INNOVATIVE DESIGN FEATURES OF TURBINES FOR HYDRO PROJECTS LOCATED IN HIMALAYAN REGION

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Agenda

• 1st topic  Challenges in Himalayan region projects

• 2nd topic  Alstom solution

• 3rd topic  Innovative features for Pelton turbine

• 4th topic  Recent feedback from sites (Himalayan region)

• 5th topic  Conclusion
Challenges during construction of power house

The geology of the Himalayan mountains presented major challenges like:-

- Remote access to the site
- Land slides
- Soil erosion
- Rock falls
- Floods
- Heavy snow
Major challenges for the design of E & M equipment

• **Equipment and power house layout design** - to offer minimum civil instabilities.

• **Stable turbine operation** - for given water conductor system considering large variation in head and discharge.

• **Design of turbine parts to resist high silt abrasive particles.** Monsoon flow will contain high silt abrasive particles with majority of quartz.
  - Protective coating on critical turbine parts
  - Hydraulic profiles to offer resistance to silt abrasion.

• **Easy and quick maintenance**
  - with minimal down time
  - Interchangeable critical turbine components.
  - Mechanical design to offer dismantling of runner, wicket gates, wearing rings and bottom rings etc. from below.

• **Environmental friendly designs** - to offer minimum pollution to river water.
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Alstom solutions

Challenge –

• Equipment and hydro plant layout design to offer minimum civil instabilities.

Alstom solution

• For under ground power houses it become more obvious to provide a robust and compact equipment design and power house layout. Some of the innovative features developed by Alstom are

  - Thrust bearing on turbine head cover
  - Ring gate in place of main inlet valve
  - Compact draft tube design
  - Hydro plant lay out design using 3D software
Thrust Bearing on Turbine Head Cover

- Used for Francis and Kaplan
- Alstom has long experience
  - since 1955, more than 350 units
  - since 5 years, more than 22 units
- Up to 30% reduction in height (btw turbine and generator C/L)
- Shorter shaft ⇒ Better dynamic behavior
- Higher stiffness ⇒ Higher natural frequency
- Thrust loads balance hydraulic forces
- Good accessibility + maintenance of thrust bearing
Thrust Bearing on Turbine Head Cover

- The cone is a simple structure that presents a high axial strength
- Fixed on or part of the head cover
- 1 or 2 access openings for shaft seal and guide bearing maintenance
- To be reinforced (if necessary) to ensure a perfect flatness.
- Operating ring can be installed on thrust cone.
Ring gate

- A ring gate is a cylinder placed between the stay ring and the distributor to cut off the flow of water.
- It replaces the traditional main inlet valve (MVI) in the power house.
- Ring gate operating is controlled by the governor through synchronized hydraulic servomotors.
- The ring gate geometry is defined by a series of model and proto tests.
Ring Gate - advantages

- Basic Technology ⇒ Alstom product patent (1947)
- More than 40 units commissioned from 1962 to 2013
- Global cost – no significant change (ring gate + modified distributor + stay ring ~ conventional inlet valve)
- Reduced civil works costs
- No obstruction in water flow ⇒ no loss of efficiency or power
- Compact solution ⇒ complete and reliable sealing
- Self closing is easily obtained (for medium size ring gates)
Compact draft tube

Advantages

• Civil excavation at site can be reduced substantially
• Most suitable for underground power house with long galleries
• Easy manufacturing, transportation and erection at site
• Improves delivery time
• Improved performance of turbine for wide range of operation
Challenge

- Stable turbine operation for given water conductor system also for large variation in head and output

- **Alstom solution**
  - Alstom R &D has developed a solution to ensure stable operation of turbine continuously at rough zone (extended part load operation).
  - Runner profile is first developed analytically (by CFD analysis / FE analysis) and checked for structural stability for life time.
  - During model testing major hot spots in runner profile are implanted with strain gauges to determine mechanical behavior during dynamic conditions and simulate operating conditions.
  - Model testing results can be validated on prototype testing at site.
Stable operation for extended part load operation
Alstom solution

Challenge

• Design of turbine parts to resist high silt abrasive particles. Monsoon flow will contain high silt abrasive particles with majority of quartz.

Alstom solution

• Continuous development of new hydraulic profiles to offer maximum resistance to silt abrasion.

• Protective coating on critical turbine parts

  ➢ Good quality of coating and consistency through extensive testing and stringent quality check at various stages and also by preparing test coupons for prototype product qualification.

• Dedicated silt erosion simulation test rig facility to carry out standard coating qualification test (adhesion, porosity, hardness…)

• to evaluate erosion rate and validate consistency of erosion resistance.

• Development of online silt measurement device.
R & D activities for services
Erosion Study on special test rig at Vadoadra lab

• Erosion is tested depending on the following parameter:
  • Pressure
  • Jet velocity
  • Angle of impingement
  • Duration of tests
  • Silt particles concentration
  • Silt particles size
  • Silt particle shape

• Solutions: Soft Coatings & Hard Coatings
  • Tests are carried to establish life span of existing coating solutions

• Typical silt erosion test parameters simulated in Alstom laboratory
Damaged runner due to silt erosion

- Runner before repair
- Runner cracks
- Repaired runner

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Stage I – Flat sample testing

- To characterize the material, flat sample testing was carried out on
  1) 13Cr-4Ni Stainless steel, 2) Thin HVOF coating, 3) Thick protection

- Erosion rate of Thick protection is 13 times lower than Stainless Steel and 9 times less than thin protection in terms of volume loss.
- Thin HVOF coating is removed after one hour of erosion test, then behavior is equivalent to Stainless Steel
Challenge

- Environmental friendly design.

- **Alstom solution**
  - Water lubricated turbine bearings
  - Self lubricated bushes for guide vanes and inlet valve trunnion
Hydrostatic Water Guide Bearings

Filtered Water for Lubrication

Pocket for Pressurized Water

Hard Ceramic Coating
Hydrostatic Water Guide Bearings

DESIGN FEATURES

- Most suitable for shaft dia ranging from 500 mm to 1500mm
- Water is supplied to bearing shell through 6 or 8 pockets provided with orifice plate
- Bearing ID and shaft sleeve are hard coated
- Clean and filtered water supply for bearing lubrication and cooling (<90microns)
- Requirement of discharge (1~3 l/sec) and pressure (penstock pressure) cooling water is quite less.
- Pressurised water flows around bearing surface ensures bearing stiffness.
- Radial offset of shaft and pressure variations in pockets brings shaft on axis.
- Inflatable air seals provided at the bottom of bearing shell can be applied during maintenance.
Hydrostatic Water Guide Bearings

ADVANTAGES

• Profitable environmental friendly solution
• Replaces bearing & shaft seal
• No consumption or replenishment of oil
• Lower friction losses than traditional oil bearing
• No cooling system required (pumps, exchangers, cooling water circuit, safety systems...)
• Same watering device as for traditional shaft seal

Alstom has long experience in supply of hydro static bearing globally for Francis turbines, bearings are performing satisfactorily.
Self lubricated bushes for wicket gates and inlet valve trunnions.

Validation by Alstom

• Validate the main characteristics of bushes available in the market

• Compare behaviour of bushes from available varieties in the market

• Classify specific use of bushes

• Validate new bushes

• Feedback from actual performance of bushes at site
Alstom’s Self Lubricated Bushes Test-rig
Self Lubricated Bushes-
Comparison of Critical Characteristics

Friction characteristic

Wear characteristic
Hydro plant layout using 3 D Software
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Innovative features for Pelton turbine

Manufacture

• Complex runner form creates difficulties for casting, NDE and manufacturing.

• Materiel defects require extensive repairs which prolong delivery periods and increase costs.

• Problems of casting quality have increased progressively over the last 30 years.

Maintenance

• Abrasion and cavitation erosion wears all buckets evenly. Wear can be predicted by experience and repaired on a programmed basis.

• Risk of fatigue cracking requires frequent inspection. Unplanned outages are required to repair cracks or exchange runner.

• Cracking frequency can be related to stress levels in the critical zone at the bucket attachment, to determine the recommended inspection intervals.
Innovative features for Pelton turbine

- Increased Efficiency =
- Increased Jet Dia. +
- Reduced Bucket Width

- Increased Jet Load +
- Reduced Attachment
- = Higher Stresses

> Number of Jets
> Jet Impacts/rev.
> Fatigue Stress Problems

Improved Efficiency > Fatigue Stress
Innovative features for Pelton turbine

The Hooped Pelton Runner offers

• Resolution of fatigue crack problems
• Extended intervals between inspections
• Reduced delivery time with reliable material quality
• Simpler maintenance operations, more convenient, with less equipment
• Accelerated repairs possible if required
• Significant savings for bucket renewal compared with a new one-piece runner
• Equivalent hydraulic performance
• Reduced vibrations
• Interchangeability

Function for buckets
Transformation of the jet’s Kinetic energy

Function for hoops
Transmission of the torque
Innovative features for Pelton turbine

Site feedback of hooped runner
Innovative features for Pelton turbine

- Water Interference Test

Before Test

After 250 hr running
Innovative features for Pelton turbine

New development for Pelton runners
Alstom has developed forged fabricated runners operating under high silt zone. Main features are

- Disc is separately forged and rough machined.
- Bucket is forged in 2 or 4 parts using die-forging
- Buckets are welded with high precision to disc.
- Complete assembly is stress relieved & finally machined as per drawing.
- Runner is hard coated before dispatched to site.

Above process ensures maximum resistance to silt abrasion during operation
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Recent feedback from site – Chamera III

- Runner before commissioning
- Runner After first monsoon
  - Fine erosion on runner
- Runner 3 monsoon season
  - Erosion on runner bend
- 3 x 77 MW V Francis turbine with Net head of 227 meter
  - Machines have operated more 11500 hours
  - Silt erosion is now evident on runner surface.
Recent feedback from site – Chamera III

Stay ring spiral casing after first monsoon

Stay ring and spiral after 3 monsoon

Max silt concentration level observed during last 3 monsoon was less than 1500 PPM
Recent feedback from site - Chuzachen

Chuzachen (2 x 55 MW Francis turbine) have completed two years of successful operation. Some of the feedback received from the site are:

- Both machines have run for approximately 8000 hrs. in one year
- Total starts and stops per machine is approx. 100 times
- Number of tripping of a machine in a year – Nil
- No major / minor mechanical failure during the year
- No appreciable change in health parameter of machines (like bearing temp, Vibrations, noise etc)
- No evidence of erosion, cavitation on critical turbine parts
Recent feedback from site - Uri II

- Uri II (4x 60 MW Francis turbine) have completed one year of successful operation.
- Silt level is low in Uri power house.
- No evidence of silt erosion on turbine components.
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Conclusion

- There are wide range of opportunities to improve the global performance of hydro plant under challenging conditions imposed by Himalayan region.

- With global data base for operation of its hydro plants located worldwide, each problem is carefully captured and analyzed.

- Our R & D centers located globally continuously innovates new solutions for performance improvement of hydro plant based on feedback.

- Careful techno–economic investigation also carried out to ensure optimum use of resources and best return on investments.