HYDROPOWER DEVELOPMENT 2017

STUDIO FROSIO
hydro engineering

# *Standardization in hydropower projects: how, when and where?*

Luxembourg, September 2017

*Original topic:*

*Standardization of hydropower projects – Aiming for further reduction of maintenance costs, storage & grid balance, digitalizing in service & maintenance of hydropower plants*

*Alternative titles proposed:*

a) *Standardization in hydropower projects: a chimera?*

b) *Standardization in hydropower projects: the pipe dream of off- the-shelf solutions*

# *How to standardize the hydropower projects?*

What does *Standardization* mean?

Oxford Dictionary (OD) definition:
*the process of making something conform to a standard*

Wikipedia (WP) definition :
*the process of implementing and developing technical standards based on the consensus of different parties that include firms, users, interest groups, standards organizations and governments.*
*Standardization can help to maximize compatibility, interoperability, safety, repeatability, or quality*

## ***Compliance with the OD definition***

*Technical standard:* formal document that establishes uniform engineering or technical criteria, methods, processes and practices

# ***What a hydropower project is made of?***

- ***Steps***
  - *Design*
  - *Construction*
  - *Commissioning*
  - *Operation*
  - *Maintenance*
- ***Works and equipment***
  - *Civil works (dam, intake, forebay, channels, …)*
  - *Hydraulic components (gates, valves, TRCMs…)*
  - *Mechanical equipment (turbines)*
  - *Electrical equipment (generators, LV, MV, HV cubicles, breakers, lines…)*
  - *Automation, control and monitoring (SCADA, PLCs…)*

# Compliance with the OD definition



| | |
|---|---|
| IEC 60041:1991 | Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines |
| IEC 60193:1999 | Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests |
| IEC 60308:2005 | Hydraulic turbines - Testing of control systems |
| IEC 60545:1976 | Guide for commissioning, operation and maintenance of hydraulic turbines |
| IEC 60609-1:2004 | Hydraulic turbines, storage pumps and pump-turbines - Cavitation pitting evaluation - Part 1: Evaluation in reaction turbines, storage pumps and pump-turbines |
| IEC 60609-2:1997 | Cavitation pitting evaluation in hydraulic turbines, storage pumps and pump-turbines - Part 2: Evaluation in Pelton turbines |
| IEC 60805:1985 | Guide for commissioning, operation and maintenance of storage pumps and of pump-turbines operating as pumps |
| IEC 60994:1991 | Guide for field measurement of vibrations and pulsations in hydraulic machines (turbines, storage pumps and pump-turbines) |
| IEC 61116:1992 | Electromechanical equipment guide for small hydroelectric installations |
| IEC 61362:2012 | Guide to specification of hydraulic turbine governing systems |
| IEC TR 61364:1999 | Nomenclature for hydroelectric powerplant machinery |
| IEC TR 61366-1:1998 | Hydraulic turbines, storage pumps and pump-turbines - Tendering Documents - Part 1: General and annexes |
| IEC TR 61366-2:1998 | Hydraulic turbines, storage pumps and pump-turbines - Tendering Documents - Part 2: Guidelines for technical specifications for Francis turbines |
| IEC TR 61366-3:1998 | Hydraulic turbines, storage pumps and pump-turbines - Tendering documents - Part 3: Guidelines for technical specifications for Pelton turbines |
| IEC TR 61366-4:1998 | Hydraulic turbines, storage pumps and pump-turbines - Tendering Documents - Part 4: Guidelines for technical specifications for Kaplan and propeller turbines |
| IEC TR 61366-5:1998 | Hydraulic turbines, storage pumps and pump-turbines - Tendering Documents - Part 5: Guidelines for technical specifications for tubular turbines |
| IEC TR 61366-6:1998 | Hydraulic turbines, storage pumps and pump-turbines - Tendering Documents - Part 6: Guidelines for technical specifications for pump-turbines |
| IEC TR 61366-7:1998 | Hydraulic turbines, storage pumps and pump-turbines - Tendering Documents - Part 7: Guidelines for technical specifications for storage pumps |
| IEC 62006:2010 | Hydraulic machines - Acceptance tests of small hydroelectric installations |
| IEC 62097:2009 | Hydraulic machines, radial and axial - Performance conversion method from model to prototype |
| IEC 62256:2017 | Hydraulic turbines, storage pumps and pump-turbines - Rehabilitation and performance improvement |
| IEC 62270:2013 | Guide for computer-based control for hydroelectric power plant automation |
| IEC 62364:2013 | Hydraulic machines - Guide for dealing with hydro-abrasive erosion in Kaplan, Francis and Pelton turbines |

***Hydropower projects (esp. large ones) are already OD standardized***

***Compliance with the WP definition***

OD definition: passive role (*complying to a set of rules* → cost)

WP definition : active role (*implementing and developing* → benefit)

***Motives to standardize***

Company level

- Pursuing specific company interests
- Solving technical problems
- Knowledge seeking
- Influencing regulation
- Facilitating market access

Hydropower project level?

## The Common Perception (CP) of what *Standardization* means

Standardization (technical) ≡ Reduction to a single type or model

Standardization (economics) ≡ production of a large quantity of goods having identical characteristics and thus as the pure serial production of an asset (through which it is preferable to produce the quantity albeit a possible decrease in the production quality).
It promotes economies of scale.

↓

**Standardization of a whole hydropower project is almost impossible**

*The magic word is:* ***REDUCTION OF COSTS***

*Reduction of costs in any phase of the project*

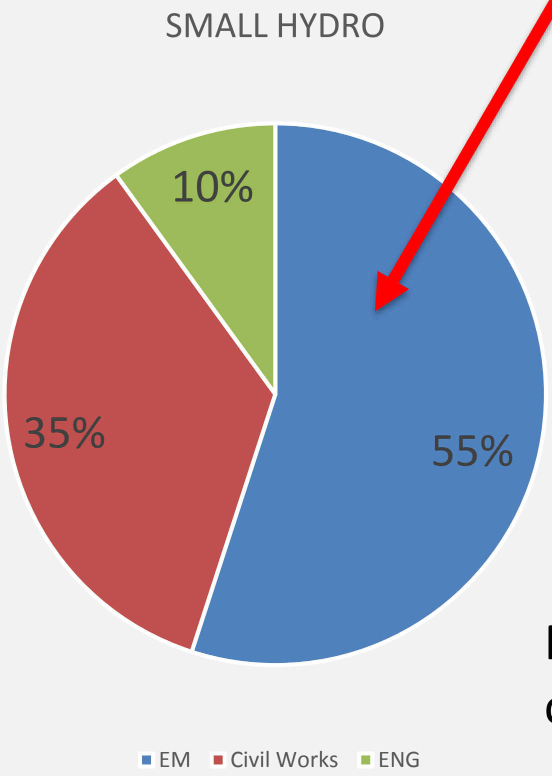
## *When*

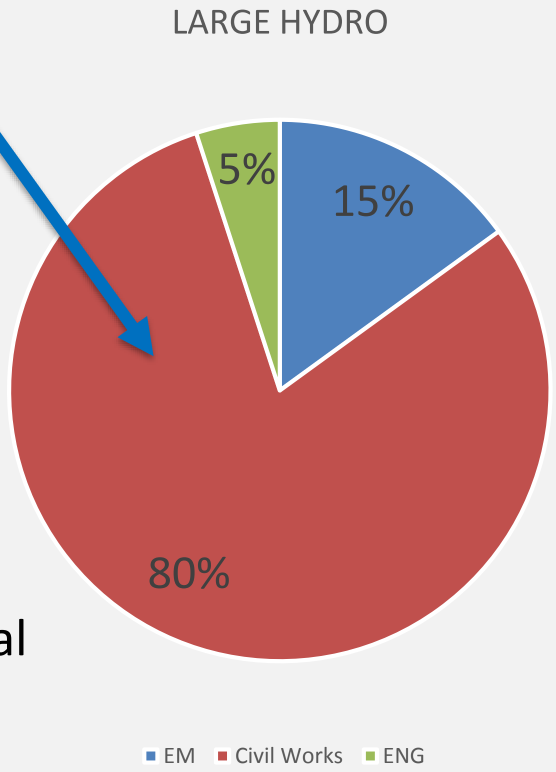
- ***Steps***
  - *Design*
  - *Construction*
  - *Commissioning*
  - *Operation*
  - *Maintenance*

## *Where*

- ***Works and equipment***
  - *Civil works (dam, intake, forebay, channels, …)*
  - *Hydraulic components (gates, valves, TRCMs…)*
  - *Mechanical equipment (turbines)*
  - *Electrical equipment (generators, LV, MV, HV cubicles, breakers, lines…)*
  - *Automation, control and monitoring (SCADA, PLCs…)*

# Where put our attention?




Percentage of total cost of a HPP

# CIVIL AND HYDRAULIC WORKS

## Main barrier: **SITE SPECIFICITY** → **No "copy and paste"**

- Geology
  - Type of foundations (shallow, deep,….)
  - Type of retaining systems (sheet piles, continuous diaphragms, jet grouting columns,…)
- Topography:
  - Optimized position of plant components
- Boundary conditions (access, use of land, ….)

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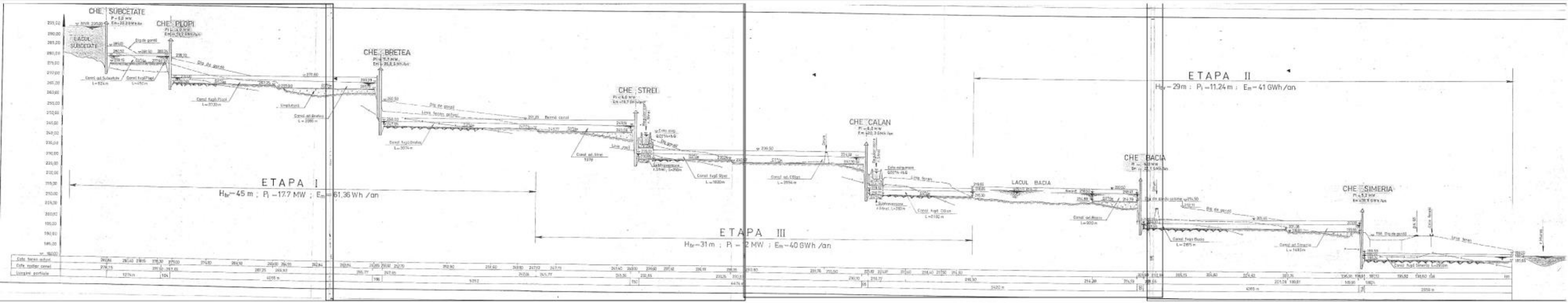
**IT'S DIFFICULT TO STANDARDIZE LARGE HYDRO**

DESIGN PLANTS LAYOUT

***When***

# The *copy and paste dream*: ~ 1990




production of a large quantity of goods

River stretch: 28 km

Total head: 105 m

Total installed capacity: 41 MW

Nr. of plants: 7 equal plants ~ 6 MW each

**When**

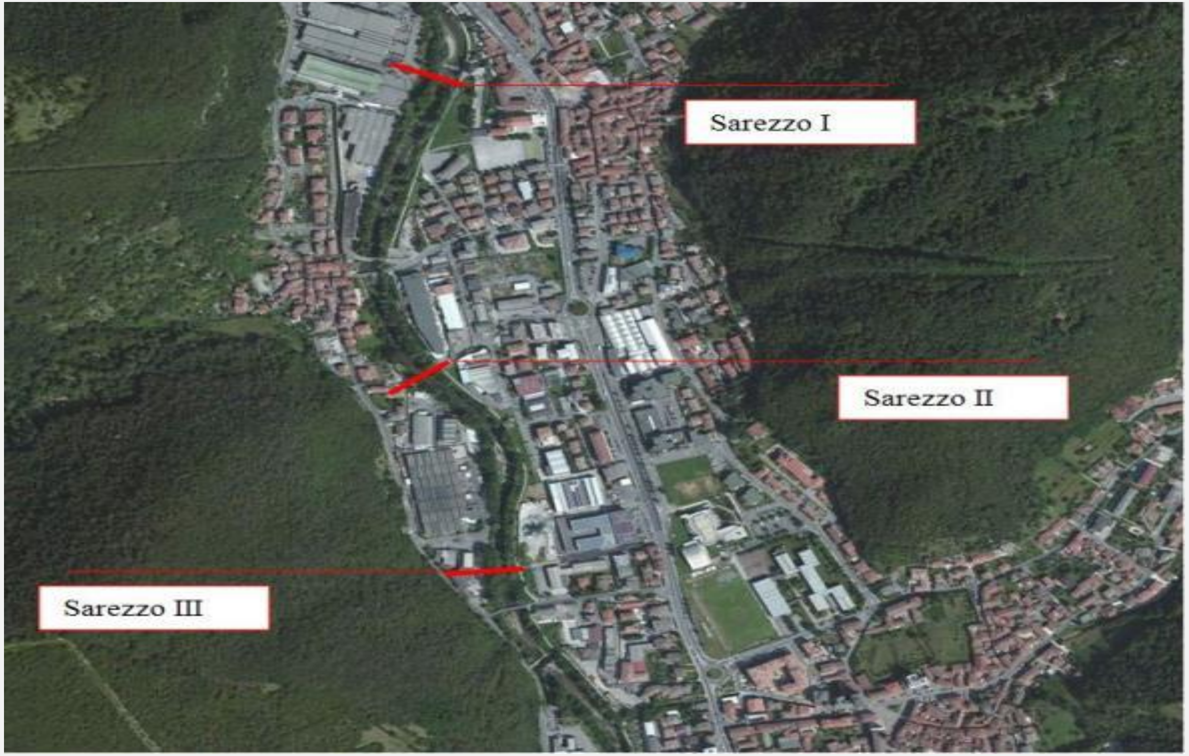
The river stretch of given total head divided in seven parts of similar head

production of a large quantity of goods

The same EM equipment solutions replicated seven times
The same civil works solutions replicated seven times
The same gates, TRCMs works solutions replicated seven times
….

# The *copy and paste* dream comes true: 2016 update

## Cascade of three equal plants



# The *copy and paste dream* comes true: 2016 update

| HPP | Sarezzo 1 | Sarezzo 2 | Sarezzo 3 | |
|---|---|---|---|---|
| Maximum diverted flow rate | 20 | 20 | 20 | $m^3/s$ |
| Average diverted flow rate | 6,79 | 6,79 | 6,79 | $m^3/s$ |
| Average gross head | 3,20 | 3,20 | 3,20 | m |
| Nominal power of the plant | 213,02 | 213,02 | 213,02 | kW |
| Turbine installed capacity | 500 | 500 | 500 | kW |
| Generator installed capacity | 625 | 625 | 625 | kVA |
| Expected yearly average energy production | 1,49 | 1,49 | 1,49 | GWh |
| Cost of design and realisation | 1.920.000 | 1.950.000 | 2.050.000 | € |
| Cost/capacity ratio | 3.840 | 3.900 | 4.100 | €/kW |
| Cost/energy ratio | 1,29 | 1,31 | 1,38 | €/kWh |
| Incentivised tariff | 210 | 210 | 210 | €/MWh |
| Expected yearly income | 313.000 | 313.000 | 313.000 | € |

# The *copy and paste dream* comes true:  2016 update

***3 equal flap gates***

***6 equal units***

***3 equal TRCMs***

***3 equal unit gates***

***3…..***

***3….***

***3…***

# The *copy and paste dream* comes true: 2017 update

## Cascade of six small hydro plants in Northern Italy

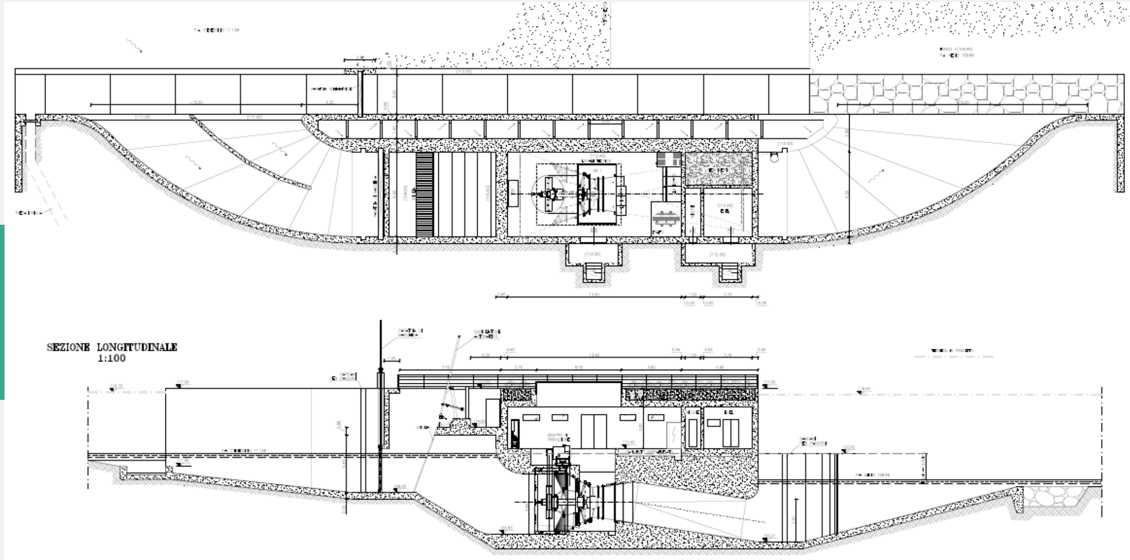
### Cost reduction: the second pillar of profitability assurance

- Plants of this size may be expected to have a higher feed-in tariff
- But construction costs are also higher in relation to performance

The realization of several similar projects represents an opportunity to reduce the overall investment

By standardizing the technical solutions, the construction, planning and operating costs can be reduced:

- the layout is basically the same for each hydroelectric power station
- the building of the powerhouse is particularly compact




The boundary conditions are almost identical:

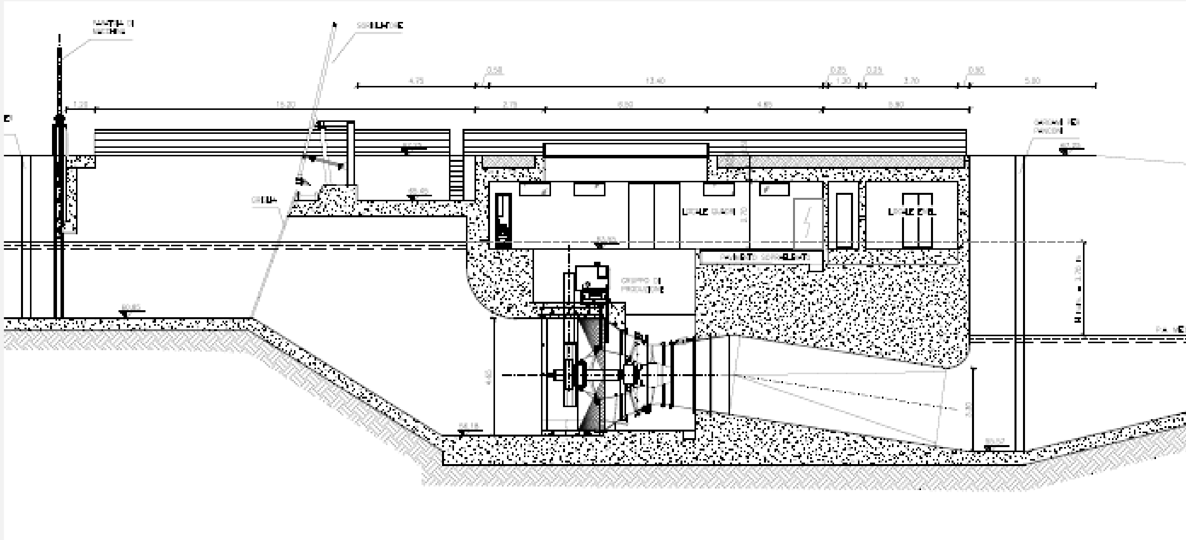
Accesses, morphology, geology, etc….

# Reduction of construction and operating costs

The choice of the machines has fallen on the belt-driven pit turbine:

- Cheaper than a Kaplan turbine
- Requires a narrower substructure
- The efficiency is nevertheless good

In cooperation with the manufacturers, we also uniformize the delivery as far as possible with regard to the size of the units



WKA Badia –Längsschnitt des Krafthauses

In this way we reduce:

- The cost of delivery (in comparison with a single order)
- The operating and maintenance costs

## Main data of the projects

- The rated flows were reduced to improve the efficiency of the projects
- **MAIN DRIVER OF THE STANDARDISATION:** **Direct access to feed-in tariffs (plants with an average output up to 250 kW)**

| SHPP | $Q_{old}$ ($m^3/s$) | $Q_{new}$ ($m^3/s$) | H (m) | $P_{TUR}$ (kW) | E (MWh/yr) |
|---|---|---|---|---|---|
| #1 | 26,00 | 9,00 | 3,70 | 300 | 1.560 |
| #2 | 26,00 | 15,00 | 2,30 | 310 | 1.190 |
| #3 | 24,00 | 15,00 | 1,60 | 220 | 800 |
| #4 | 24,00 | 15,00 | 3,40 | 460 | 1.660 |
| #5 | 24,00 | 13,00 | 3,50 | 410 | 1.680 |
| #6 | 17,00 | 15,00 | 2,00 | 270 | 750 |
| **TOTAL** | | - | - | **1.970** | **7.640** |

# ELECTRO-MECHANICAL EQUIPMENT DESIGN

*Standardization of hydro turbines*

Process started between ‘70s and ‘80s XX century

Range of power 100 ÷ 5.000 kW

- Choice of the typical machine
- Choice of the acceptable simplifications

Reduction of design time → Reduction of delivery time → Reduction of investment costs

Use of off-the-shelf components:
→ Reduction of the O&M costs

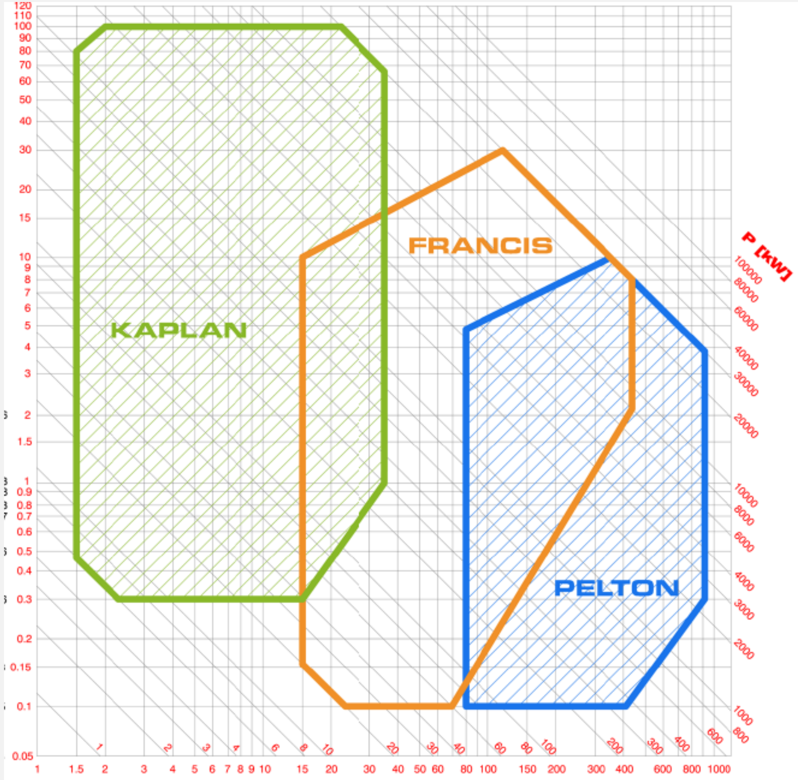
# ELECTRO-MECHANICAL EQUIPMENT

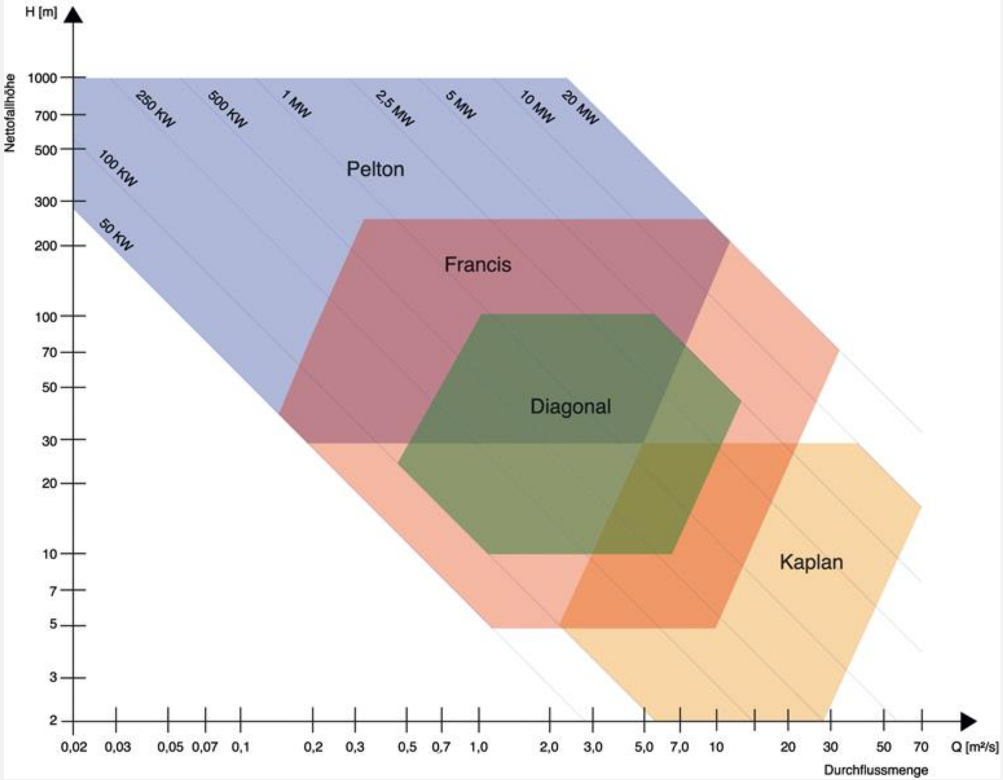
1987

| H (m) | Type | Nr. models | Features | Axis | Speed | Speed increaser |
|---|---|---|---|---|---|---|
| 2,5÷10 | 4 blades KT | 1 | Single regulated | V-Incl. | 158-625 | Y |
| 7,5÷20 | 5 blades KT | 1 | Single regulated | V-Incl. | 158-625 | Y |
| 13÷20 | Francis | 1 | Distr. 12/12 blades or 12/6 blades | V-H | 200/1500 | Y/N |
| 85÷400 | 1-2-3-4 jets Pelton | 1 | Single type of runner | V-H | 750/1500 | N |

# ELECTRO-MECHANICAL EQUIPMENT

2017



# ELECTROMECHANICAL EQUIPMENT DESIGN AND MANUFACTURING

*Chinese approach:*
Development of a limited sets of machines from each prototype model – chosen from the smallest possible number of models

- Off-the shelf products
- Pre-fabrication and storage of large amounts of units
- Oriented to markets where the attention to efficiency is low

# ELECTROMECHANICAL EQUIPMENT DESIGN AND MANUFACTURING

*European approach:*
Development of a large sets of machines from each prototype model – chosen from the smallest possible number of models. Each standardized machine covers a narrow area of the hill chart

- Customized products
- Set of construction drawings already done for each model in each of the installation versions
- Oriented to markets where the attention to efficiency is high

# PLANT AUTOMATION AND CONTROL

Sector where the standardization is easier thanks to the large set of International Standard (ISO, CEN, IEC, IEEE, etc.) available:

- IEEE Std 1010-2006: Guide for Control of Hydroelectric Power Plants
- IEEE 1249-1996: Guide for Computer-Based Control for Hydroelectric Power Plant Automation
- IEEE Guide for Control of Small Hydroelectric Power Plants
- EN 61850-7-410:2013-01: Communication networks and systems for power utility automation Part 7-410: Basic communication structure - Hydroelectric power plants

# PLANT AUTOMATION AND CONTROL

Low cost of collecting data from the field

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Predictive maintenance: what would have been "unplanned stops" are transformed to shorter and fewer "planned stops", thus increasing plant availability

## Model Based Condition Monitoring

- temperatures monitoring
- vibration analysis
- sound level measurements
- oil analysis

# OPERATION AND MAINTENANCE

Some common sense remarks:

Hydropower plants are made of many off-the-shelf components

Standardization can help to maximize *compatibility* and *interoperability*

That's particularly true if a single operator manages many different powerplants or a single plant with many units. Costs reduction for:

- Spare parts costs
- Maintenance contracts of special components
- Training of personnel for ordinary maintenance activities

# CONCLUSIONS

- Site specificity makes difficult to get technical standardization (Reduction to a single type or model) of hydropower projects, especially large ones (and it doesn’t make much sense, too)
- Standardization (technical and economics related) can be got in single components of a hydropower project as for any other industrial process
- Small hydro cascade systems can benefit from standardization at each stage of the project

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Thanks for your attention.