Diagnostic Methods

Model Based Diagnostic Methods part 1

Outline

- Introduction
- Model based diagnostic methods
- Fault tree (FT)
  - Construction
  - Basic elements
  - Strengths
  - Case study

Introduction

- Diagnosis is a complex reasoning activity, which is currently one of the domains where Artificial Intelligence techniques have been successfully applied.
- A variety of fault detection and diagnosis techniques have been developed for the diagnostic problem solving process.
- These techniques include model based approaches and model free approaches.

Model based diagnostic methods

- In model-based fault detection, a model (mathematical or heuristic) is employed to describe the nominal behaviour of a specific system.
- Fault diagnosis passes through three phases:
  - Fault detection: Detect malfunctions in real time, as soon and as surely as possible.
  - Fault isolation: Find the root cause, by isolating the system component(s) whose operation mode is not nominal.
  - Fault identification: to estimate the size and type or nature of the fault.

Fault Tree (FT)

- **Fault tree** is a graphical tool to explore the causes of system level failures.
- It uses boolean logic to combine a series of lower level events and it is basically a top-down approach to identify the component level failures (basic event) that cause the system.

Fault Tree (FT)

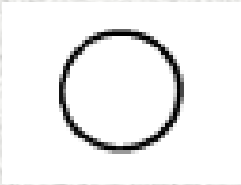
- The fault tree itself is a graphic model of the various parallel and sequential combinations of faults that will result in the occurrence of the predefined undesired event.
- The faults can be events that are associated with component hardware failures, human errors, or any other events which can lead to the undesired event.
- A fault tree thus depicts the logical interrelationships of basic events that lead to the undesired event-which is the top event of the fault tree.

FT Construction

- Define the system. This includes defining what is considered a failure.
- Define top-level faults.
- Identify causes for top-level **fault.**
- Identify next level of events.
- Identify root causes.

FT Basic Elements

- **Primary events**: The primary events of a fault tree are those events, which, for one reason or another, have not been further developed.
- There are four types of primary events. We focus on:
  - The Basic Event: A basic initiating fault requiring no further development.



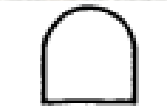
FT Basic Elements

- Undeveloped event: An event which is not further developed either because it is of insufficient consequence or because information is unavailable.

- **Intermediate event:** A fault event that occurs because of one or more antecedent causes acting through logic gates.

FT Basic Elements

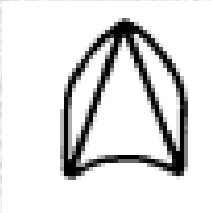
- **Gates,** we focus on:
  - AND: Output fault occurs if all of the input faults occur.



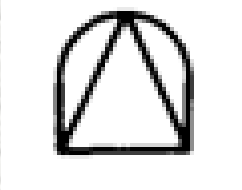
  - OR: Output fault occurs if at least one of the input faults occurs.

FT Basic Elements

- EXCLUSIVE OR: Output fault occurs if exactly one of the input faults occurs.

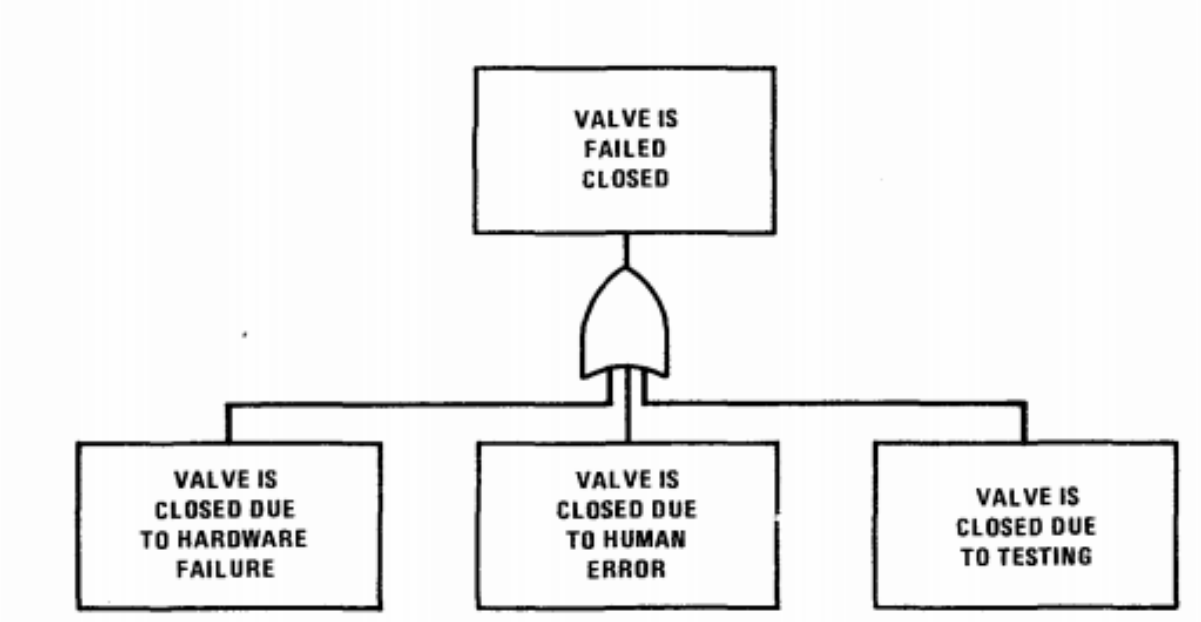


- PRIORITY AND: Output fault occurs if all of the input faults occur in a specific sequence.



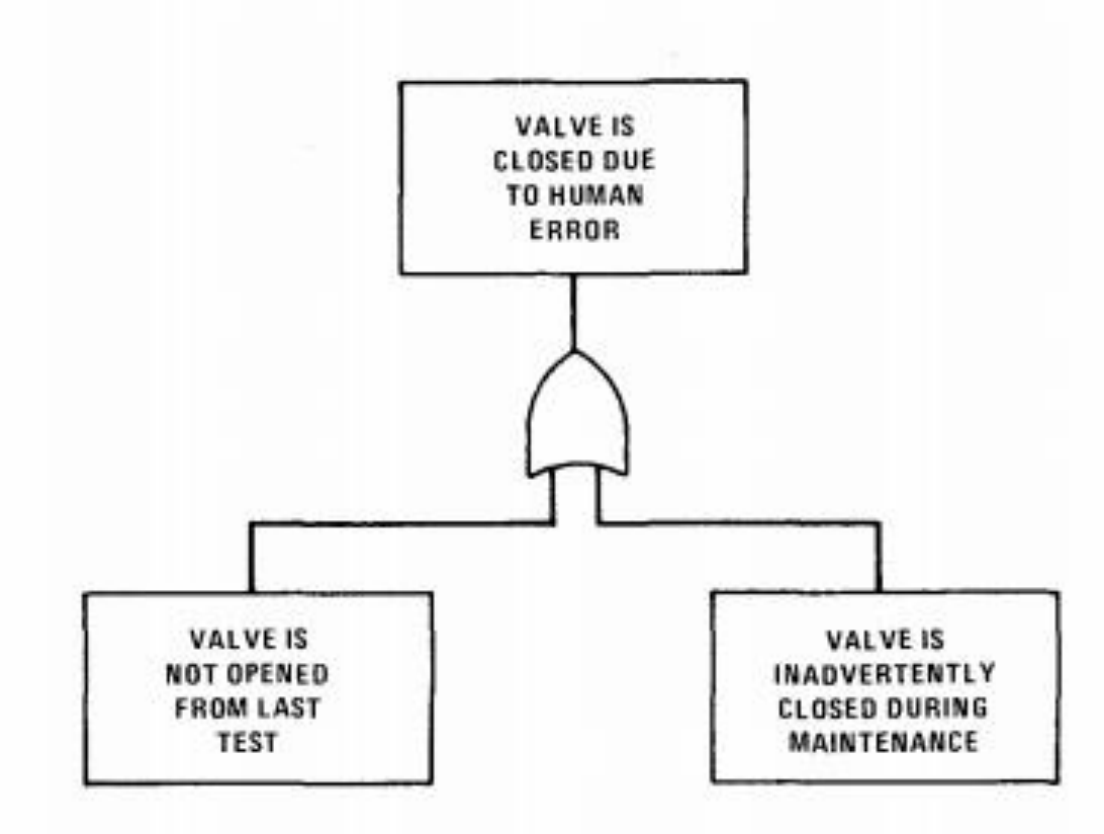
FT Basic Elements

- Specific Example of the OR-Gate:



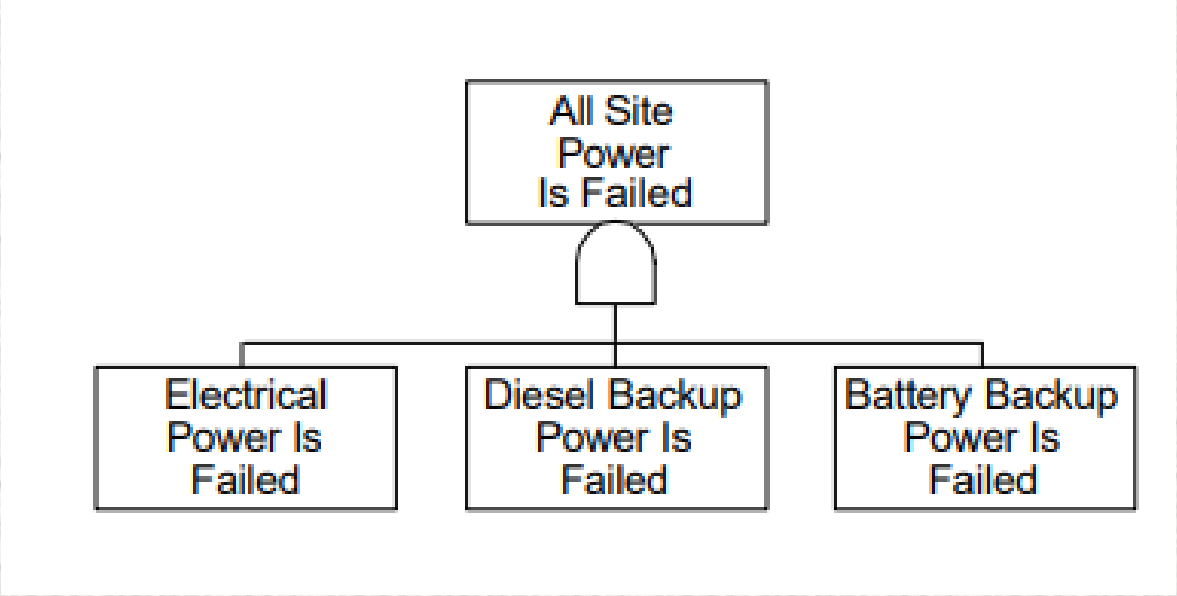
FT Basic Elements

- OR-Gate for Human Error:



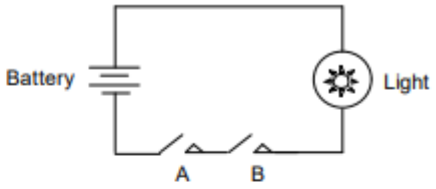
FT Basic Elements

- An example of AND gate:



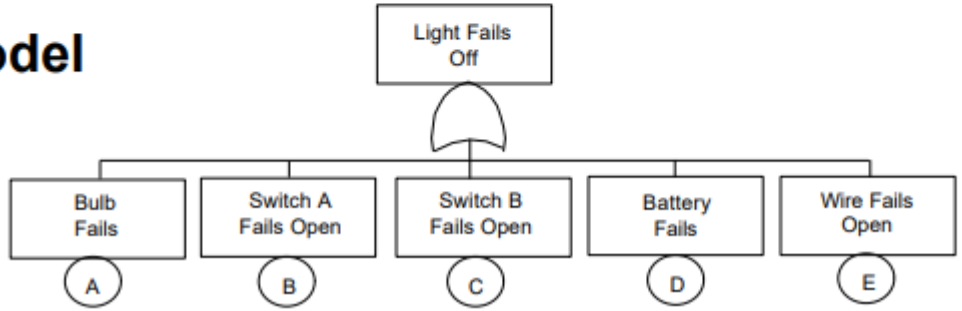
FT Basic Elements

System



System Undesired Event: *Light Fails Off*

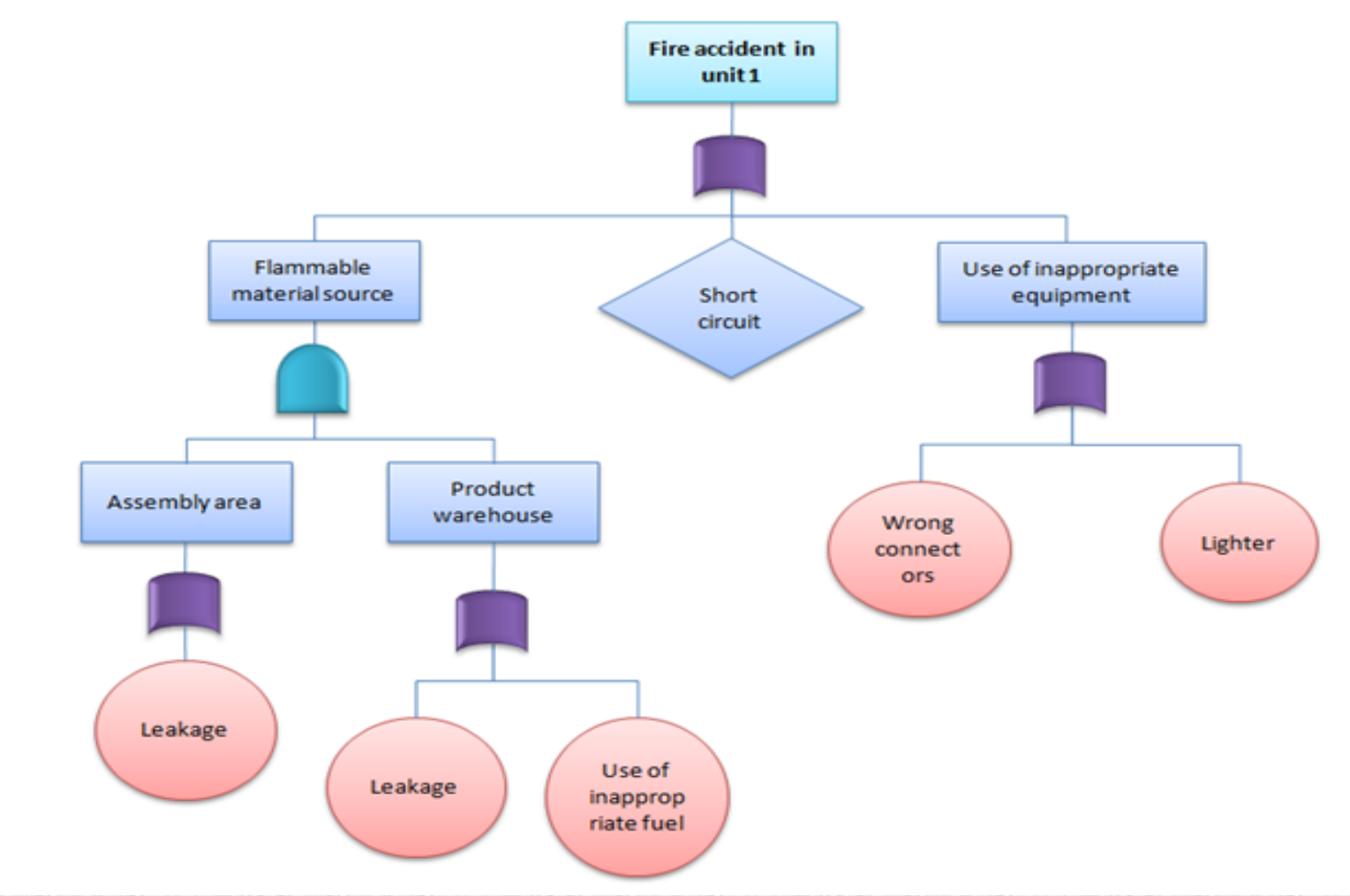
FT Model



FT Strengths

- Visual model: cause/ effect relationships.
- Easy to learn, do and follow.
- Models complex system relationships in an understandable manner.
- Combines hardware, software, environment and human interaction.

Case Study 1


Fire accident in unit 1
Flammable material source
Short circuit
Use of inappropriate equipment
Assembly area
Product warehouse
Wrong connect ors
Lighter
Leakage
Leakage
Use of inapprop riate fuel

Case Study 2

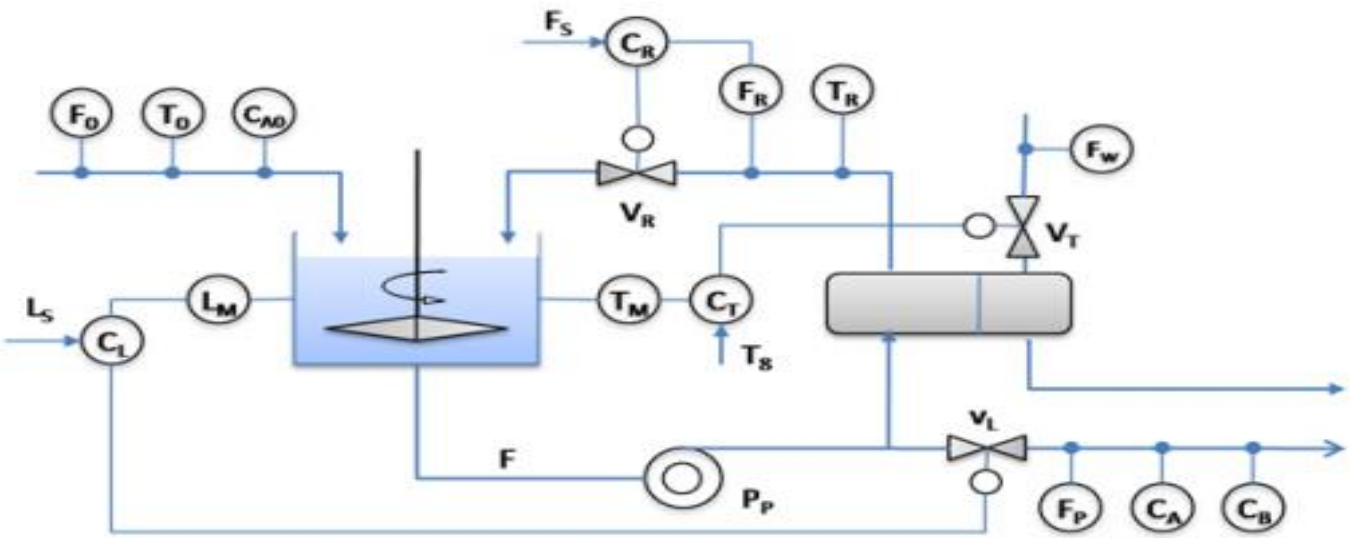
- This example is part of a Master thesis.
- It is related to a diagnostic system in a dairy.
- The studied process Is composed of the following elements:
  - Reactor.
  - Heat exchanger.
- The temperature in the reactor is set at a constant value through a preheated liquid in the heat exchanger where another cooling liquid lowers the temperature of the liquid leaving the reactor.

Case Study 2

- The flow of this liquid is controlled using a controller and a valve in addition to another controller is used to stabilize the level of liquid in the reactor.

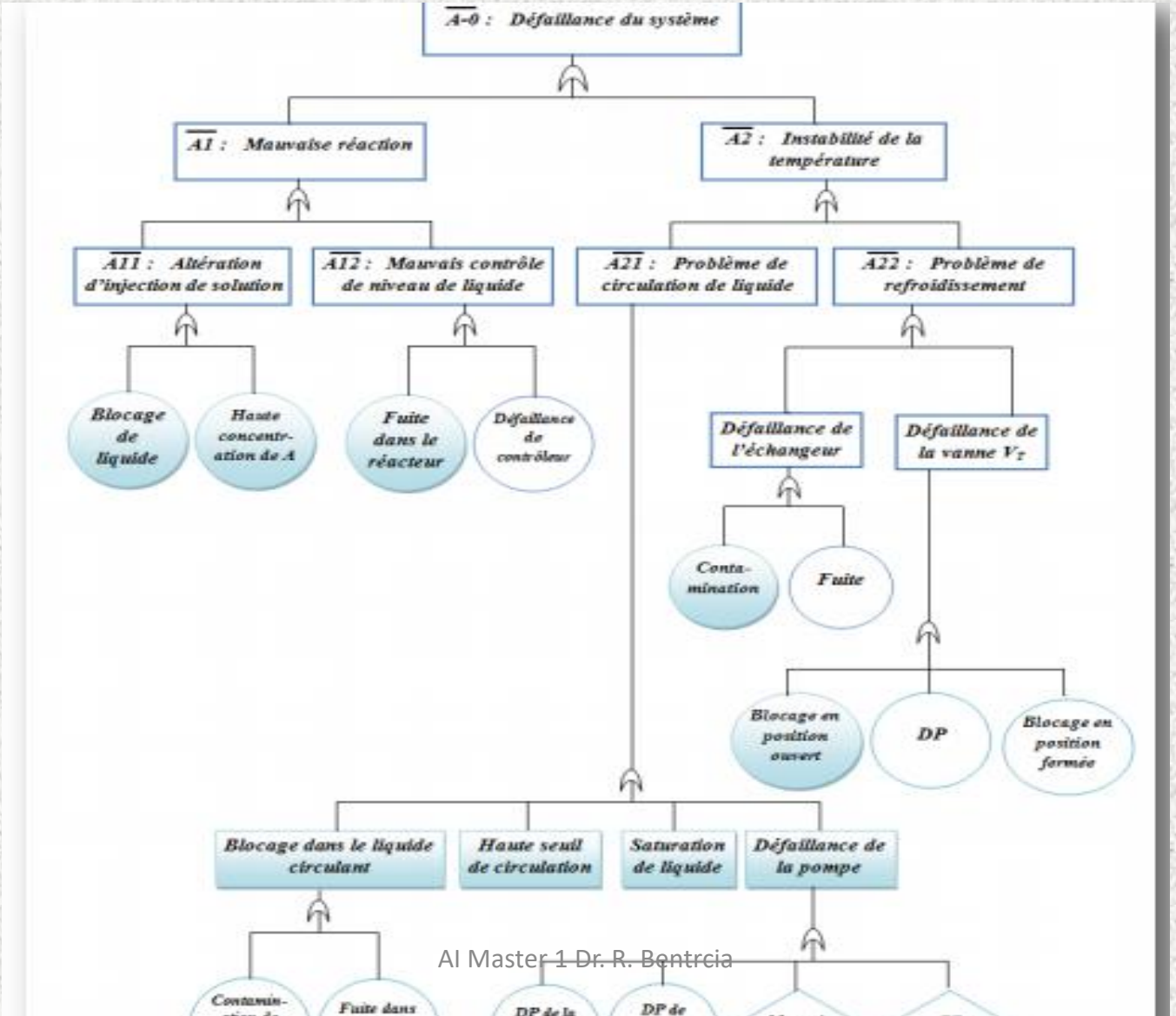
Case Study 2

- Industrial process with reactor and heat exchanger



F_0 : Liquide entrant au réacteur.
T_0 : Température du liquide entrant au réacteur.
C_{A0} : Concentration de la substance A dans le liquide d'entrée.
L_M : Niveau du liquide dans le réacteur.
T_M : Température du réacteur.
F_P : Liquide sortant du processus.
C_A : Concentration de la substance A dans le liquide sortant.
C_B : Concentration de la substance B dans le liquide sortant.
F_W : Liquide refroidissant dans l'échangeur de chaleur
F_R : Liquide circulant.
T_R : Température du liquide circulant.
C_R : Sortie du contrôleur de circulation.
C_L : Sortie du contrôleur de niveau.
C_T : Sortie du contrôleur de température du réacteur

Case Study 2


A-0 : Défaillance du système
A1 : Mauvaise réaction
A2 : Instabilité de la température
A11 : Altération d'injection de solution
A12 : Mauvais contrôle de niveau de liquide
A21 : Problème de circulation de liquide
A22 : Problème de refroidissement
Blocage de liquide
Haute concentr-ation de A
Fuite dans le réacteur
Défaillance de contrôleur
Défaillance de l'échangeur
Défaillance de la vanne V_T
Conta-mination
Fuite
Blocage en position ouvert
DP
Blocage en position fermée
Blocage dans le liquide circulant
Haute seuil de circulation
Saturation de liquide
Défaillance de la pompe