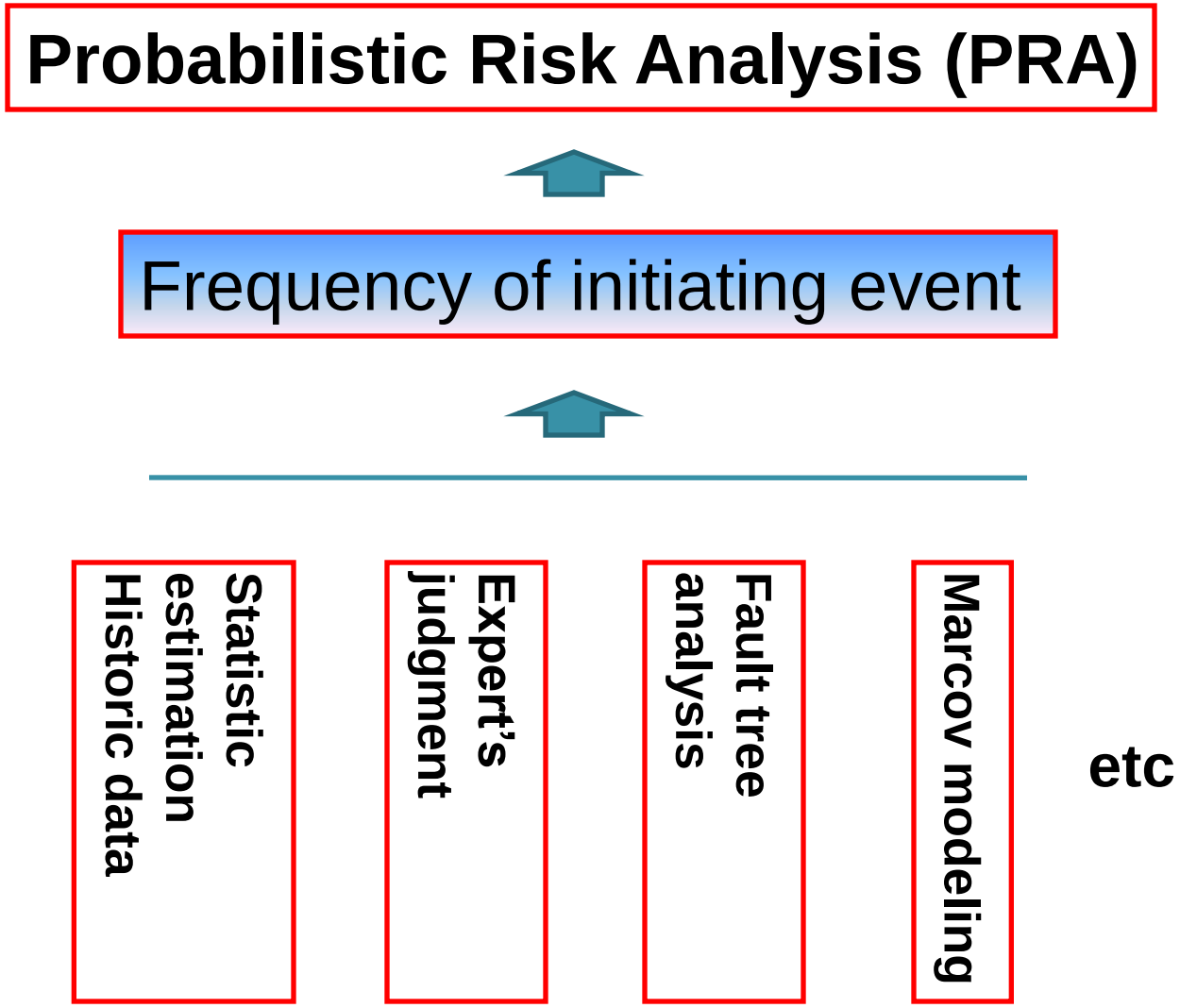
Outline

1. Background
2. Proposed method of MC Simulation
3. An example of MC simulation
4. Remarks

1. Background (1)



1. Background (2)

Specific system composed with redundant trains

- Statistic estimation:

  no enough historic events

- Experts judgment or the mechanism analysis:

  a coarse way but not a perfect choice

- Fault Tree analysis:

  has difficulty to deal with dynamic system

- Marcov modeling:

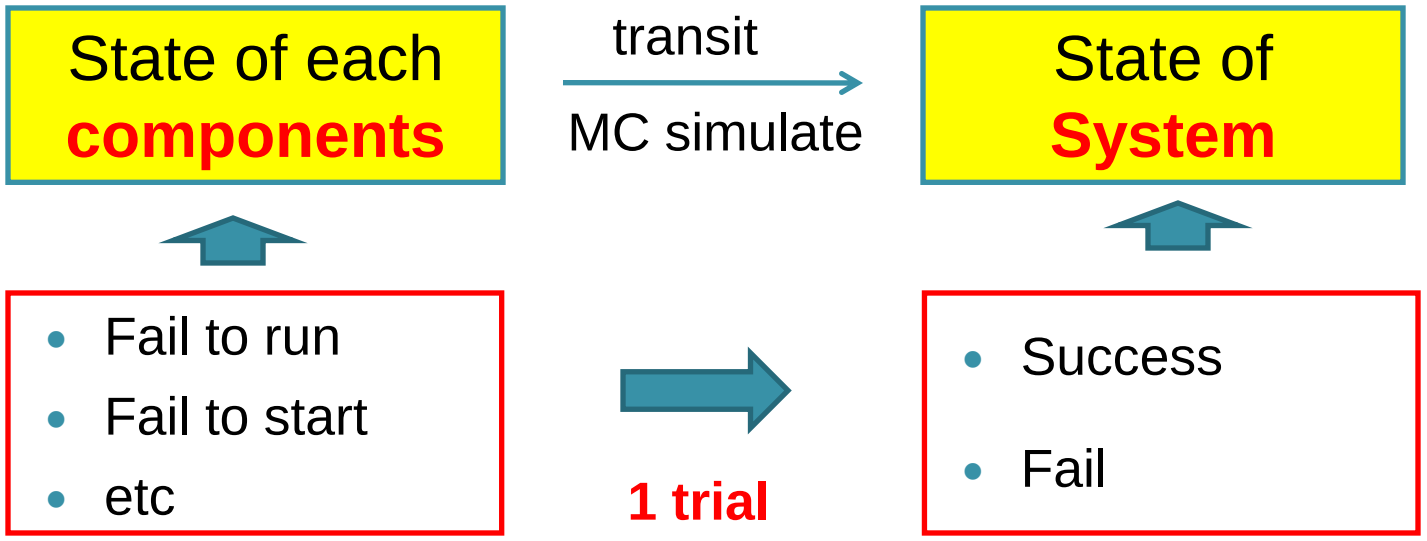
  the number of the redundant trains can hardly exceed three

2. Proposed method of MC Simulation

Monte Carlo Simulation:

- simulating the system evolution by simulating the **transition** between different system states.
- collecting the information of interest from a relatively large number of simulation trials.

2. 1 Overview

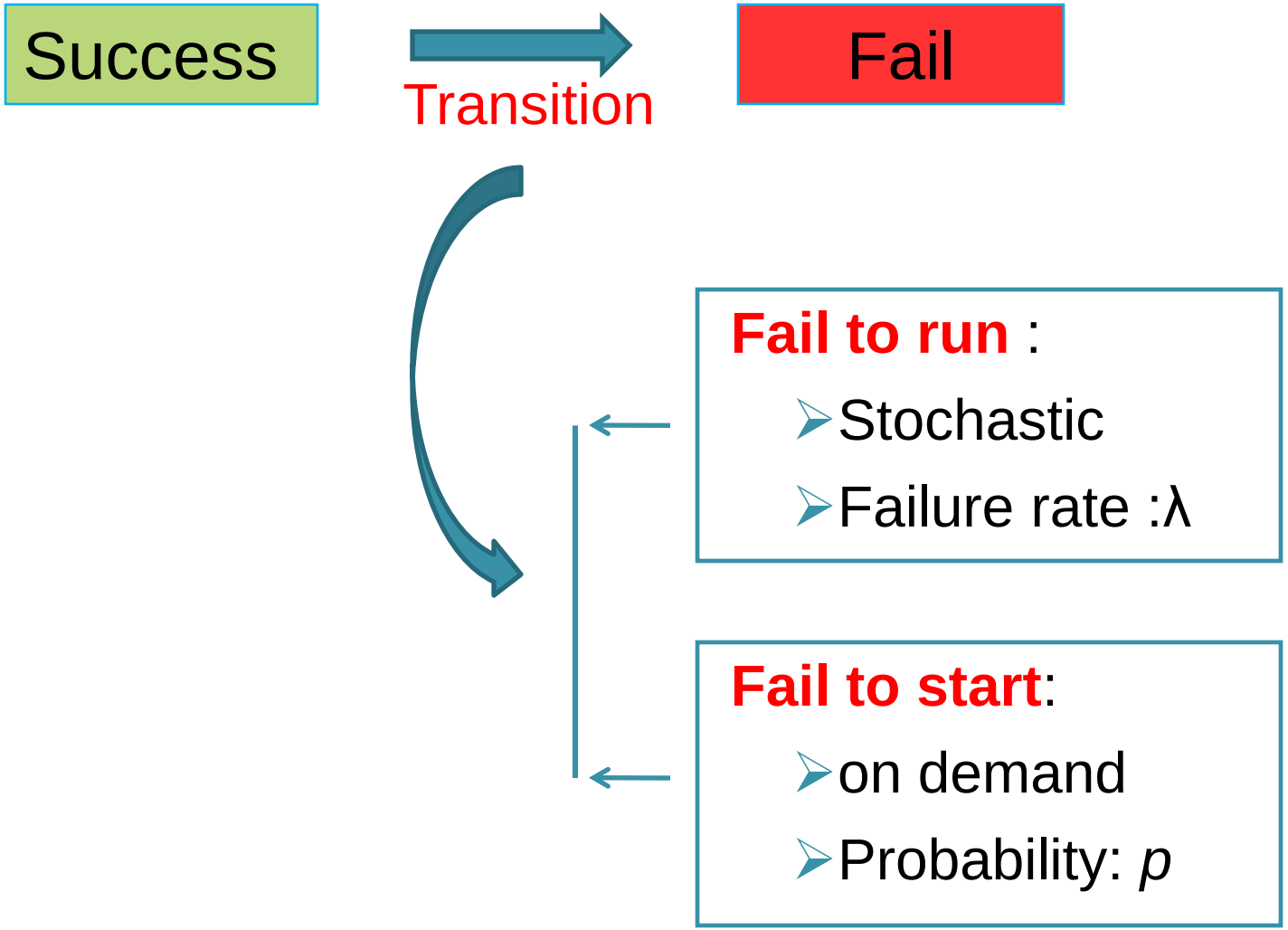


annual

The **frequency** of system failure

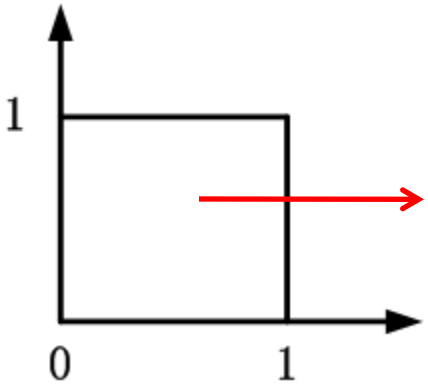
$$= \frac{\text{No. of failed trials}}{\text{No. of all trials}}$$

2.2 transition of component (1)



2.2 transition of component (2)

- **For stochastic transition**

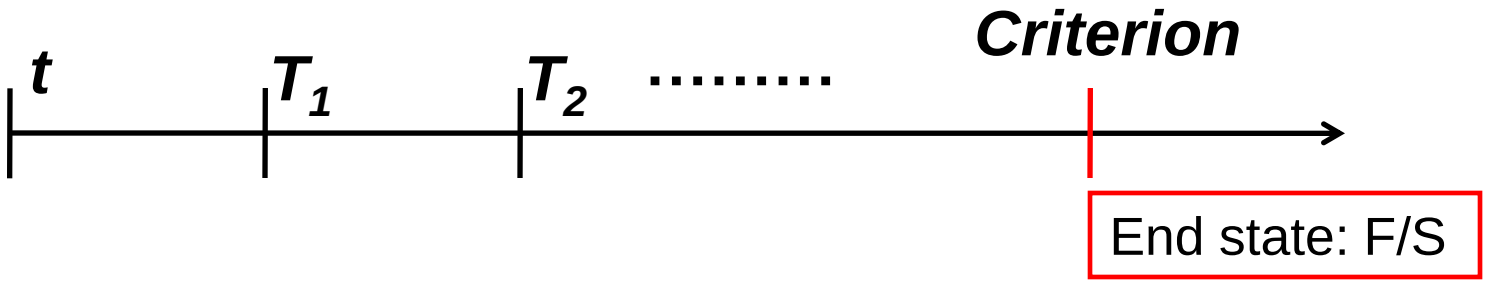


U ⟶ R(t)

$$R = e^{-\lambda \cdot \Delta t}$$

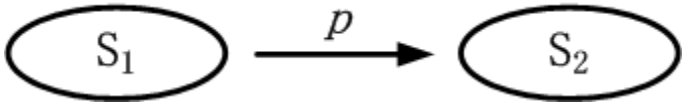
$$T = t + R^{-1}(U)$$

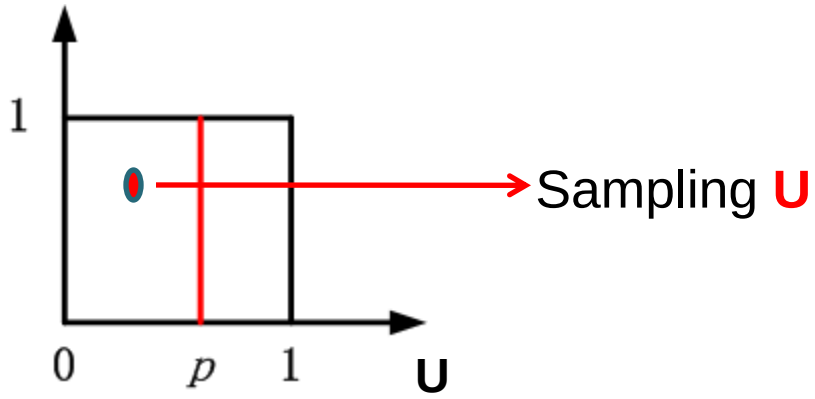
t -- the current time;
T-- the time of transition



2.2 transition of component (3)

- **For transition on demand**





- U ⟶ ***p***
- U<*p* component fails to start;
- U>*p* component start successfully.

3. An example of MC simulation

3.1 System description

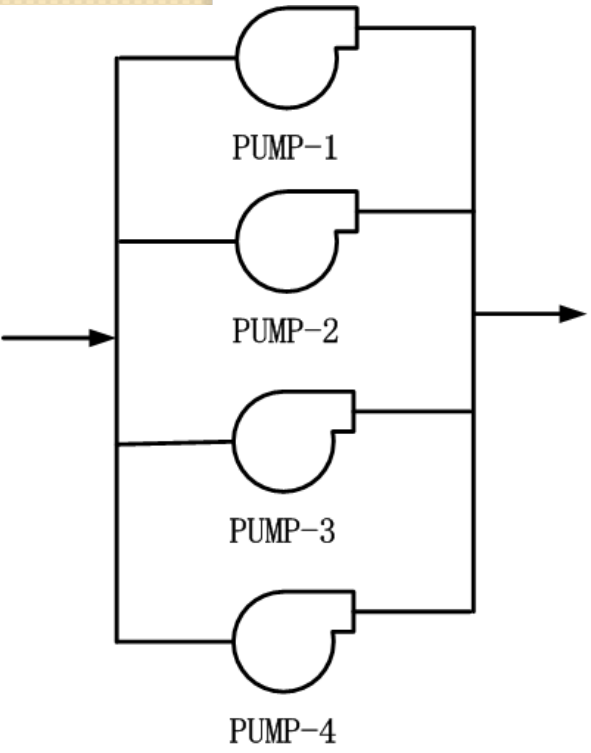
3.2 Transition modes need simulation

3.3 Treatment of CCF

3.4 Result

3. 1 System Description (1)

A simplified seawater system



- 4 trains (each train 100% capacity), One pump run, others standby;
- The Routine switch happens once a quarter, the switching order: 1-2-3-4-1.
- Switching is automatically.
- The repair action for failed pump consider human error.

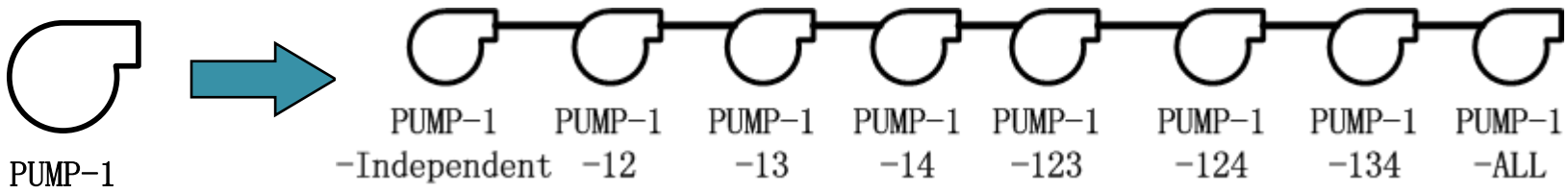
3. 2 Need to simulate

- fail to start: *(sampling directly)*
  - Pump independent failure
  - Pump CCF failure (2-CCF/3-CCF/ALL-CCF)
- fail to run: $R = e^{-\lambda \cdot \Delta t}$
  - Pump independent failure
  - Pump CCF failure (2-CCF/3-CCF/ALL-CCF)
- Repair: $R = e^{-\mu \cdot \Delta t}$
- Human error: *(sampling directly)*

3.3 Treatment of CCF

Treat one pump as a series of independent part, and CCF parts.

Example: for PUMP-1



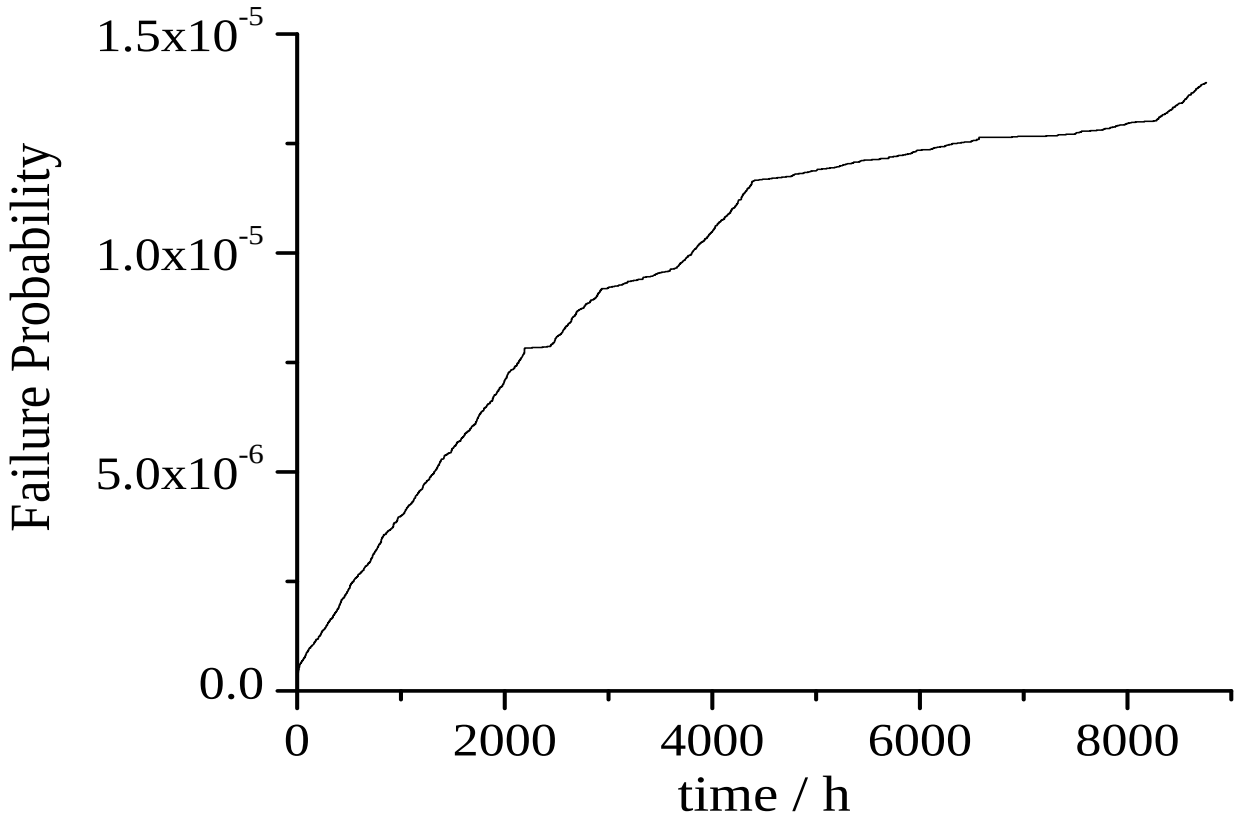
8 parts

3.4 Result (1)

- Assumption:
  - Fail to start: p=2.4E-5
  - Fail to run: λ=5.8E-6/h
  - Repair rate: μ=0.1/h;
  - CCF: MGL model
  - HFE: 0.01～0.5
- **Ending criterion of one trial:**
  - Mission time of a trial:8760hrs (ie.1 year)
  - When the system fails (all pumps fail), trial is end.

3.4 Result (2)

- No. of trials: 3.0E+6
- The frequency of system failure is about :1.4E-5/y



4.Remarks

- MC simulation can well simulate the behavior of dynamic system and provide insight information of system's operation.
- MC simulation has outstanding performance in initiating event frequency assessment.
- there is no generic software tool to provide a platform to model different systems easily . Analysts need to code from the very beginning in different applications.

Thank you for your attention

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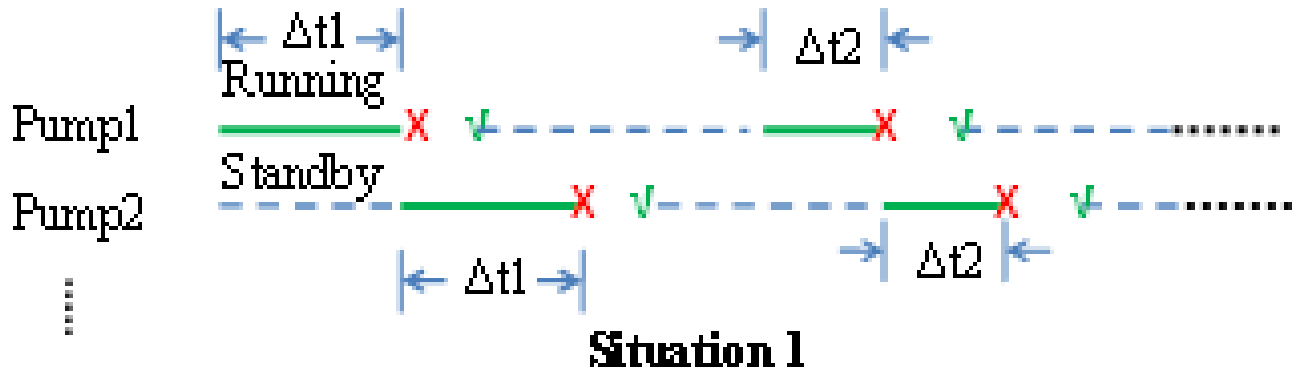
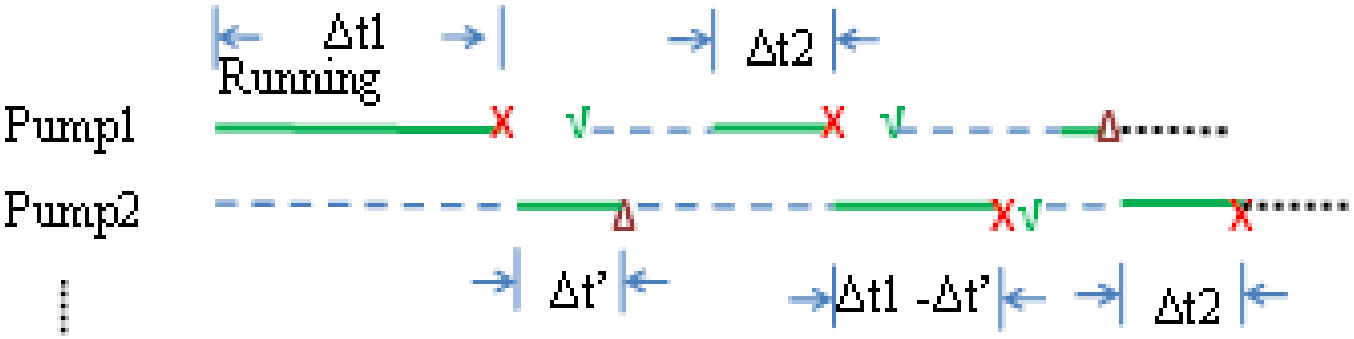


Situation 1



Situation 2

Running state
standby state
X Common Cause Failure
√ Repair back to normal
Δ switch off by other reasons
.... ellipsis