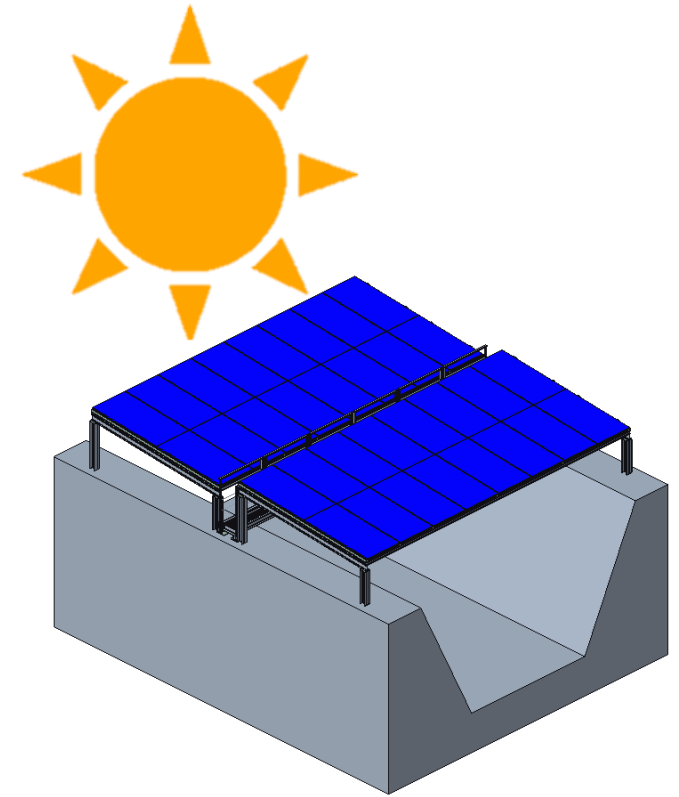


Hybridization of Hydro Power Plant: Enel experience



HyperNext Global Program 2023-2030: Hidden Treasure

Water meets Solar: possible pipeline



CANALS

- Capacity: **496 MW**
- Production: **545 GWh/y**



DAMs

- Capacity: **58 MW**
- Production: **63 GWh/y**



SMALL BASINS

Forebay, Discharge Tank, Setting basin

- Capacity: **246 MW**
- Production: **270 GWh/y**



LARGE BASINS

- Capacity: **2,9 GW**
- Production: **3,2 TWh/y**



BD perimeter

**Canals, Small Basins, Dams:
800 MW of new PV Capacity
880 GWh/y**

Solarification: Hydro Asset Next Gen

Smart Canal: Sustainability and IoT

SENSORS & AUTOMATION

- New Solar Scada used by both plants, combined with:
 - Installation of additional sensors (Vibration, Water Level & Flow, Structural)
 - RTU Scada Upgrade

that allow :

- Predictive Analysis (e-Maintenance)
- Efficiency Analysis (HYDEA...),
- Remote Management & Failure Events
- Canal As Regulated Reservoir

SECURITY

- Cameras & Monitoring System
- Fencing

WATER RESOURCE

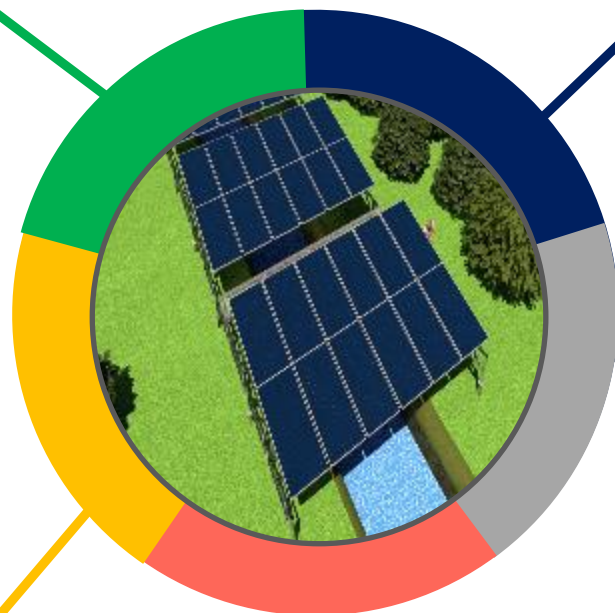
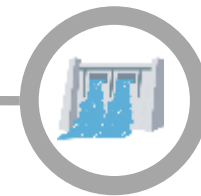
- Reduce Evaporation due to canal PV coverage
- Plant Flexibilitazion: ancillary services or Unique Virtual Power Plant

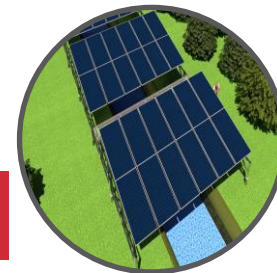
CIVIL & HYDRAULIC SAFETY

- Green Cleaning Canal Banks
- Reduction of seaweed
- Mechanical stress from thermal excursion or reduction of algae presence
- Emergency water flow closure

CONNCTIVITY

- New Connection through New Fiber Optic





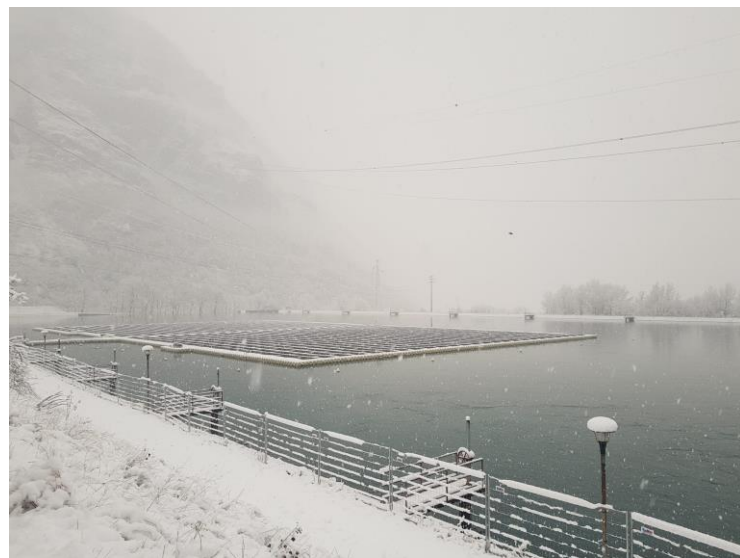
Venaus Floating PV: 1 MW

Italy - Nord Ovest - UT Torino



Project Overview

Connection Authorization	Municipality & Permitting	Capacity (MW)	Energy (MWh/y)	COD	Length (Km)	Width (m)	Area (m2)
eD Quotation Received	DILA - Comune Venaus	1	1,295	Dec 2023	-	-	10.000



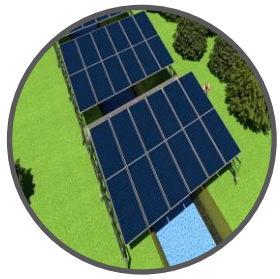
Highlights

- STMG confirmed in Nov'22
- Approved in the REC SC
- Detailed design final review (Deposito GC)
- Authorization (DILA) next month Feb 23
- IC tbd in Feb '23
- SoC in Jun 23
- COD on October the 18th

Key Points & outcomes

- Usage of ENEL's 3SUN Module 370 Wp Model
- Sungrow String Inverters for improved modules balancing & predictive diagnostic

Authorized in 3 Months, Construction Site in 3 Months, Extra production due to cooling effect & albedo (PR from 81,57% to 82,27%)



Venaus Floating PV: 1 MW

Italy - Nord Ovest - UT Torino

Hydro Improvement Projects



Sensors

- Temperature Data integration from Honeywell Multitrend Sensor
- Camling DGA monitoring solution data integration for transformer predictive maintenance
- RCE (Registro Cronologico Eventi) data integration
- Rittmeier flowmeter sensor in valves room data integration



Automation

- New IT Device will be in charge for all plant's VM, SMAV and Solar SCADA & DATA GATHERING (PI)
- NEW SCADA for Plan Suffi and DATA GATHERING (PI)
- PI - AF Event Management for failure & alarming



Water Resource

- Online efficiency calculation (ABC Project) and Flow Differential Measurement (ΔQ), for safety improvements
- Evaporation reduction
- Reduction of seaweed



Connectivity

- Fiber Optic connecting reservoir with valves room, passing from pumping plant Pian Suffi (2.5 km)
- Dismissal of mobile SIM & satellite connection

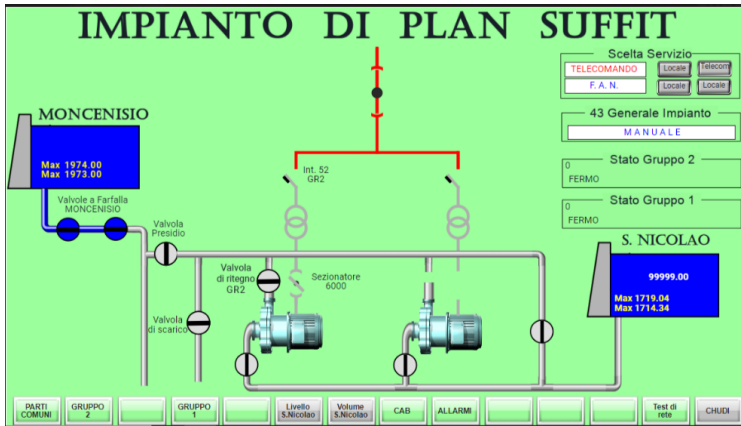


Monitoring

- Cameras for operation purposes on pumping station (Plan Suffi), valve room and floating PV
- CCTV Cameras & Monitoring System for security purposes

Data Gathering

Venaus IoT project



REMOTIZATION OF THE GUTTER PUMPING PLANT CONNECTED TO VENAUS PPT

Thanks to the optical fiber laid inside the old penstock and the network shared with the PV system, the following was obtained:

REMOTE SUPERVISION OF THE PLAN SUFFIT SYSTEM

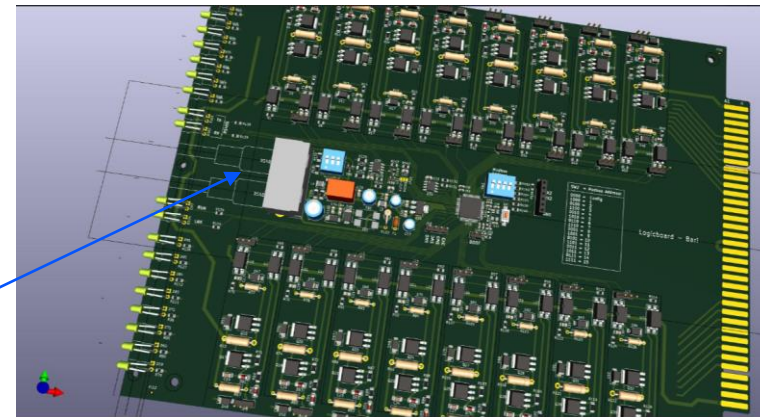
- Signal remotization
- Block recovery from remote
- monitoring cameras in the monitoring room and in the intake



SMART OLD AUTOMATION REMOTIZATION

Substitution of the cards of the old automation ((Unificato ENEL) with new cards capable of remotize signal. Card became a useful part of the old system

Digital Connection for smart remotization of all the signal



Enel Green Power – Asset digitalisation



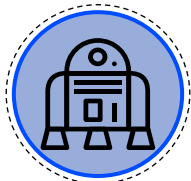
The Data Model as enabling core technology

Remotization and Data Gathering need a unique language to leverage modelization of system for Predictive, Efficiency analysis and so on. Enel Green Power use the so called Enel Data Model based on **4 main pillars**



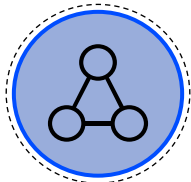
Based on International Standard Frameworks IEC 61850 and ISO/IEC 81346

Future-proof for long durability/life, uniformity cross-country, common to other renewables Technology (IEC 61400-25 WIND technology, IEC 61850 SOLAR technology)



Totalizing approach with automation as core aspect

Starting from field automation up to HMI, Remote Control Center, asset monitoring Plant documentation (P&ID, circuit diagrams, software, visualization and reporting)



Multidisciplinary process improvement in all enterprise aspects

Revolutionizes engineering, operation and maintenance allowing machine-to-machine processes with outstanding quality in design and performance



Homogeneous information taxonomy in the whole Enterprise Data Chain

Possibility to deploy advanced workflows (analytics, performance,..) over the entire fleet in a click

Enel Green Power – Data Model

Structured, semantical designation



	RDS (PROCESS SECTION)					IEC 61850 (LOGICAL NODE SECTION)				
	Process type "Site" CD (Conj Des)	BL0 Main Area	BL1 System, subsystem	BL2 Basic function	Subfunction IED name «RDS structure»	Logical Node		DO	DA	DO Type
						Class	Inst			
<i>Tag modeling</i>	ITHMNTL	M01	MKA00	BJ001		MMXU	01	TotW	Mag.f	MV
<i>Description</i>	HYDRO POWER PLANT MONTELUPONE	UNIT 1	GENERATOR	ACTIVE POWER METER		Measurement in a three-phase system		TOTAL REAL POWER	MAGNITUDE (FLOATING)	
<i>Tag Name</i>	ITHMNTL.M01.MKA00.BJ001/MMXU01.TotW									

Value from RDS

- Standard name (Semantic & Hierarchical)
- Companion standard for cross technology

RDS paradigm is used on:

- Documents, P&I drawings and schemes
- Physical components
- Software, visualization and reporting
- Etc ..

Value from IEC 61850

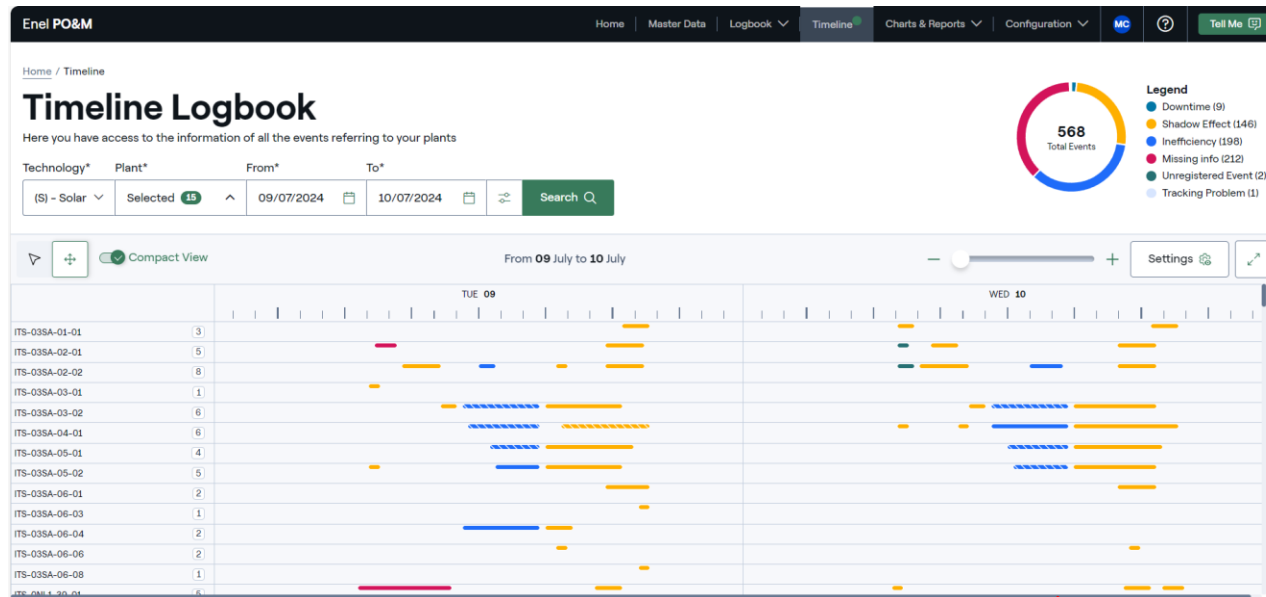
- Standard name & meanings of data
- Formal configuration language
- Self-description
- Standard abstract service
- Companion standard for cross technology

Logical Nods are used on:

- Control System & protection

Event Management for Hydro

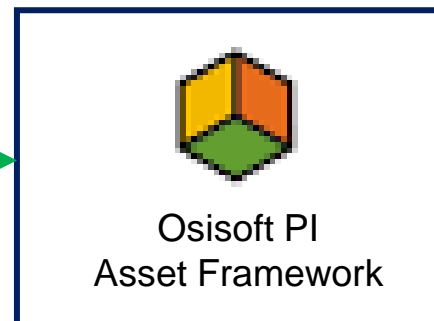
Application for all technologies



- ✓ Automatic creation of the failure event with full details **by using common template**
- ✓ Automatic Lost Production calculation for each event
- ✓ Definition of the technical components involved in the event. Possible improvement by SAP coordination



*Already in place
(es. Venaus FV)*



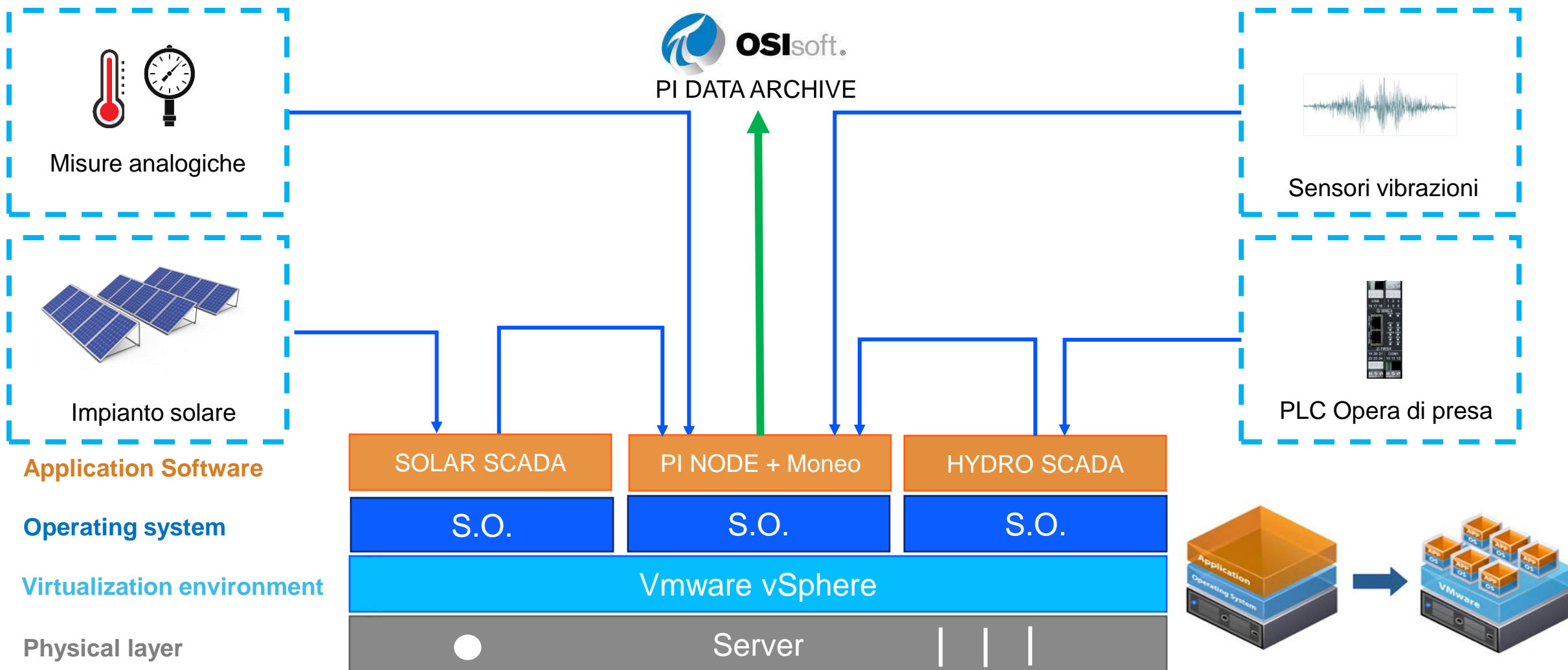
*Ready to send all the information
thanks DigiCAB and Server with PI
node. Good connection by fiber*



Impianto idro

Virtualization

Hybridization opportunity: virtualization of IT device



Hydro Control System

Benefit on Virtualization of OT



Reduction of physical machines

- Ease of maintenance (from €10k to €5k)
- License reduction (€5k per license)
- Simplify and automate backups
- Lower environmental impact (construction/disposal/energy)

More business continuity

- Simplified recovery, the VM must be moved to new hardware, but the SCADA software does not need to be reconfigured
- Virtualization increases vendor independence

Better Cybersecurity governance

- Centralized security patching
- Possibility of carrying out tests on 'twin' VMs of the process

Asset Life cycle OT oriented

- Extension of the life of the SCADA software up to the life of the plant's PLC (PLC=25/30 years VS Server=8/10 years).

Elimination of the 'Vendor lock-in'

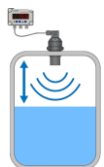
- The server is a standard hardware component (also IT oriented)

Venaus II phase

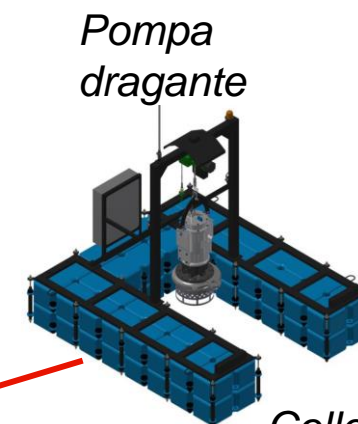
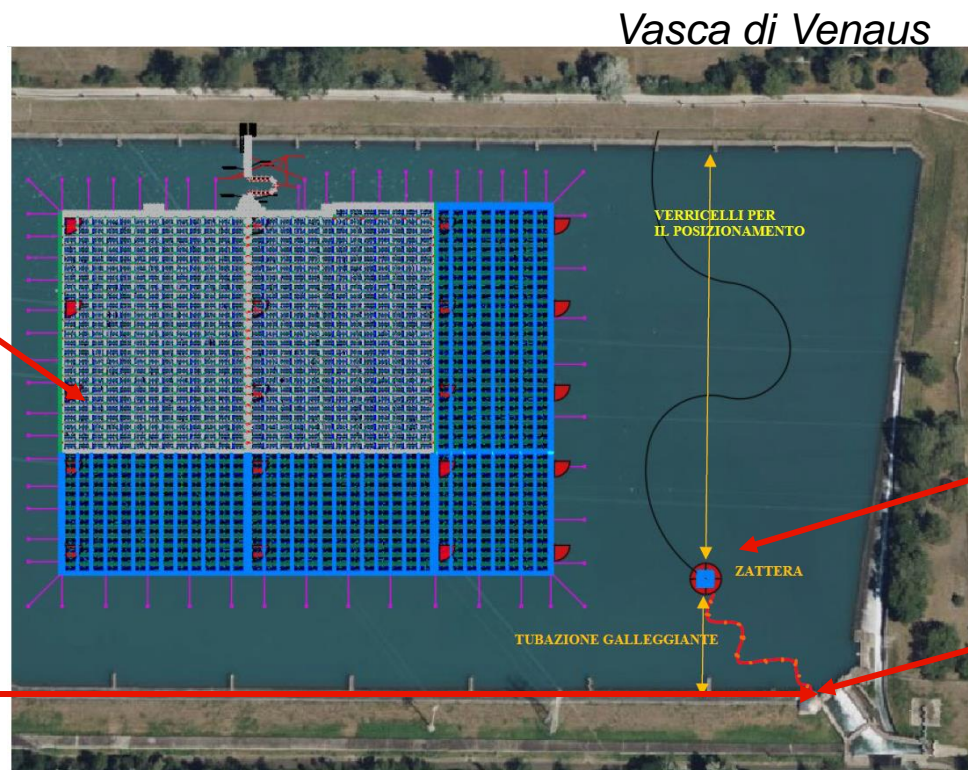
Floating PV extension (from 1MW to 2) & Integrated Desedimentation



Agitatori



Sensori



Floating infrastructure shared with desedimentation devices: PLC, Energy, IoT with optic fiber with decrease of costs and implementation time

Continuous Desedimentation

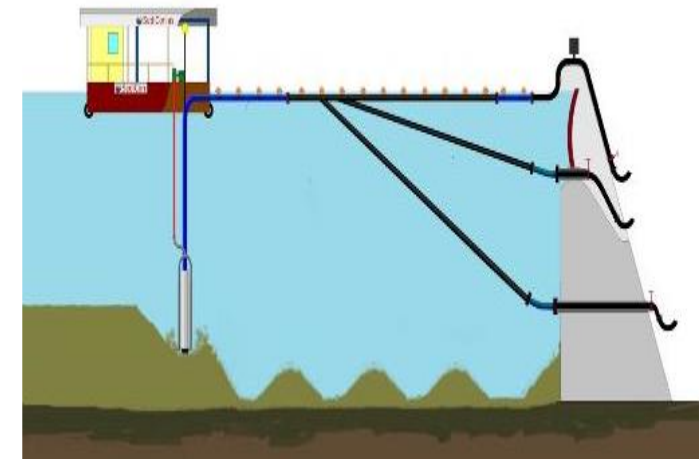
Technology benefits



Continuous desedimentation consists of a mobile floating system that removes sediment in the basin and/or loading tanks in a controlled manner. The sediments are removed by a suction unit and transferred downstream of the dam, through a network of collectors, directly bypassing the crest of the dam or by flushing through the turbine

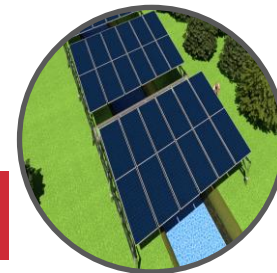
Main features

- Ability to remove most types of sediment: cohesive clay, sand and gravel (grain size up to 60 mm)
- No interference with the production of the main plant. Sediment will pass through the turbine (thanks to extreme dilution). Monitoring plan is defined to check possible issue
- Accurate control of the concentration of the sediment removed
- Automated systems, without the presence of any operator
- Reduction of approximately 2/3 of the estimated cost compared to traditional dredging technologies (from 30-40 €/m³ to 10 - 15 €/m³)
- The system is sustainable: the extreme dilution do not create problems to the fauna, and it is possible to stop the desedimentation if the river has high concentration



Scheme

The presence of the floating PV reduce costs and implementation time of the desedimentation system



Montelupone Canal Coverage: 1 MW

Italy – Marche - Macerata

Hydro Improvement Projects



Connectivity

- Fiber Optic connection from intake to hydro powerhouse (3.5 km ?), through armored wire directly anchored on canal surface
- Dismissal of mobile SIM & satellite connection
- Intake Watergates automation & remote control, through new HPU (SOD)



Civil & Hydraulic Safety

- Static Verification & Maintenance of Canal Bridges
- New Canal Fencing
- Vegetation Cleaning & Canal Banks Maintenance with installation of white reflective sheeting placed on the embankment to prevent plant growth



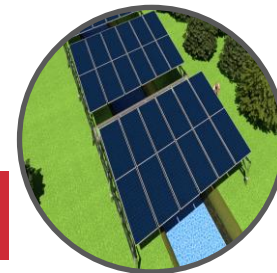
Monitoring

- CCTV Cameras & Monitoring System for security purposes
- Camera in Intake for operation purposes



Free installation of armored fiber optic directly on Canal anchored on an inox wire-
rope





Montelupone Canal Coverage: 1 MW

Italy – Marche - Macerata



Hydro Improvement Projects



Sensors

- Vibration issue in Unit 2 analyzed with MTS & UT. Solution identified shall include new vibration sensors installation & remote monitoring



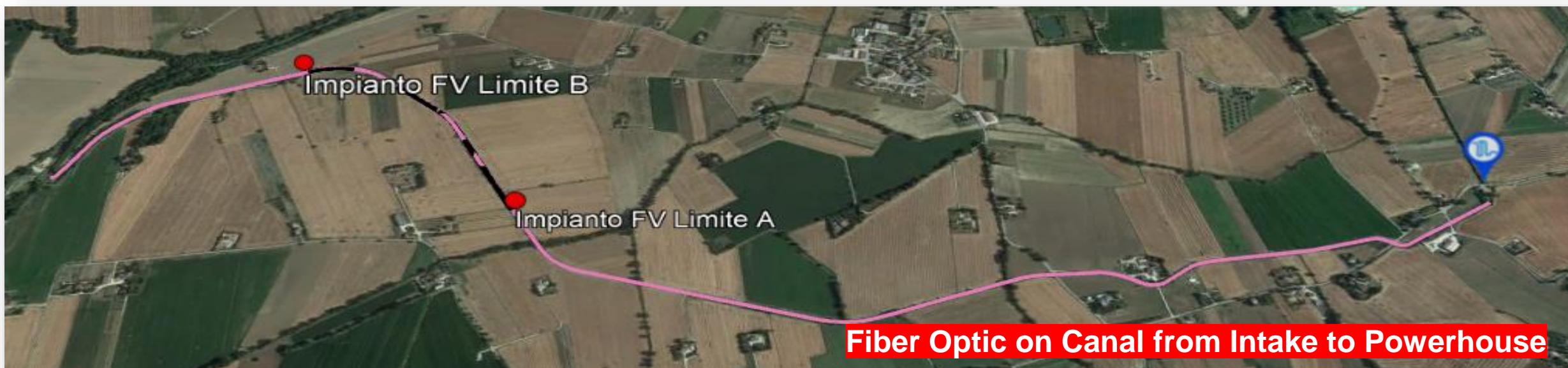
Automation

- New IT Device will be in charge of Solar SCADA, monitoring & virtualization of existing Hydro SCADA
- PI - AF Event Management for failure & alarming

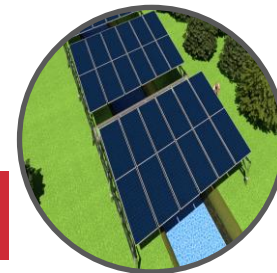


Water Resource

- 2 NEW flowmeters (Intake and upstream penstock)
- 1 NEW level sensor in plant discharge
- Online efficiency calculation and Flow Differential Measurement (ΔQ) for safety improvements
- Evaporation reduction
- Reduction of seaweed



Fiber Optic on Canal from Intake to Powerhouse



Narzole Canal Coverage: 1 MW

Italy – Piemonte - Cuneo

Project Overview

Connection Authorization	Municipality & Permitting	Capacity (MW)	Energy (MWh/y)	COD	Length (Km)	Width (m)	Area (m ²)
eD Quotation Received	DILA - Comune Narzole	1	1,426	Dec 2023	0.9	8	-



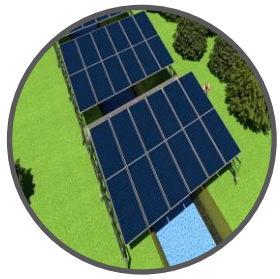
Highlights

- STMG confirmed in Dec'22
- Approved in the REC SC
- Detailed design final review
- Authorization (DILA) next month Feb 23
- IC tbd in Feb '23
- SoC expected in Jun 23

Key Points

- CSV Projects with Municipality (New Bicycle Track along the channel)
- White sheeting installed on the embankment to eliminate the growth of plants dangerous for the infrastructure and increase the albedo effect

Extra production due to the cooling effect (to be finalized the PR increase). The new Bicycle track improve safety and security of the Channel in a sustainable way



Narzole Canal Coverage: 1 MW

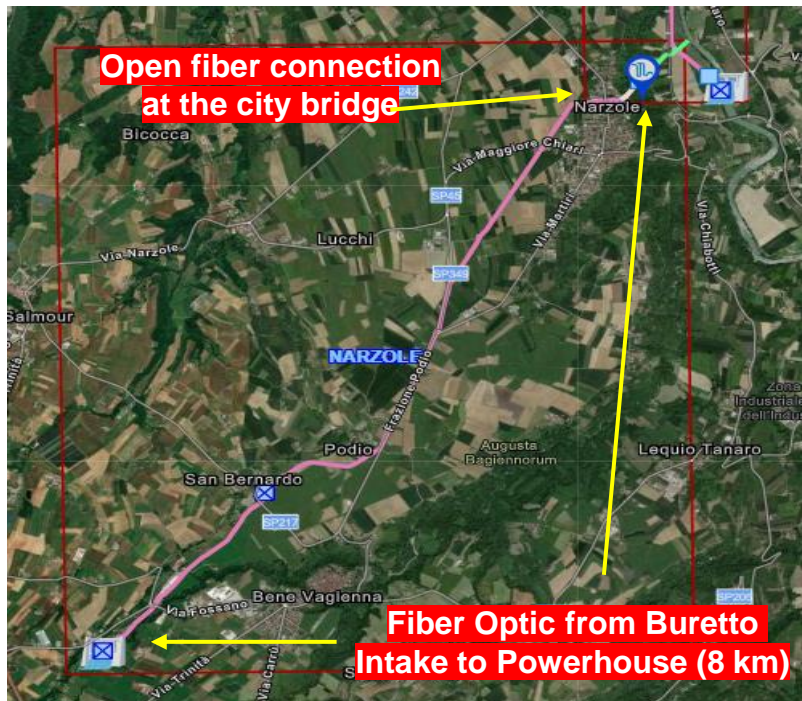
Italy - Piemonte- Cuneo

Hydro Improvement Projects



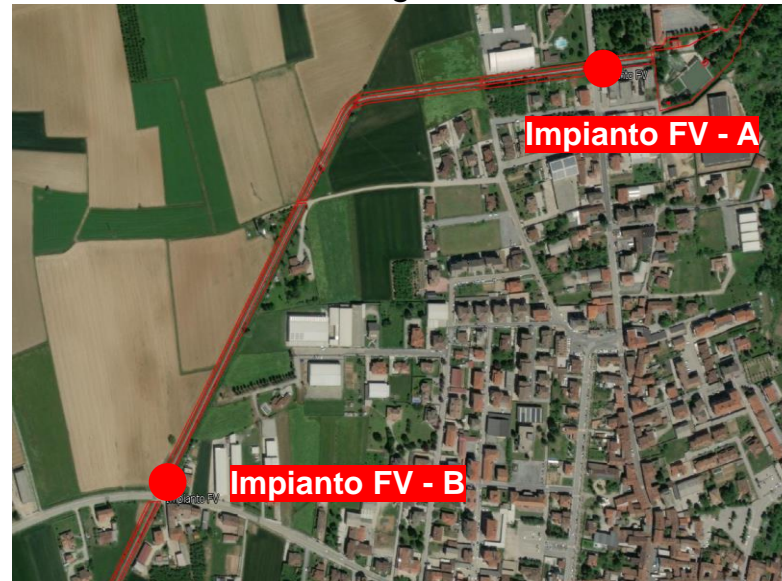
Connectivity

- Fiber Optic connecting from Buretteto Intake to Powerhouse (8 km)
- Dismissal of mobile SIM & satellite connection



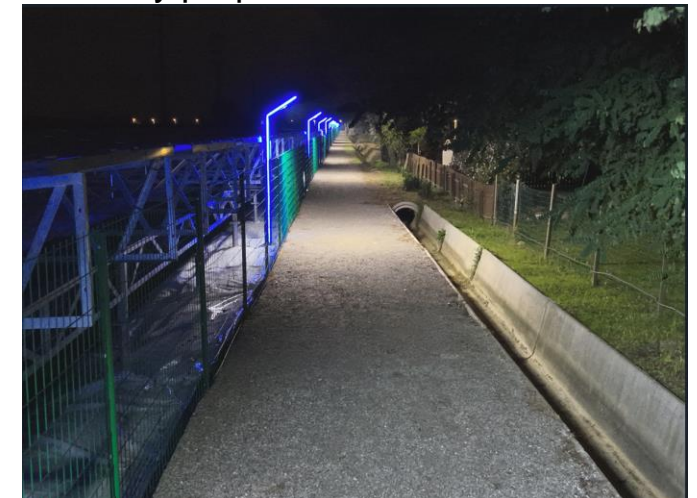
Civil & Hydraulic Safety

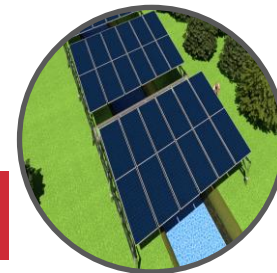
- New HPU (SOD) for Forebay Tank gates + maximum effort sensors
- Discharge gate & sealing gaskets maintenance in second loading tank
- Vegetation Cleaning & Canal Banks Maintenance
- New Canal Fencing



Monitoring

- Trash-rack cleaner review/maintenance and Camera in Forebay Tank for operation purposes, including New LED Illumination system
- Cameras and remotization of Buretteto intake and Deila Gate for operation purposes
- CCTV Cameras & Monitoring System for security purposes





Narzole Canal Coverage: 1 MW

Italy - Piemonte- Cuneo

Hydro Improvement Projects



Sensors

- NEW Penstock base pressure sensor
- NEW Rotary Valve end-point sensor
- Integration of additional field data in existing ABB automation (in collaboration with MTS)



Automation

- New IT Device will be in charge for all plant's VM and Solar SCADA & DATA GATHERING (PI)
- Gate commands remotization in Buretto & Deila intakes
- PI - AF Event Management for failure & alarming



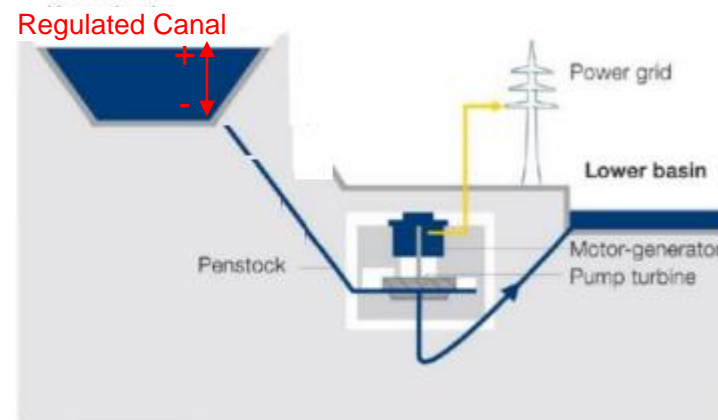
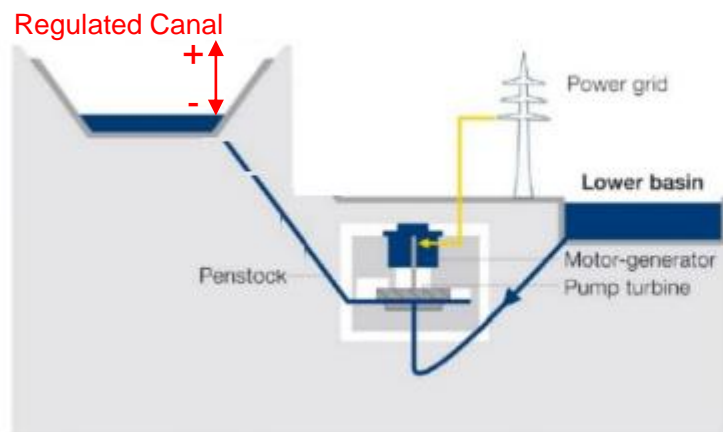
Water Resource

- Online efficiency calculation) and Flow Differential Measurement (ΔQ), for safety improvements
- Evaporation reduction
- Reduction of seaweed



Grid ancillary services

- Secondary regulation service using the canal as a regulated basin. Thanks to the sensors, the fiber optic connection the new Server capable to virtualize also the new RTU Software the plant use the water of the Canal to perform service



Dams Hybridization project

Alpe Gera



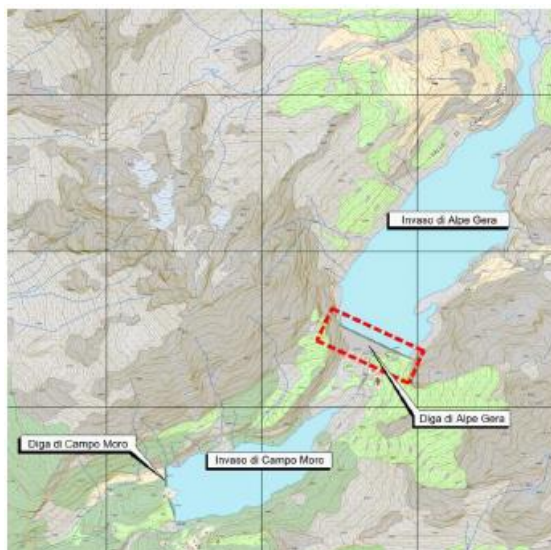
ALPEGERA, 5,5 MW- Rendering

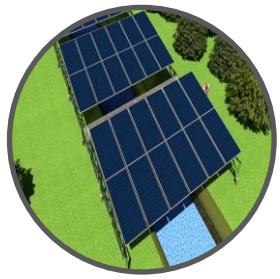


- Potentially the first plant on a wall of this power in Europe
- The area falls within an area within the landscape constraint
- Project already pre-shared with all the public body involved
- Cost analysis on going to manage logistic and risk assessment regarding weather conditions
- IoT (Data Gathering, Virtualization and Remotization) will involve Campo Moro Power Plant
- PV coverage will reduce thermal stress on the dams

SMART DAMS Concept: leverage the photovoltaic structure and its connectivity to implement a remote and real-time monitoring system through the upgrade of current measurement instruments and sensors or installation of new ones, integrating the DAM BEHAVIOR with O&M GIS portal

- Propaedeutic to be able to unify the guardianship with that of the Campo Moro dam (10km)





Alpe Gera Dam: 5,3 MW

Italy – Lombardia - Sondrio

Hydro Improvement Projects



Sensors

- **New Smart Instruments:**
 - 3 automatic pendulum, piezometric cell, hydrometer, rain gauge and snow gauge
- **New topografic monitoring system:**
 - Fiber Optic interferometric strain gauge
 - Targets equipped with static GPS GNSS system



Monitoring

- New video surveillance and remote-control system of the Alpe Gera dam through cameras and access control sensors



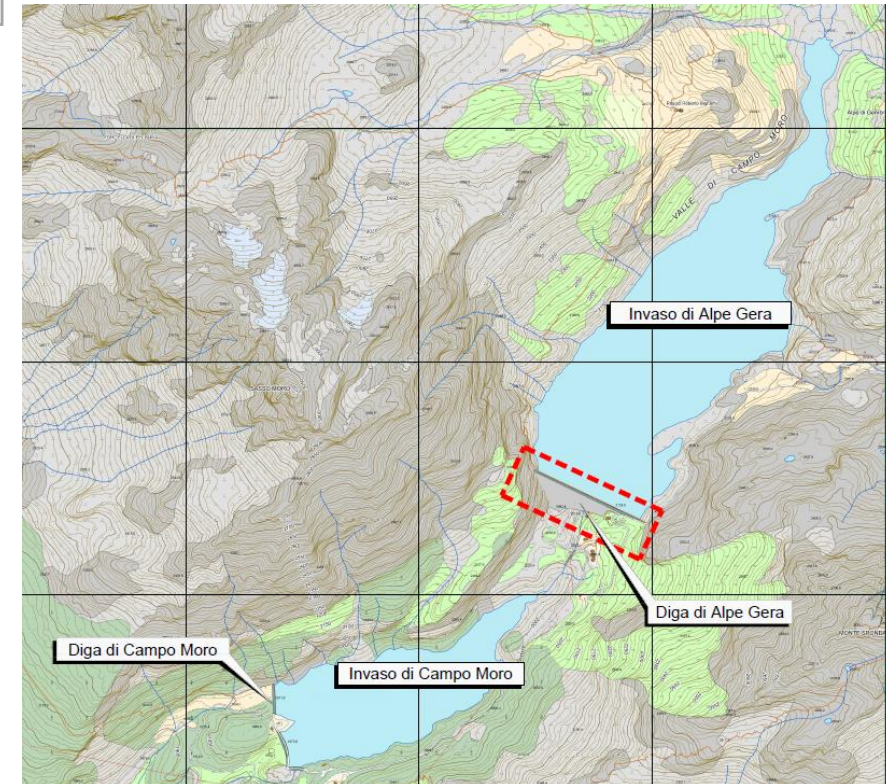
Automation

- **SMART DAM REMOTE and REAL TIME DAM BEHAVIOR** through new smart sensors installation and remot-controlling upgrade of the existing



Connectivity

- Fiber Optic wire connection between Alpe Gera Dam and Campo Moro Dam
- **SURVEILLANCE OPTIMIZATION** enabling the remote-control of both Alpe Gera and Campo Moro Dam directly from Campo Moro



Ancipa Dam: Existing Heat Shield

Italy – Sicilia - Enna



- **Already present the “Heat Shield” installed to reduce the thermal stress on the Dams.**
- Project consist in by adding PV panel on the existing Heat Shield. It has been already shared with public body involved
- Request for temporary installation of 24 modules to evaluate color-landscape rendering (in progress)



Installation of modules on the **Heat Shield** created to reduce the effects of thermal excursion on the surface of the facing

PV on Hydro asset vs. green field

PRO & CONTRA



PRO

- Permitting (No land usage)
- No land lease
- Extra PV production (floating and channel coverage) due to water cooling effect
- Logistic: Existing space for the Hydro Asset Maintenance for Canal, Dams or Tank is usually sufficient for the construction site
- MT Lines presence in the existing Hydro plant make connection simpler and cheaper
- Reduced evaporation
- Improved of Security Hydro Plant
- Improved of Civil Safety Hydro Plant
- IoT for Hydro
- Virtualization and digital enabler

CONTRA

- No tracker
- Plant geometry not efficient for Canal Coverage
- Tilt reduced for Canal Coverage & Floating. Not optimized for Dams
- Access System to be designed since the beginning to manage safety risk
- Hydro Asset Maintenance must be considered in the Design

Possible improvement for the Hybrid Projects

- Ad hoc permitting (as for the Industrial Warehouse) with dedicated regulation
- Hybrid Connection. Shared connection should be managed in a simplified approach and foreseen by the Distributors
- Unique SCADA with Regulation System could include BESS to improve the ancillary services

Hydro Hybridization

Main remarks

- ❑ Focusing on **existing Hydro plants**
- ❑ Simpler **acceptance by the community** of the project due to the existing relations with all the Stakeholder
- ❑ Activities strong related with **hydraulic civil works safety**
- ❑ **Synergies with Hydro CAPEX** to maximize revenues of whole plant
- ❑ **Synergies in O&M** activities
- ❑ **Digitalization for Hydro** with reduced investment (IoT)

Hydro O&M knowledge on site as a key factor to manage construction site and tailor the project to the Hydro Plant needs



Back up

Common vision for Hybridisation engineering process



Traditional vs. Model-Based, Top-Down Engineering

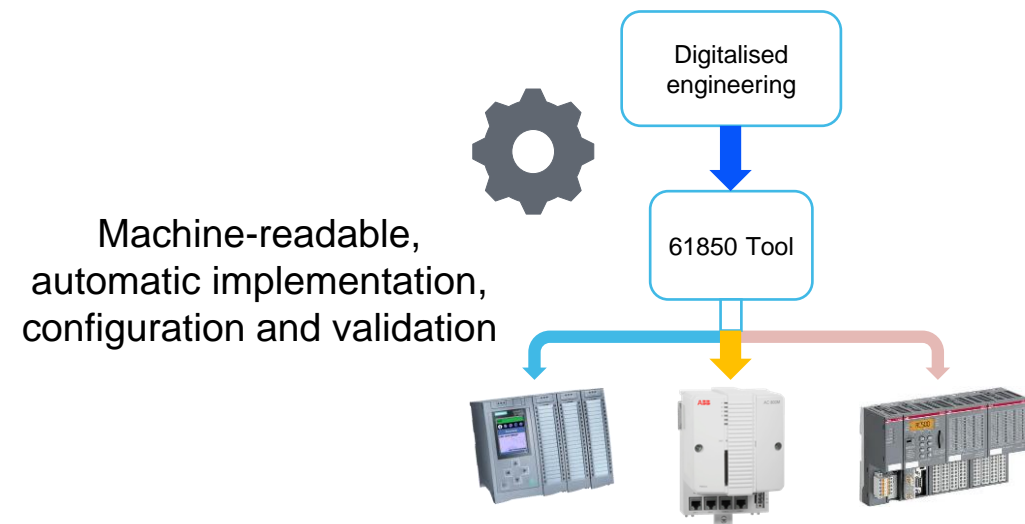
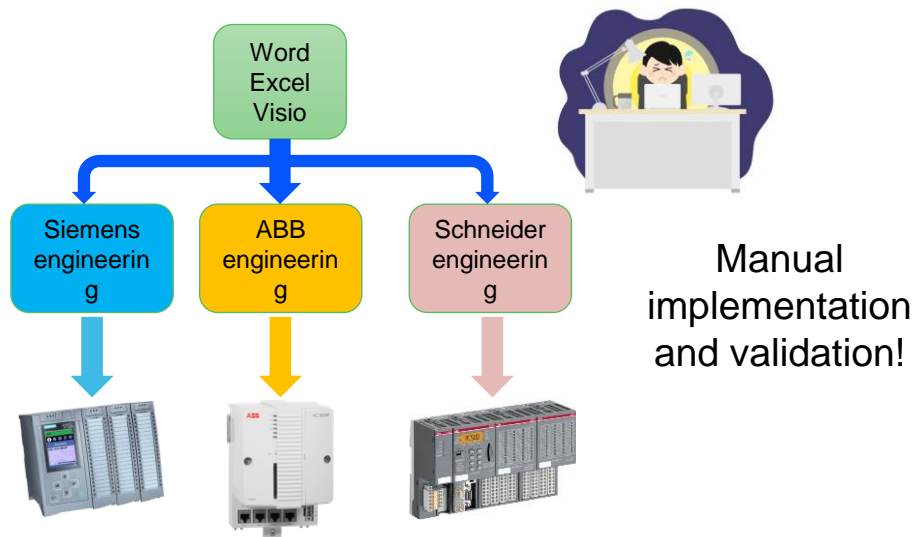
Traditional Design



61850 Automated engineering

Prone to errors
Relies on individual expertise
Extensive copy-pasting
Vendor dependency (lock-in)
Lacks scalability
(individual implementations)

Controlled libraries
One-time design, repeatable implementations
High-level specifications
Improved quality
Repeatable results



Hydro Control System

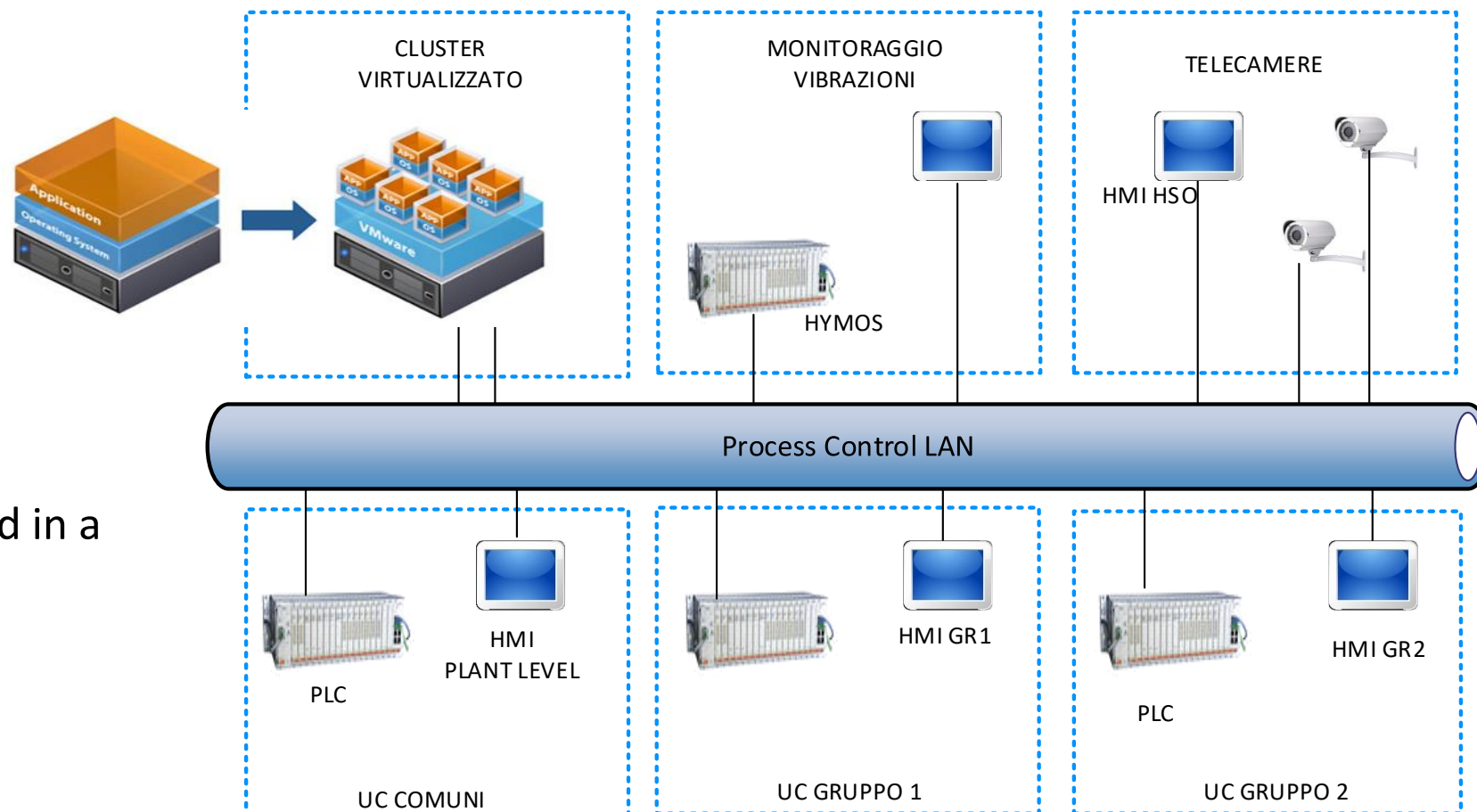
Architecture TO-BE

Virtualization is the ability to transform physical assets into software.

A single hardware can host multiple virtual physical assets.

Multiple functions, virtualized, can be hosted in a single hardware:

1. Hydro Plant Scada
2. U1 Scada
3. U2 Scada
4. Solar Plant Scada
5. Video Manager
6. Hymos Vibrazioni
7. PI node
8. Domain Controller



Within Hybridization we always include Virtualition of the existing IT machine

Data Gatering

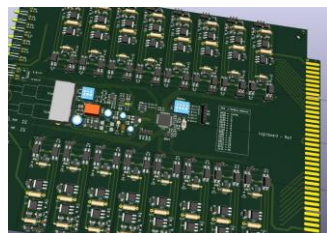
Abilitazione dell'invio tramite nodo PI

New Automation with SCADA



Tag according Enel Data Model transmited by OPC-DA/UA protocol

Old Automation



Data aquisition digital signal by DigiCAB in MODBUS-RTU / TCP

Automatismo unificato per gruppi **non** regolanti:

- DCM602 – ALLARMI e BLOCCHI - **AGGIORNATA**
- DCM604 – INGRESSI - **REALIZZATA**
- DCM605 – USCITE - **REALIZZATA**

Automatismo unificato per gruppi regolanti:

- DCM613 – ALLARMI e BLOCCHI – **IN SVILUPPO**
- DCM617 – INGRESSI – **IN SVILUPPO**
- DCM618 – USCITE – **IN SVILUPPO**



Acquisizione misure analogiche da registratori Multitrend in MODBUS-TCP

NODO PI



PI DATA ARCHIVE

- ✓ Enabler: Predictive analysis (alarm reaction time, ecc)
- ✓ Efficiency calculation in real time
- ✓ Fault analysis / PO&M