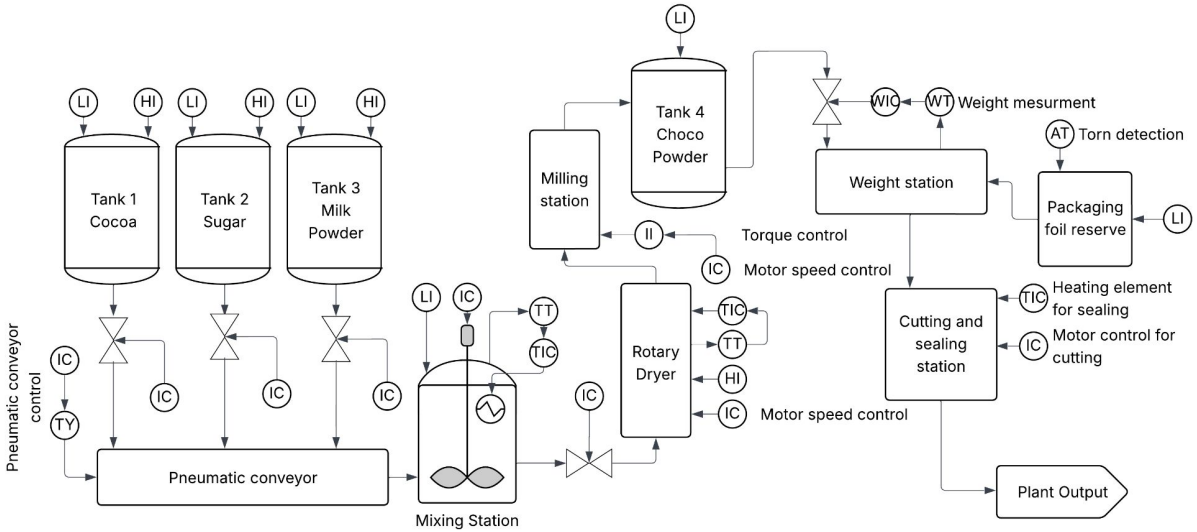
ChocoMation Automation

Emanuel, Florian,
Marko, Muratcan

Functional Analysis

Plant Overview



1. Raw Material Handling

- Assumptions: Large vertical tanks, drained from valve at bottom
- Input Signals
  - 3x Level measurement (**SITRANS LR100**, 4...20mA, distance in cm)
  - 3x Humidity sensor (**QFM2101**, 4...20mA, % of saturation)
- Output Signals:
  - 3x Material outlet (**SIPART PS2**, 4...20mA, valve in % of opening)
  - Pneumatic Conveyor (**Elmo Rietschle G-BH1 2BH1** + **SIRIUS 3RF2 relais**, on/off
- Alarms:
  - Material below threshold (Operations Warning)
  - Humidity above threshold (Quality Warning)
- Interlocks:
  - Fire/E-Stop triggered: Valves close up

2. Mixing Station

- Assumptions: Vat is fed from the top using pneumatic conveyors, and drained from valve at the bottom
- Input Signals
  - Level measurement (**SITRANS LR100**, 4...20mA, distance in cm)
  - Temperature measurement (**SITRANS TS500**, 4...20mA, temperature in C°)
- Output Signals
  - Motor speed/torque (**SINAMICS S120** + **SIMOTICS T-1FW3**, 4...20mA, PROFINET, RPM+NM)
  - Heating element (**SIRIUS 3RF2 relais**, duty cycle in %)
  - Material outlet (**SIPART PS2**, 4...20mA, valve in % of opening)
- Alarms:
  - Material above threshold (Operations Warning)
  - Temperature above quality threshold (Quality Warning)
- Interlocks:
  - Temperature above safety threshold: E-Stop triggered, Heater forced off
  - Fire/E-Stop triggered: Heater and Mixer forced off, Valve closes up

3. Drying and Milling

- Assumptions: Open ended drying drum, directly feeding into milling machine
- Input Signals:
  - Temperature measurement (**SITRANS TS500**, 4...20mA, temperature in C°)
  - Humidity sensor (**QFM2101**, 4...20mA, % of saturation)
  - Torque sensor on milling gear shaft (**Kistler 4503B**, 4...20mA, NM)
- Output Signals:
  - 2x rotation speed (drying drum and milling gears, **SINAMICS S120** + **SIMOTICS T-1FW3**, 4...20mA, PROFINET, RPM+NM)
  - Temperature (hot air dryer, **SIRIUS 3RF2 relais**, duty cycle in %)
- Alarms:
  - Milling gears get stuck (Operations Warning)
  - Temperature above threshold (Safety Critical or Quality Warning)
- Interlocks:
  - Temperature above safety threshold: E-Stop triggered, Dryer forced off
  - Fire/E-Stop triggered: Dryer and Milling Machine forced off

4. Packaging

- Assumptions: Cocoa Powder buffered in another Tank, Packaged in thermally sealed plastic bags
- Input Signals:
  - Filling weight (**SIWAREX WP231 + WL260 SP-S SC**, PROFINET, weight in grams)
  - Amount of packaging foil left (**SITRANS LR110**, 4...20mA, distance in cm)
  - Foil is “there” and not torn (photoelectric sensor, **SIRIUS 3RG7**, PNP digital out, boolean)
  - Buffer Tank Level measurement (**SITRANS LR100**, 4...20mA, distance in cm)
- Output Signals
  - Spout with valve (**SIPART PS2**, 4...20mA, valve in % of opening)
  - Heating element for sealing (**SIRIUS 3RF2 relais**, on/off)
  - Cutting mechanism for sealing (**SINAMICS S210 + SIMOTICS S-1FK2**, PROFINET, Position)
- Alarms:
  - Buffer Tank overflows (Operations Warning)
  - Packaging foil is torn or runs out (Operations Warning)
- Interlocks:
  - Fire/E-Stop triggered: Heating element and Cutting mechanism forced off, Valve closes up

5. Safety

- Input Signals:
  - Fire/CO detectors (fire hazard, especially due to heating elements, **OP921 Cerberus PRO fire/CO detector**, two-wire circuit)
  - Powder detectors at exhausts (**Sintrol S203 Ex**, tribo-electric, Modbus)
  - Emergency Stop buttons (**SIRIUS ACT 3SU1**, hardwired)
- Output Signals:
  - Alarm Signal (for fire and explosion detectors, **SIRIUS 8WD46**, hardwired)
  - Fire extinguishing system (**FOGTEC high-pressure water-mist system**)
- Alarms: 1 alarm per input (Safety Critical)
- Interlocks:
  - Every alarm forces plant to off state until cleared

Automation Architecture

Finding the correct PLC:

- **Siemens Control Configurator**
  https://www.siemens.com/global/en/products/automation/systems/industrial/plc/simatic-controller-configurator.html
- We want
  - Distributed System (since factory is somewhat spacious)
  - Small sized applications (less than 50 I/Os)
  - FBD / LD / SCL + ST / Graph
  - Including Input Measuring
  - Hardware PLC

Chosen PLC

- **Compact+Modular Main PLC:** SIMATIC S7-1500
  - Will handle central processes
  - Additional Interface modules as needed
  - Supports many different fieldbus protocols
- **2 Redundant Safety PLCs** for safety signals
  - For Fire, Dust/Explosion, etc.
  - Different options, we will use **SIMATIC S7-1200 G2**
- **IO Modules** where needed
  - Also different options, we will use **SIMATIC ET 200SP**

Communication: Fieldbuses + Network Protocols

- **Fieldbuses**
  - Our PLC supports many different Fieldbuses
  - Therefore mainly depends on I/O modules
  - If possible, use **PROFINET** everywhere
- **Network Protocols:** Open Process Control - Unified Architecture
  - Ethernet
  - IP
  - TCP
  - UA Binary Protocol
  - PubSub Model

Supervision

SCADA - Requirements

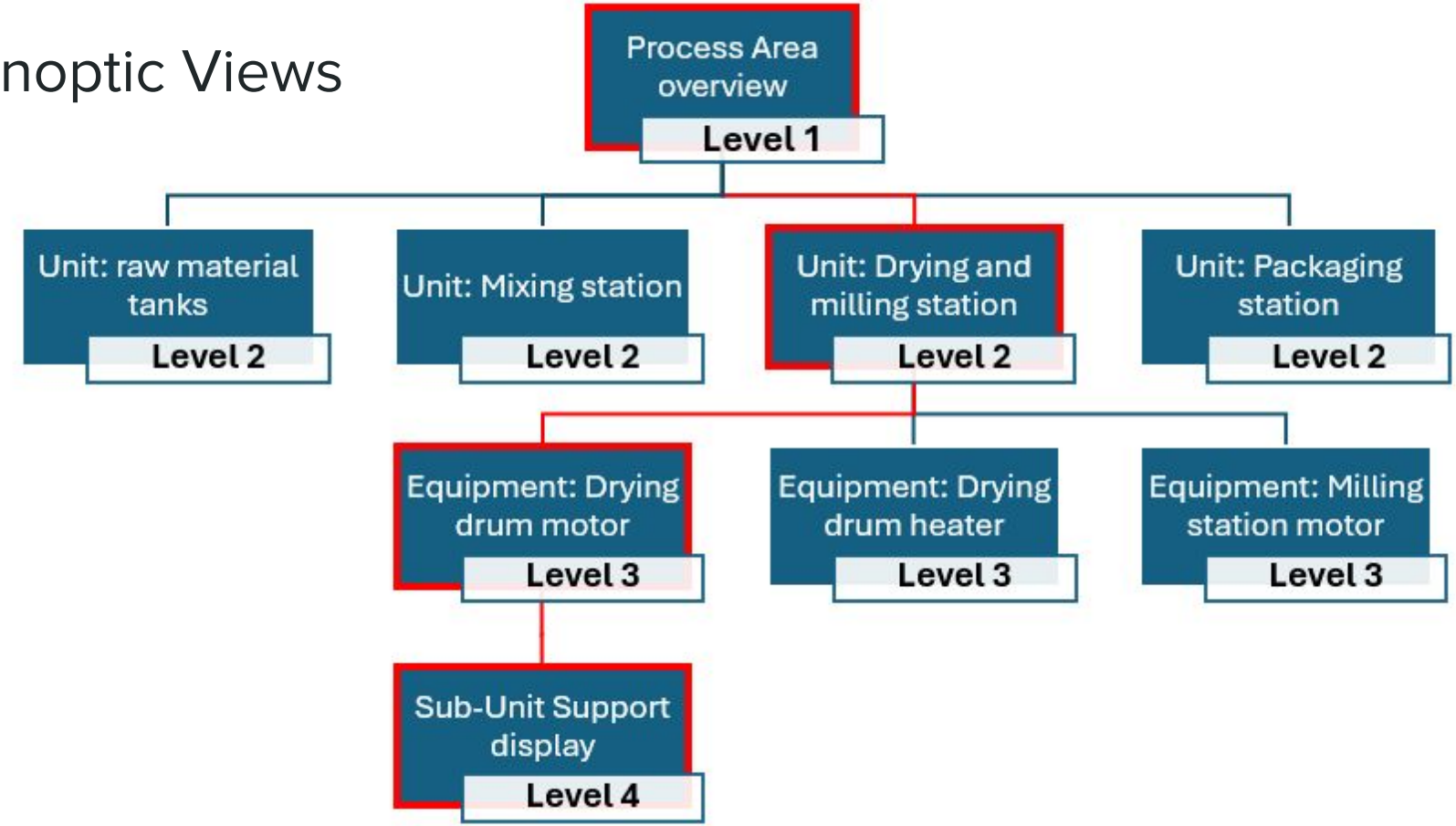
- As per the functional analysis of the plant, number of I/O is **less than 50**.
- **OPC UA** support is required.
- Functionalities should include alarm handling, data logging and user management (roles-based access for engineers and operators).
- Has to be integrable with the chosen **PLCs S7-1500 & S7-1200.**

SCADA - Market Survey

- **Siemens WinCC Unified** (Native Siemens PLC support OPC UA support, paid but included with TIA Portal)
- **Ignition** (Extra setup is needed for Siemens PLCs, OPC UA support, paid)
- **Open Automation Software** (OPC UA support, requires Siemens PLC integration, paid/additional modules are needed)
- **COPA-DATA zenon** (OPC UA support, Native Siemens integration but costly)
- **AVEVA** System Platform (No price info available readily, mainly for Schneider PLCs)

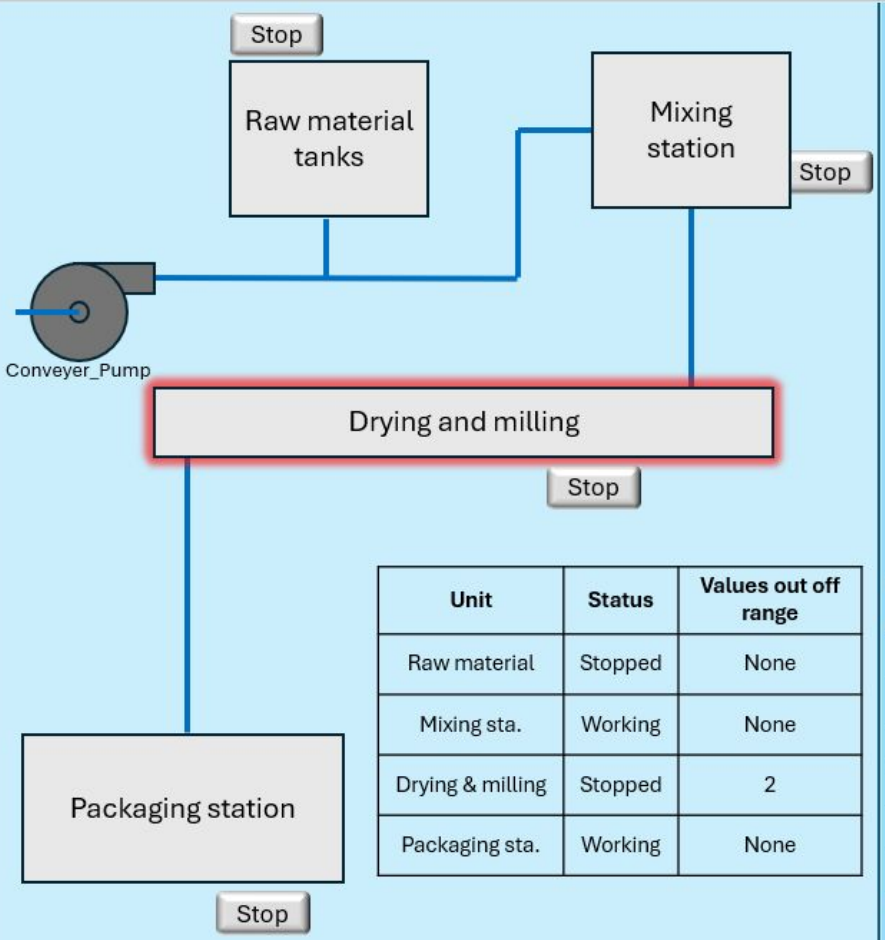
Based on the market survey, **Siemens WinCC Unified** is the most suitable option for this application.

Synoptic Views



Navigation

- Global view
- Tanks
- Mixing
- Drying & Milling
- Packaging



Unit	Status	Values out off range
Raw material	Stopped	None
Mixing sta.	Working	None
Drying & milling	Stopped	2
Packaging sta.	Working	None

Safety

	Status
Smoke_detectors	Working
CO2_detectors	Working
Powder_detectors	working

Alarms	Severity	Time
#########	#####	##############
#########	#####	##############
#########	#####	##############

Sat. 04/12/2025 21:32:42

Navigation

Drying & Milling

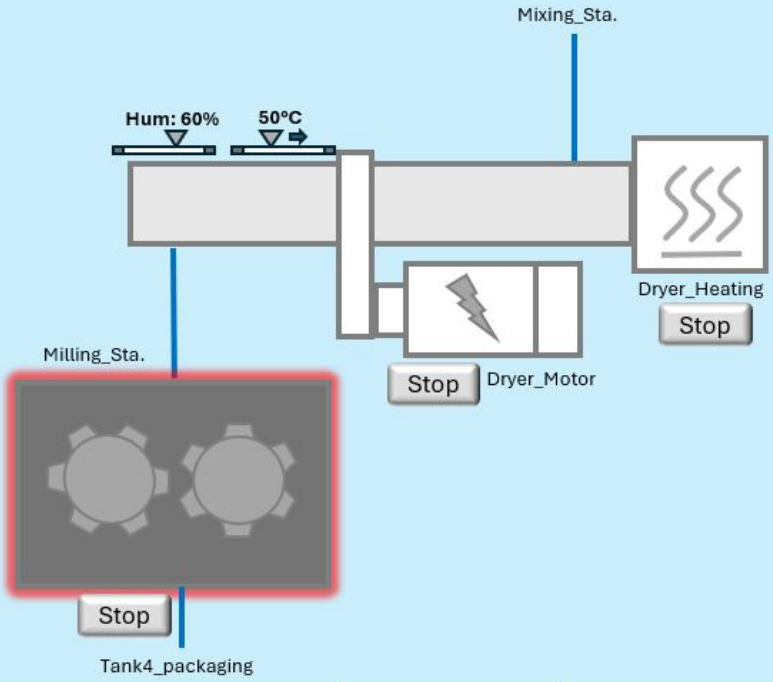
Back to Global view

Equipment

Dryer motor

Heating

Milling station



Device	Unit	Reference
Dryer_Heating	°C	Auto.
Dryer_Motor	rpm	Auto.
Milling_Sta.	rpm	50

Inputs

	value	Indicator + trend
Temperature_dryer	50°C	
Humidity_dryer	60%	
Torque_milling	10N	

Outputs

	value	Indicator + trend
Dryer_Heating	60°C	
Dryer_Motor	80%	
Milling_Motor	10N	

Alarms	Severity	Time
#########	#####	##############
#########	#####	##############
#########	#####	##############

Sat. 04/12/2025 21:32:42

Navigation

Drying & Milling

Back to Global view

Equipment

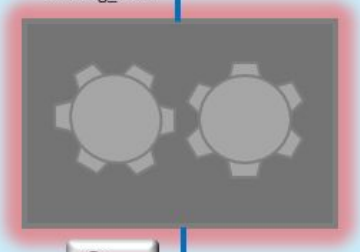
Dryer motor

Heating

Milling station

Drying_drum

Milling_Sta.



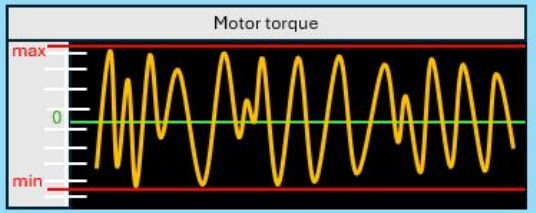
Stop

Tank4_packaging

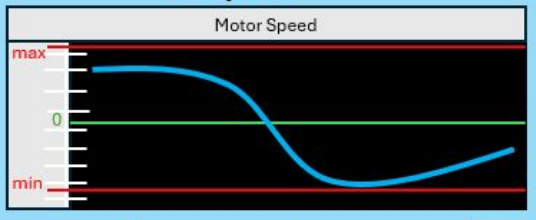
Diagnostic

Device: Milling motor	Unit	Reference	
Speed	rpm	100	auto
		Apply	

Inputs



Outputs



Alarms	Severity	Time
#########	#####	##############
#########	#####	##############
#########	#####	##############

Sat. 04/12/2025 21:32:42

Navigation

Drying & Milling

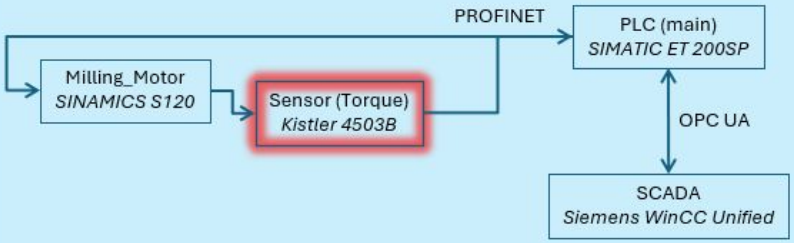
Back to Global view

Equipment

Dryer motor

Heating

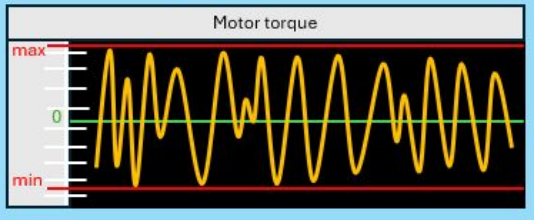
Milling station



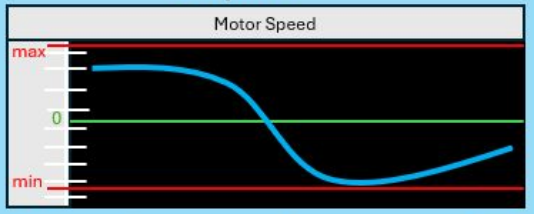
Close diagnostic

Alarm	Time	Localisation	Comments
#########	#####	##############	##############
#########	#####	##############	##############
#########	#####	##############	##############

Inputs



Outputs

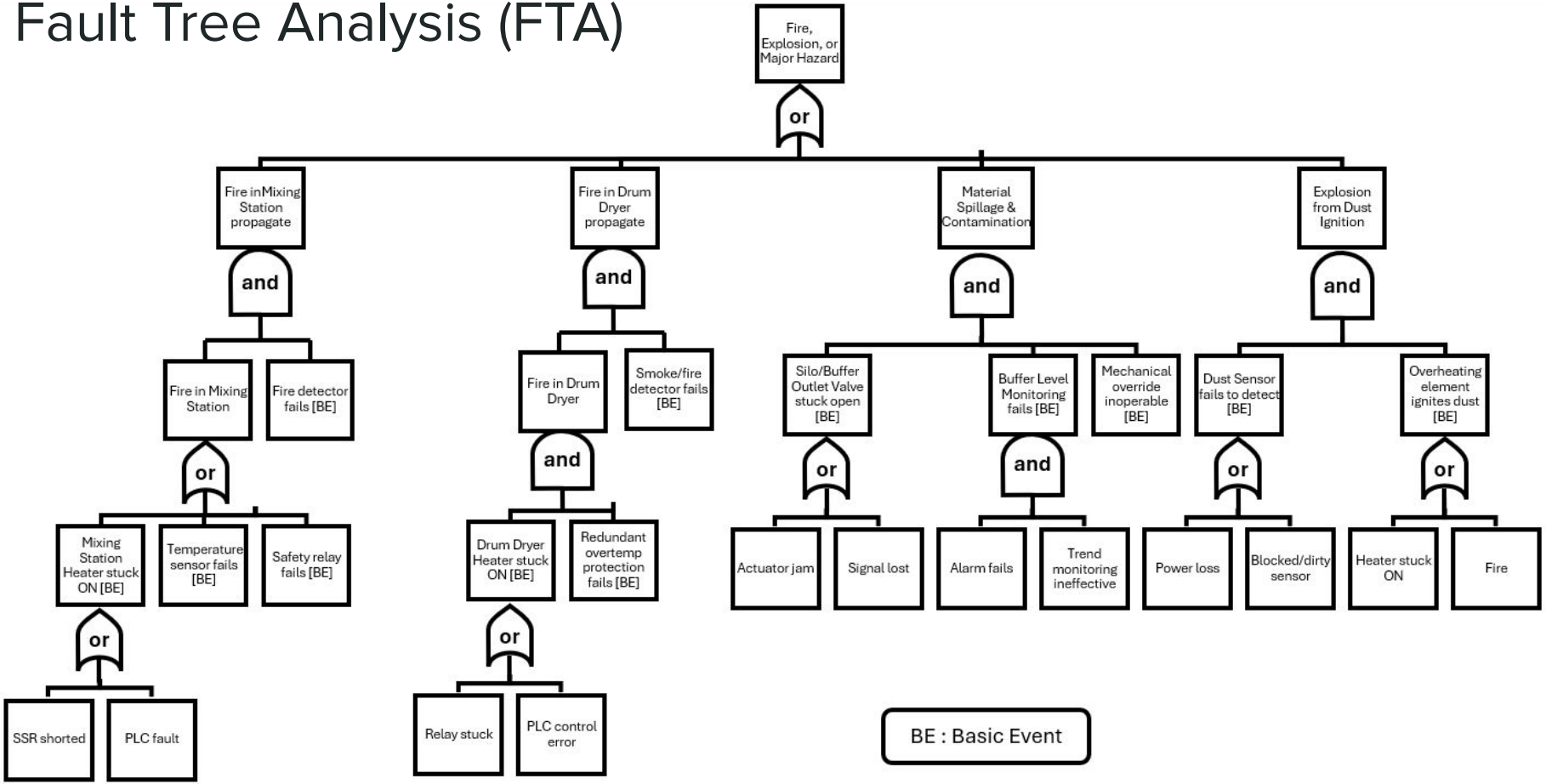


Alarms	Severity	Time
#########	#####	##############
#########	#####	##############
#########	#####	##############

Sat. 04/12/2025 21:32:42

Fault Tree Analysis

Fault Tree Analysis (FTA)



Q&A

1. Raw Material Handling: Pseudocode (merged)

```
for tank in tanks:
    if tank.level below TANK_HEIGHT_10CM:
        stop_conveyors()
        trigger_alarm(
            "Tank {tank} is out of material!",
            LEVEL.OPERATIONS_WARN)

    if tank.humidity above TANK_HUMIDIDTY_5_PCT:
        trigger_alarm(
            "Tank {tank} has high humidity!",
            LEVEL.QUALITY_WARN)
```

2. Mixing Station: Pseudocode (merged)

```
if vat.temp >= TEMP_CRIT:   # Temperature ↔ heater
    alarm_light.on();  extinguisher.on();  shutdown_all_machinery()
    trigger_alarm("Vat temperature CRITICAL!", LEVEL.SAFETY_CRITICAL)
elif vat.temp >= TEMP_MAX:
    heater.off();      trigger_alarm("Vat temperature high!" , LEVEL.QUALITY_WARN)
elif vat.temp < TEMP_SET - TEMP_HYS:
    heater.full_on()
else:
    heater.set((TEMP_SET - vat.temp) * Kp)   # simple P-trim

if vat.level < LEVEL_MIN:   # Level ↔ motor & feed
    motor.off();       trigger_alarm("Vat level low – mixer stopped!", LEVEL.OPERATIONS_WARN)
else:
    motor.on()

if vat.level > LEVEL_MAX:
    feed.off();        trigger_alarm("Vat level high – feed stopped!" ,LEVEL.OPERATIONS_WARN)
```

3. Drying and Milling: Pseudocode (merged)

```
if drum.temp >= TEMP_CRIT:   # Hot-air dryer
    alarm_light.on();  extinguisher.on();  shutdown_all_machinery()
    trigger_alarm("Drum temperature CRITICAL!", LEVEL.SAFETY_CRITICAL)
elif drum.temp >= TEMP_MAX:
    dryer.off();        trigger_alarm("Drum temperature high!", LEVEL.QUALITY_WARN)
elif drum.humidity > HUM_SET + HUM_HYS:
    dryer.full_on()
else:
    dryer.set((HUM_SET - drum.humidity) * Kd)

if mill.torque >= TORQUE_STUCK:   # Milling-gear torque interlock → both motors
    drum_motor.off(); mill_motor.off();
    trigger_alarm("Milling gears STUCK!", LEVEL.OPERATIONS_WARN)
else:
    drum_motor.set(DRUM_SPEED)
    mill_motor.set(MILL_SPEED)
```

4. Packaging: Pseudocode (merged)

```
# Packaging procedure
if (not foil.present) or (foil.left_cm <= FOIL_LOW_CM):
    spout.close(); heater.off(); cutter.off()
    trigger_alarm("Packaging foil missing!", LEVEL.OPERATIONS_WARN)
    wait_until(foil.present and foil.left_cm > FOIL_LOW_CM)
    continue

wait_until(bag.present)                          # empty pouch in place
while bag.weight < FILL_TARGET_G: spout.open()
spout.close()

heater.on(); wait(SEAL_TIME_S); heater.off()  # seal
cutter.on(); wait(CUT_TIME_S); cutter.off()   # cut
```

5. Safety: Pseudocode (merged)

```
if smoke_co2.detected():              # fire risk
    alarm_light.on()
    extinguisher.on()
    shutdown_all_machinery()
    trigger_alarm("Smoke detected!",   LEVEL.SAFETY_CRITICAL)

if powder.level > DUST_15g_m3:        # dust-explosion risk
    alarm_light.on()
    shutdown_all_machinery()
    trigger_alarm("Powder explosion hazard!", LEVEL.SAFETY_CRITICAL)

if estop.pressed():                   # any emergency stop pressed
    alarm_light.on()
    shutdown_all_machinery()
    trigger_alarm("Emergency Stop pressed!", LEVEL.SAFETY_CRITICAL)
```