



AFRICA 2013

International Conference and Exhibition

SHP training seminar - 15th April 2013, Addis Ababa

- 1. Design of small low head and high head plants under the aspect of using local sources*
- 2. Water storage on small scale and construction of simple small dams*
- 3. Automation and managing aspects*

Lecturer: Nino Frosio

SMALL HYDRO FIELD

Common definitions:

10 MW <	Large Hydro
10 MW ≥	Small > 1 MW
1 MW ≥	Mini > 100 kW
100 kW ≥	Micro

AFRICA 2013

International Conference and Exhibition

SHP training seminar - 15th April 2013, Addis Ababa

Part 1

***Design of small low head and high head plants under
the aspect of using local sources***

CIVIL WORKS RELEVANCE

Total amount of civil works

- *High head plants: ~40% of total costs*
- *Low head plants: ~60% of total costs*



€! £! \$!



They are important not only for their economic relevance; they are also a *crucial technological component* of the plant, as they strongly contribute to the success of the process which transforms the potential energy of the natural source in the most easy-to-use form of energy, such as the electric one. A supply canal or tailrace in low head schemes, as well as a penstock in high head ones, undoubtedly aren't simple foundations or shelters for some electromechanical equipment, like, for example, in thermal, wind or solar plants, but they take active part to the process and dramatically affect the final performances of the plants.

CIVIL WORKS: SOME BASIC KEY POINTS

1. *Specific skillness and experience in the hydraulic works design*



2. *Accurate geomorphologic survey*



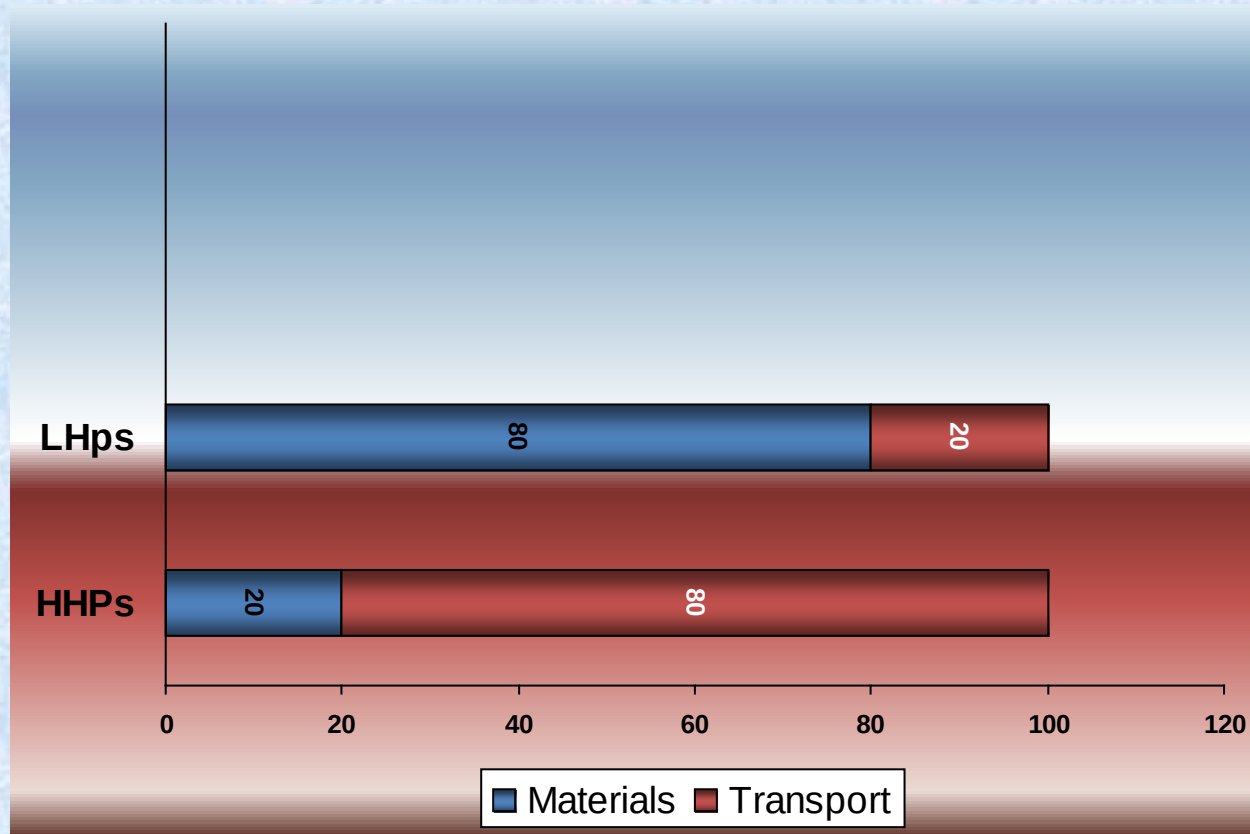
3. *Take into consideration in the design phase the transport facilities for the erection as well as for maintenance*



4. *Reduce the transport cost using as much as possible local materials with appropriate techniques*

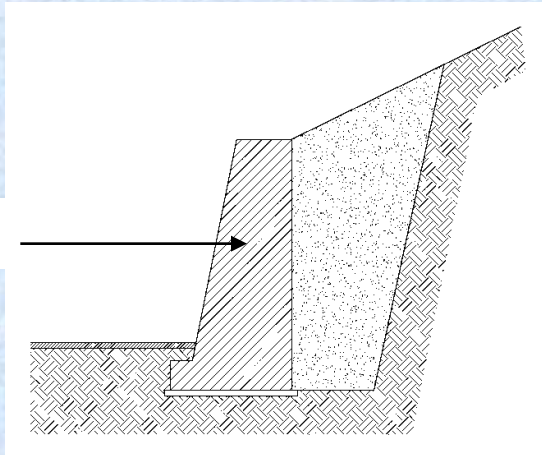


CIVIL WORKS: INFLUENCE OF THE TRANSPORT COSTS ON THE TOTAL COSTS



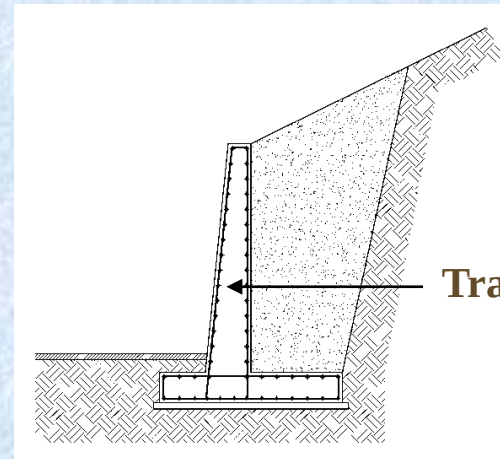
CIVIL WORKS: INFLUENCE OF THE TRANSPORT COSTS ON THE TOTAL COSTS

Local materials



Reduce the transport cost using as much as possible local materials with appropriate techniques

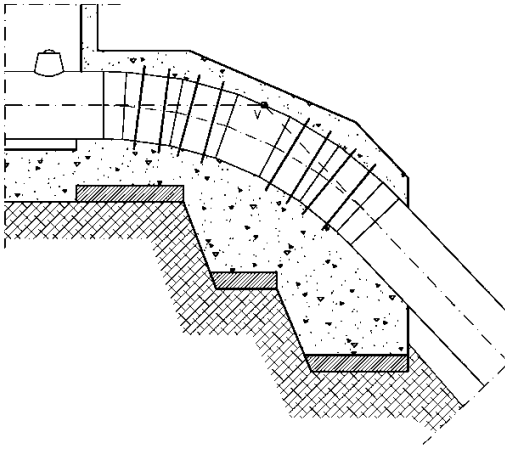
Otherwise use high quality transported materials with sophisticated techniques



Transported materials

HPPs: PENSTOCKS

SEZIONE LONGITUDINALE

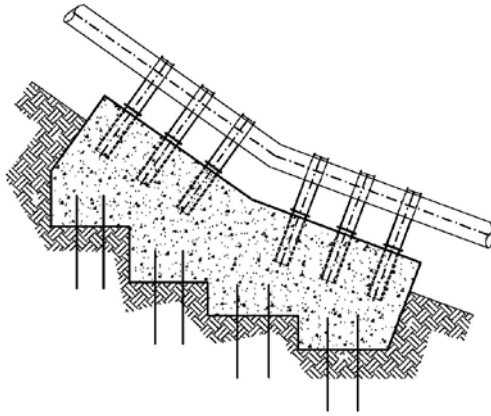


Covered anchoring block



HPPs: PENSTOCKS

SEZIONE LONGITUDINALE

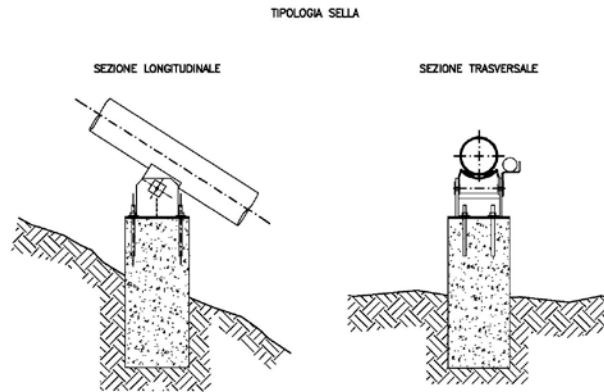


Uncovered anchoring block



HPPs: PENSTOCKS

Saddles



AFRICA 2013

International Conference and Exhibition

SHP training seminar - 15th April 2013, Addis Ababa

Part 2

***Water storage on small scale and construction of
simple small dams***

WHAT'S A SMALL DAM?

The Italian legislation

Large dams are those exceeding 15 m in height
or

storage volume $> 1,000,000 \text{ m}^3$

Usually they allow for a seasonal transfer of the water



Small dams are those not exceeding 15 m in height
and
not exceeding $1,000,000 \text{ m}^3$ of storage volume



Small dam normally means small plant: **NO** seasonal transfer chance

WATER STORAGE ON SMALL SCALE

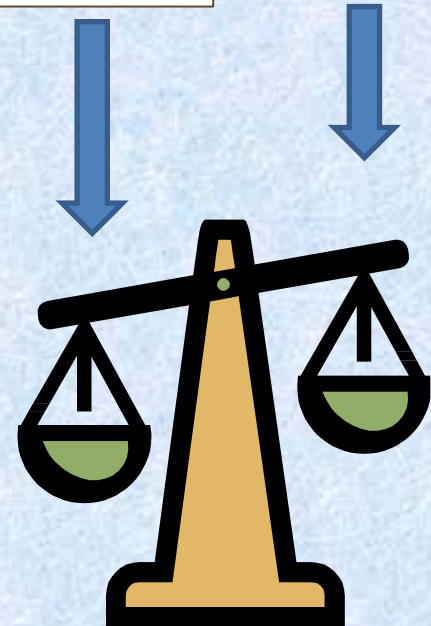
Why to store?



How much to store?

Storage
incomes

Storage costs

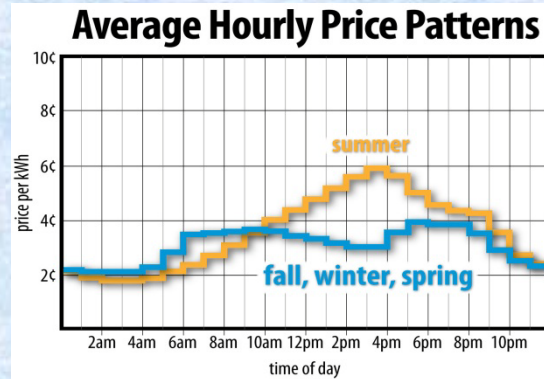


WHY TO STORE?

HOW MUCH TO STORE?

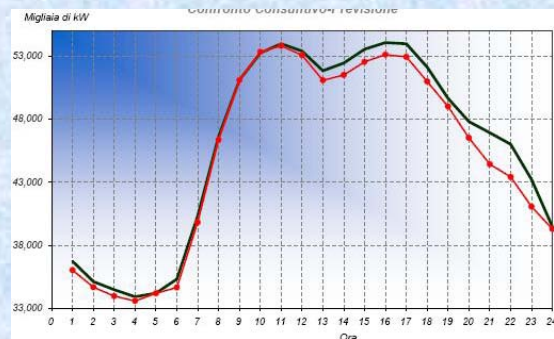
ON-GRID SHPs

1. *To get better tariff in the peak-hours*



Deterministic or statistical approach ~ 8 - 12 h (to cover daily peak)

2. *To get the premium fee for the production planning*



At least 48 h of storage (to cover two day program)

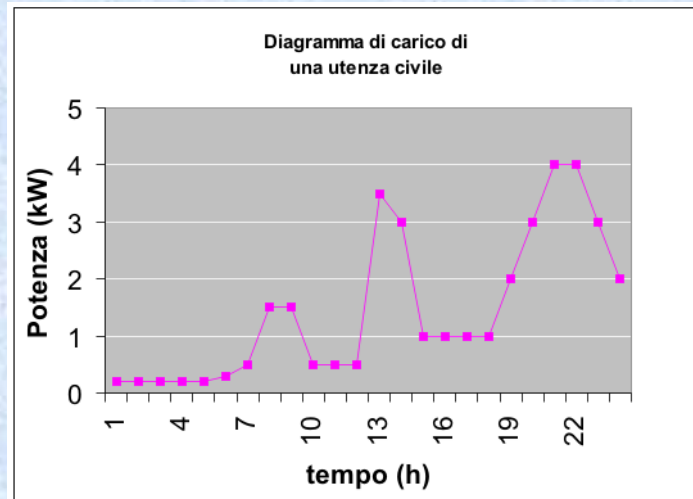
WHY TO STORE?

HOW MUCH TO STORE?

OFF –GRID SHPs (*stand alone plants*)

1. *To better meet the demand on daily scale*

*~ 4 h of storage
(daily peak load)*



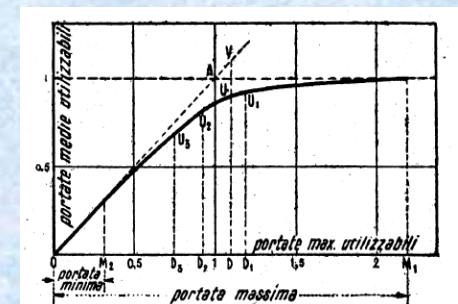
2. *To better meet the demand on weekly scale*

*~ 24-48 h of storage
(weekly peak load)*

WATER STORAGE ON SMALL SCALE

Other advantages:

1. *Prevent the units from working at very low flow rate ($\rightarrow$ very low η)*
2. *Easy routine maintenance without energy losses*
3. *Increasing a bit the Q_{mean} with respect to Q_{max}*



WATER STORAGE ON SMALL SCALE

$$E = \gamma H V \quad \longrightarrow \quad V = k \frac{E}{H}$$

- E = stored energy
- γ = gravity acceleration factor
- H = reservoir average elevation
- V = water volume of the reservoir

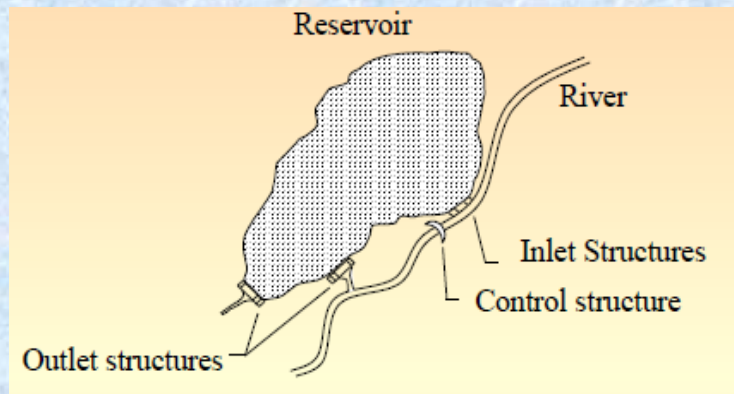
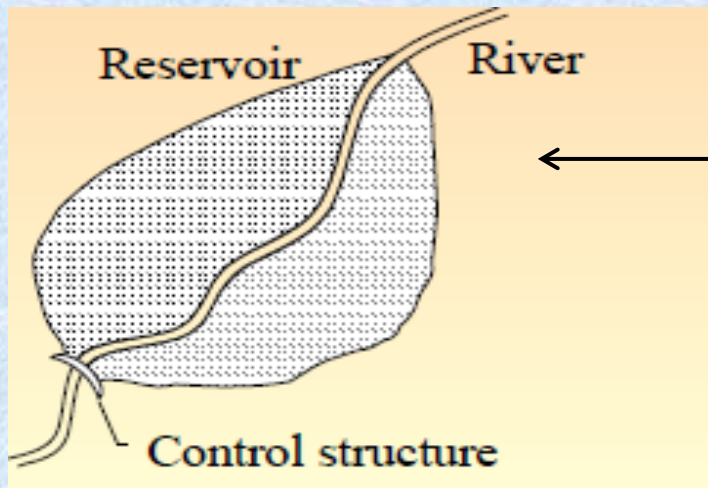
THE CAPACITY NEEDED DECREASES WITH THE HEAD INCREASING



STORAGE IS CHEAPER FOR HIGH HEAD PLANTS

WATER STORAGE ON SMALL SCALE

On line or off line reservoir?



WATER STORAGE ON SMALL SCALE

OFF RIVER PONDAGE MAIN CHARACTERISTICS

Structures safety



☺ The maximum flow rate is a design data, not the natural flood flow!

Managing costs



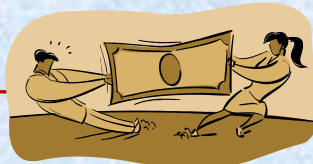
☺ No solid transport, no basin interment

Environment



☺ No fluvial continuum interruption

Construction costs



☹ Usually more expensive to build (but depending on specific site morphology)

WATER STORAGE ON SMALL SCALE



Sand accumulation is more relevant in small pondages where the available volume can be significantly reduced quickly because of the solid transport of the river

Hight = 22,5 m
Erection date = 1939
Original capacity = 50 Mm³



Hight = 22,5 m
Erection date = 1939
Original capacity = 50 Mm³



High = 22,5 m

Erection date = 1939

Original capacity = 50 Mm³

Present capacity = 20 Mm³



Hight = 22,5 m

Erection date = 1939

Original capacity = 50 Mm³

Present capacity = 20 Mm³



Sand accumulation example



Sand accumulation example



Sand accumulation example

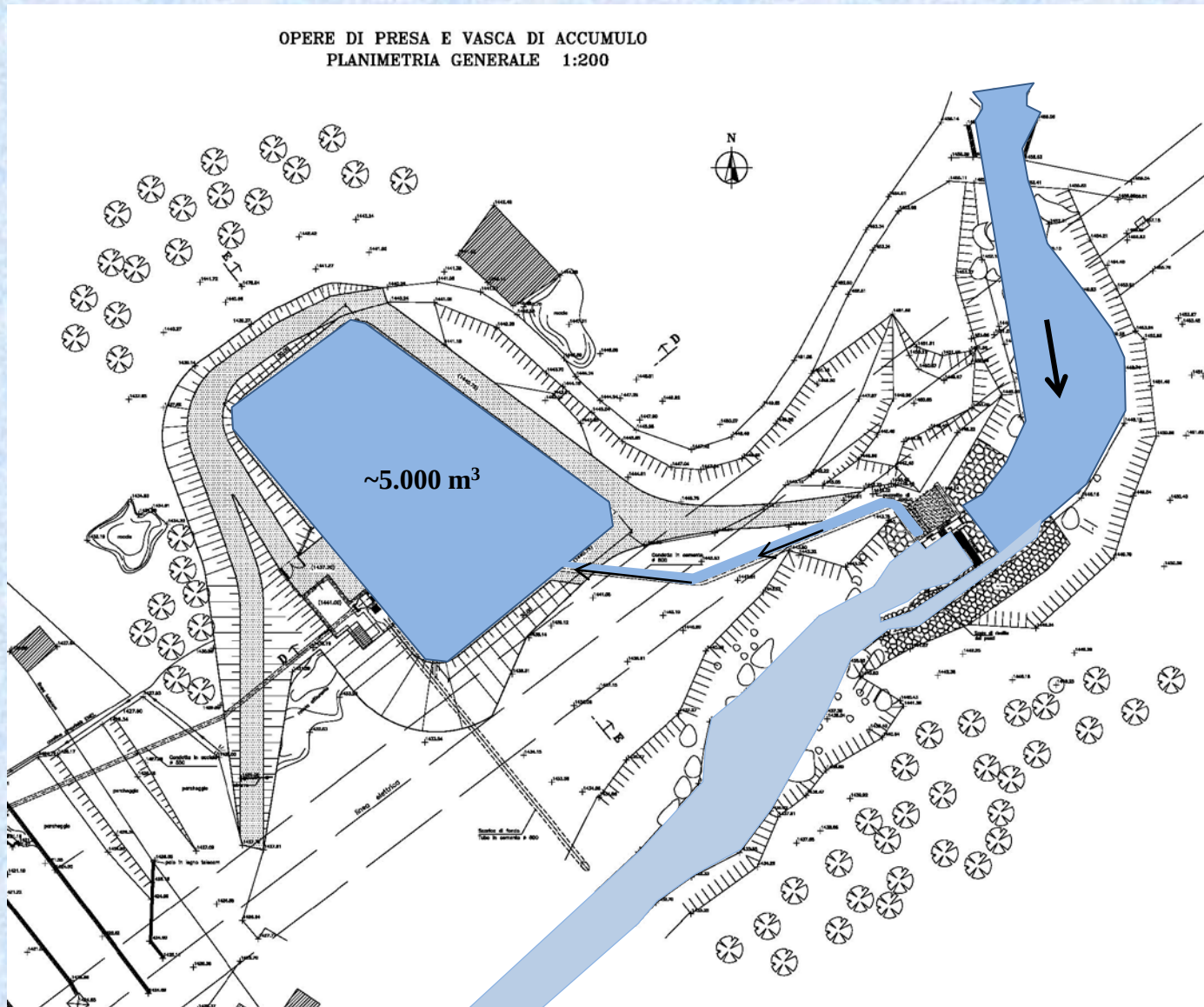


SHP in Tanzania – Preliminary design of one off-river pondage

Design data: SHP supplying a small stand alone grid

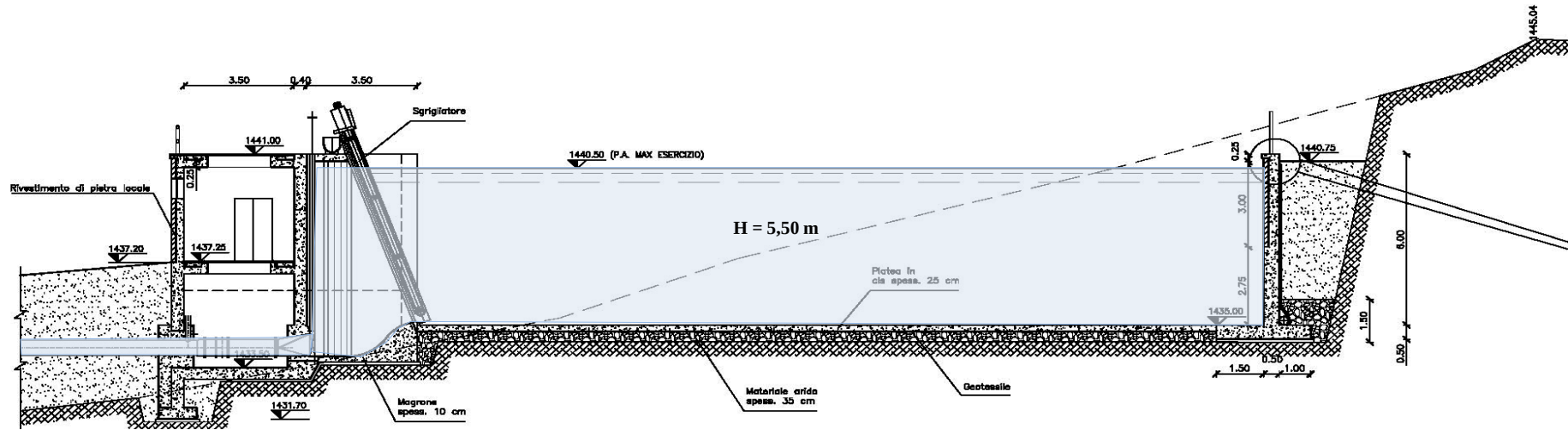
- Average net head = 440 m
- Min flow rate (dry season) = 195 l/s
- Max flow rate of the plant (rain season) = 500 l/s 
- Max flow rate in the river (flood) = 100 m³/s = 100.000 l/s 
- Daily empty hours = 12 h
- Daily full load hours = 8 h
- Daily peak hours = 4 h
- Capacity in the full load hours ($Q = 195$ l/s) = 715 kW
- Min capacity needed in the empty hours = 300 kW
- Flow rate needed in the empty hours = 82 l/s
- Capacity needed in the peak hours = 2.000 kW
- Flow rate needed in the peak hours = 545 l/s
- Storage capacity needed = $(545 - 195) \times 4 \times 3,6$ = 5.042 m³
- Flow rate available for filling the storage = $(195 - 82) = 113$ l/s
- Time needed to fill the storage ~ 12 h

Off-river pondage example

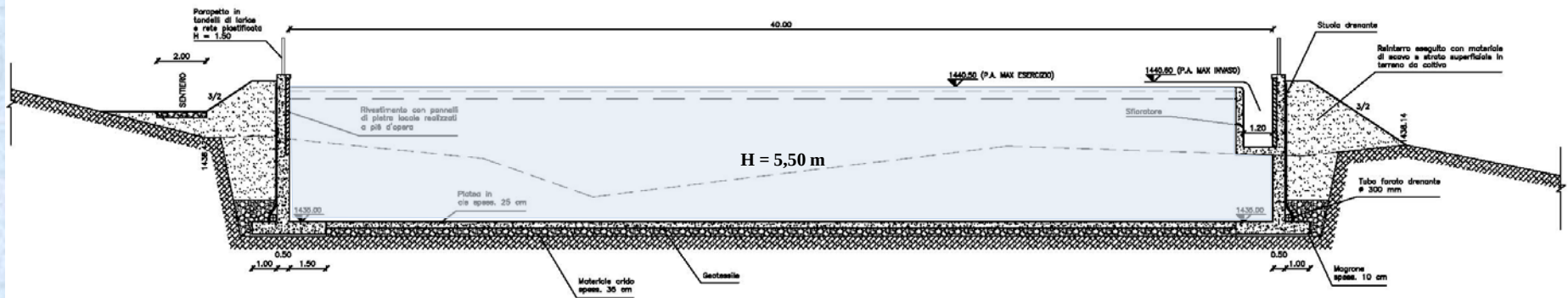


Off-river pondage example

SEZIONE D-D



SEZIONE E-E



Off-river pondage example





AFRICA 2013

International Conference and Exhibition

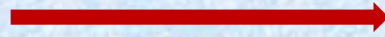
SHP training seminar - 15th April 2013, Addis Ababa

Part 3

Automation and managing aspects

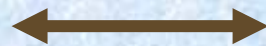
PLANT MANAGEMENT

Plant Management



1. *Information*
2. *Rules*
3. *Drives*

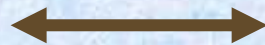
Manned plant



Man



Automatic plant



PLC



An unmanned plant doesn't mean uncared-for plant. It must be seen every day. There are also remote access facilities (internet, GPS etc...) in order to warn about the alarm.

PLANT MANAGEMENT: *INFORMATION* from the plant



Generators



Switchgears



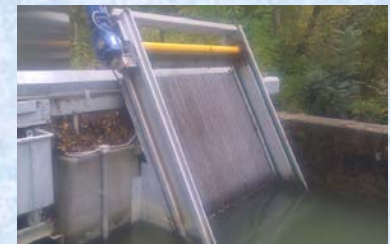
Turbines



Pumps & HPUs



Gates



Trashracks

PLANT MANAGEMENT: *INFORMATION* from an attended plant



Direct view or through measuring devices reading ...

but other senses can as well be used in peculiar situations:

- *olfaction* → *burning smell*
- *hearing* → *abnormal noise*
- *touch* → *excessive vibrations or temperatures*

PLANT MANAGEMENT: *INFORMATION* from an unattended plant

Current transformers



Voltage transformers



Digital flow switch



PT100 probe



Vibration transducers



Pressure switch



Analogic flow switch



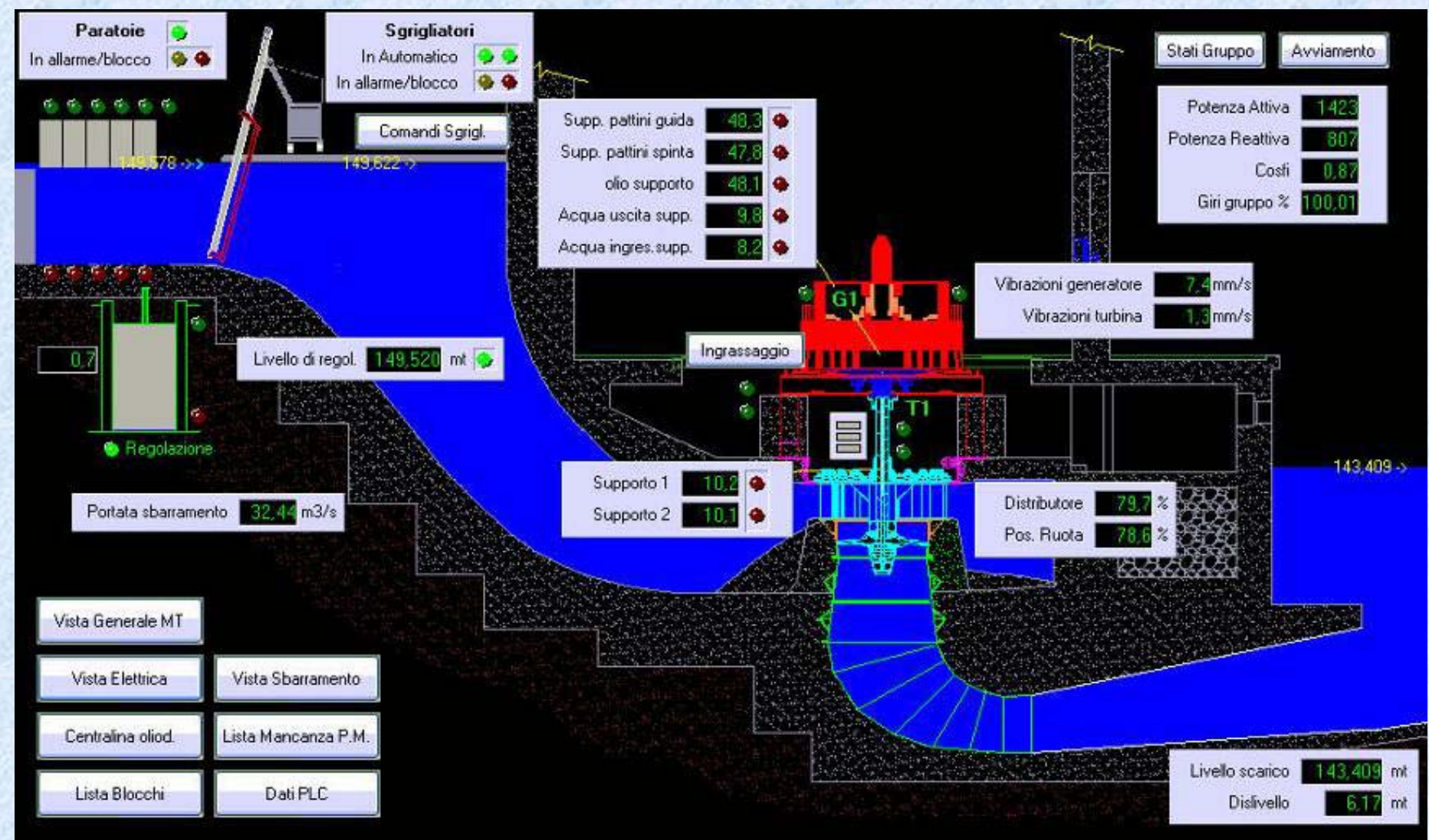
Level transducers



Digital pressure switch



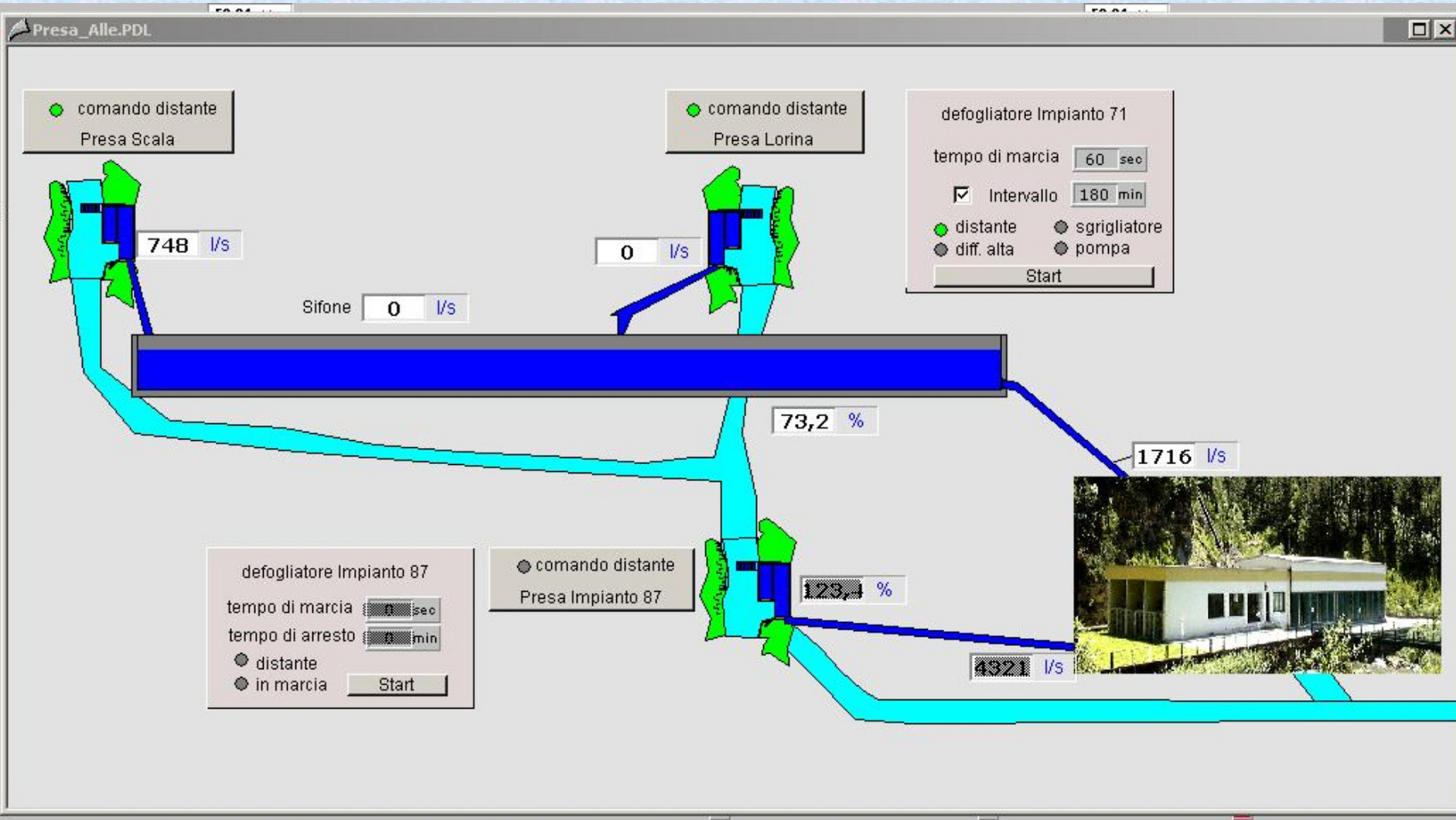
PLANT MANAGEMENT: *INFORMATION* from the plant



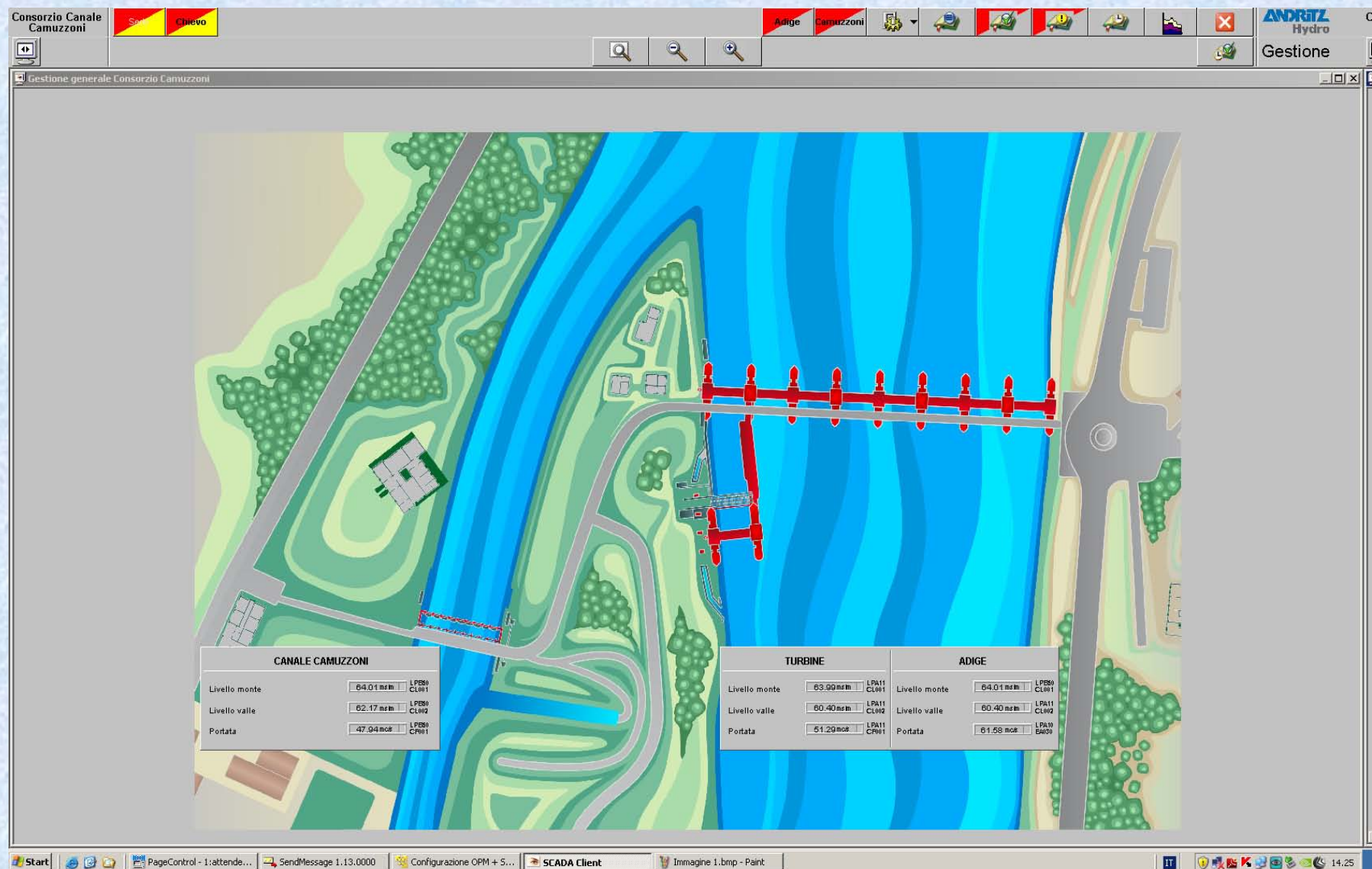
PLANT MANAGEMENT: *INFORMATION* from the plant



PLANT MANAGEMENT: *INFORMATION* from the plant



PLANT MANAGEMENT: INFORMATION from the plant

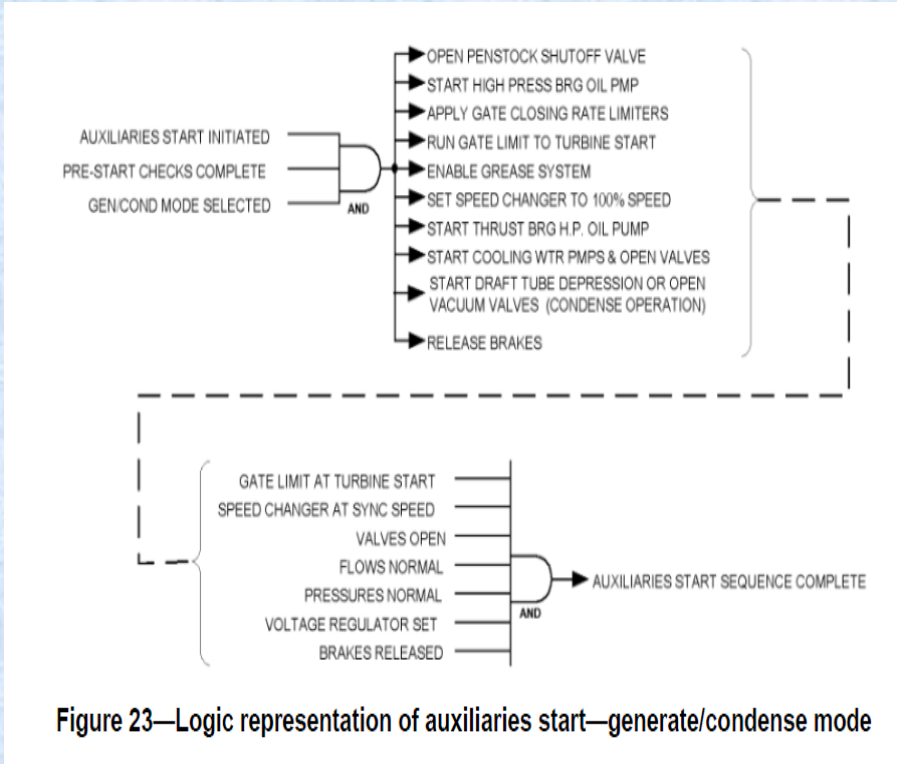


PLANT MANAGEMENT: INFORMATION storage and management (SCADA)

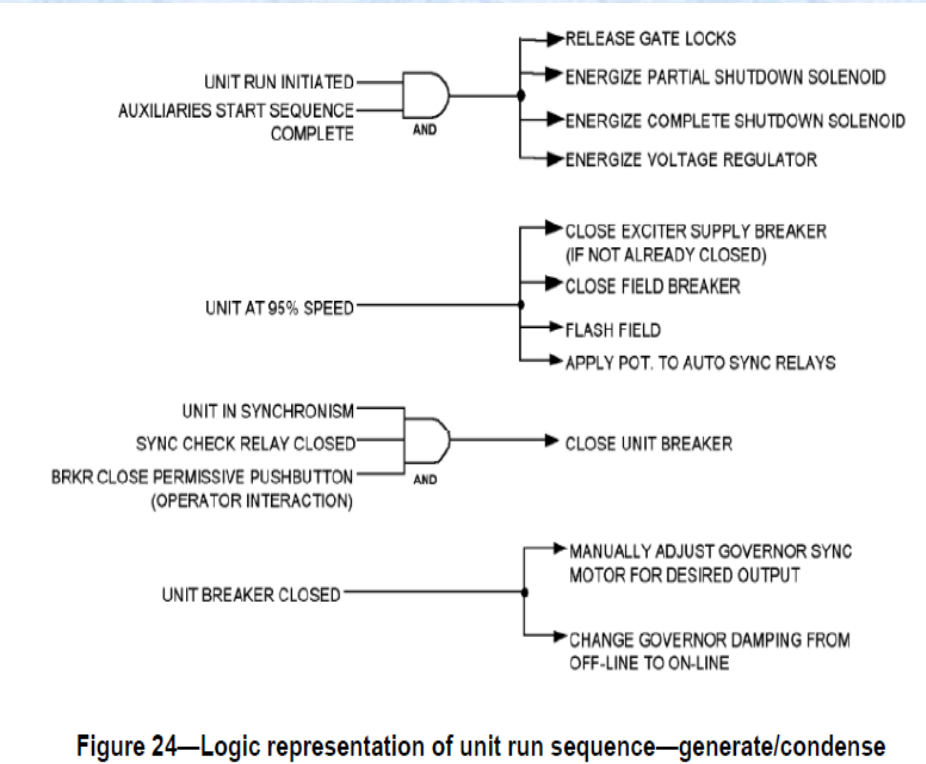


PLANT MANAGEMENT: *RULES* for managing the devices

Auxiliaries start ...



... unit run



PLANT MANAGEMENT: *RULES* for managing the devices

Control sequencing-generating units: auxiliaries start

Input	Position for startup	Type ^a	Originating from ^b	Notes
Mode switch	Generate	C	SB If used.	
Gate limit	Turbine start	C	GV	
Speed changer	100%	C	GV	
Manual voltage regulator	Pre-start	C	EX	
Automatic voltage regulator	Pre-start	C	EX	
Thrust bearing oil press	Normal	C	GN	
Cooling water flow	Normal	C	OT	
Penstock shut-off valve	100% open	C	OT If used.	
Guide bearing oil flow	Normal	C	OT	
Brakes	Released	C	OT	

^aC = control; P = protection.

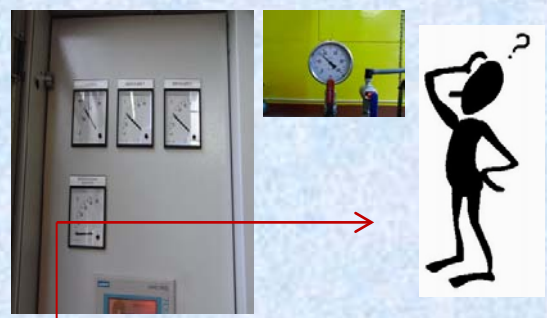
^bTR = transformer; GN = generator; TB = turbine; GV = governor; EX = exciter; SB = unit system; OT = other.

PLANT MANAGEMENT: *ACTUATORS* to drive the equipments



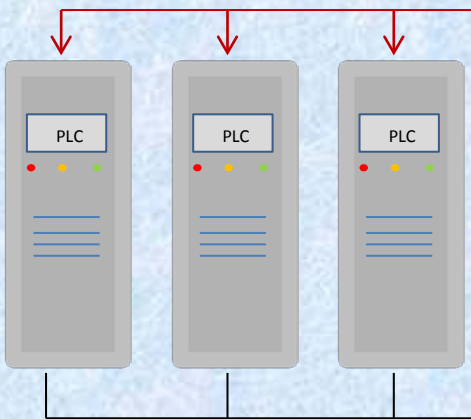
PLANT MANAGEMENT LEVELS: attended plant

PLANT LEVEL

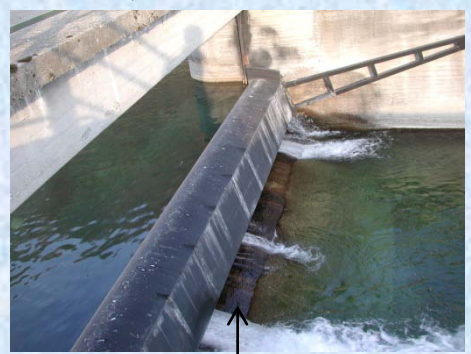


Plant supervisor

UNITS LEVEL



To control specific devices: mainly power units, but also valves, gates, mobile weir, screen cleaner ...



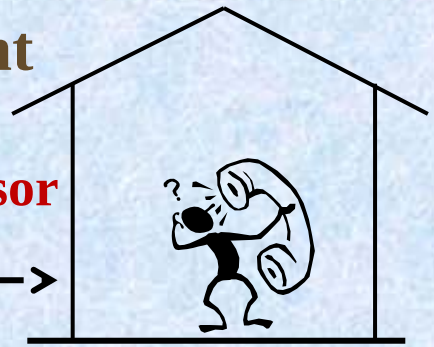
PLANT MANAGEMENT LEVELS: unattended plant

PLANT LEVEL



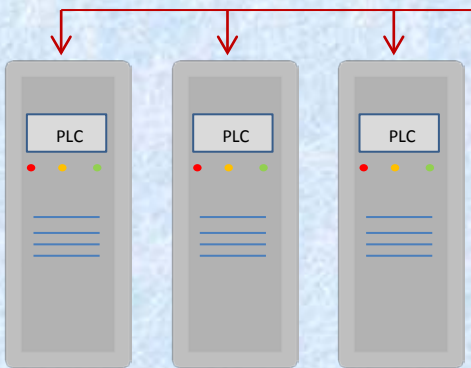
Plant supervisor

← Gps; Internet; ... →



UNITS LEVEL

To control specific devices: mainly power units, but also valves, gates, mobile weir, screen cleaner ...





AFRICA 2013

International Conference and Exhibition

SHP training seminar - 15th April 2013, Addis Ababa

THE END

Lecturer: Nino Frosio