Operation and Maintenance Problems of Hydro Power Units – Research Based Solutions from Real Life Typical Cases

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Abstract-*This paper attempts to present a combined view of various operation & maintenance problems in the areas of turbine, generator, governing and associated equipments, static excitation system and various other auxiliaries, which are constituents of a Hydro power generating unit in a Hydro power station. The effect of these problems on the relevant part of the machine is brought out together with remedial measures to solve them and to prevent their recurrence as a long term measure.*

Keywords: Draft tube; Generator circuit breaker, Main slide valve of governor, Cooling Water, Push Button; Governor Oil; Tripping logic; Cavitation; load throw off: Flooding of power house; Stator earth fault; Generator Field Breaker, Electro hydraulic transducer.

Abbreviations: AVR: Automatic Voltage Regulator; CW: Cooling Water; DT: Draft Tube:EHT: Electro Hydraulic Transducer; ESV: Emergency Slide Valve; GA: Guide Apparatus; GCB: Generator Circuit Breaker; GFB: Generator Field Breaker; MSV: Main Slide Valve; OPU: Oil Pressure Unit; PB: Push Button; PH: Power House; DW: Dewatering; TRC: Tail Race Channel.

I. INTRODUCTION

To harness the renewable energy of available water resource, it is well known that Hydro Power Stations are uniquely designed/built based upon many factors like topography of surroundings, upstream storage capability, downstream requirements etc. This uniqueness leads to requirement to manufacture and supply a tailor made machine consisting of turbine for specific conditions of head; discharge, submergence etc. and matching generator and associated equipments. The Governing system which controls the machine is also part of this uniqueness, whereas the excitation system which puts life in the machine is quite independent of its type [1].

Operational problems may start appearing from day one on first spinning of a new machine or after capital maintenance thereof, until its first synchronization and loading in the grid. Usually, such problems are tackled jointly by site engineers of manufacturers and the owner and thereafter, 72 hours continuous on load run would further confirm suitability of the machine for commercial operation by the owner under guidance of manufacturer's engineers.

A new machine in the hands of owner for operation can give more problems until their operation and maintenance engineers get comfortable with various operational procedures, routine maintenance requirements etc. as per the operation and maintenance manuals of suppliers and site commissioning reports of the machine.

II. PROBLEMS IN THE MECHANICAL/ELECTRICAL AREAS

In the Table 1 below, the problems of mechanical nature related to turbine, generator, water conductor system etc. and of electrical areas for governor and excitation system etc. are given, which have been usually encountered in the past at various project sites.

Table 1: Problems, Cause & Effects and Remedial Measures [2-3].

S. No	Problem	Probable Cause(s)	Effect on performance and remedial measures	Remarks
1.	Very fast rise or excessive slow rise of guide bearing temperatures during first run	1. Presence of foreign material in the bearing housing 2. Unbalance of rotor 3. Low oil level in bearing housing 4. Wrong bearing clearances 5. Inadequate bedding or chamfering of pads 6. Poor cooling of pads from insufficient oil/CW circulation 7. Un calibrated/defective thermo sensing devices	1. Commissioning schedule distributed 2. Replacement/repair of pads and journal cleaning 3. Oil replacement or its cleaning and testing 4. Re-calibration of thermo device(s) 5. Re cleaning of bearing housing 6. Resetting of clearances	1.Very fast rise in temperature is the result of rubbing which causes damage to babbit metal of pad(s). 2.Tripping on over temperature protection will not work on rubbing.

2.	Rubbing of rotor fan with air guide(s) or vapor seal segment(s) touching shaft or Kaplan runner hitting its chamber	1. Inadequate clearances during erection	1. Stop machine and increase clearance(s) 2. Scrapping of runner chamber to increase clearances will be time consuming	Vapour seal segments can be installed later after balancing
3.	Excessive vibrations/noise	1. Rotor unbalance 2. Pressure Pulsations in turbine 3. Unequal GV^S Opening 4. Excessive bearing clearances or non-concentric bearing circles	1. Fatigue failures 2. Commissioning delay 3. Inability to take full load	Carry out balancing of rotor as soon as possible
4.	Oil splash from guide bearing(s)	1. Inadequate height/varying gap between oil retaining sleeve and shaft 2. Excessive incoming oil but inadequate outlet 3. Less viscous oil	1. Loss of bearing oil and chain of defects	
5.	Excessive thrust bearing temperature	1. Unclean bearing housing 2. Excessive/Uneven load on pads due to i) Hydraulic thrust more than designed ii) Incorrect difference in magneticaxes of stator and rotor iii) Uneven spring mattress bed/setting of pads 3. Inadequate cooling	1. Likely damage to bearing causing forced shut down for repair/resetting or replacement of pads/springs	
6.	Excessive sound from flow of CW in pipes	1. Oversized pipes vis-à-vis required rate of flow	1. Health problems of operators 2. Difficulty in talking/hearing in the PH	Use globe valves instead of gate valves to control flow
7.	Mixing of water and oil in the bearings	Oil cooler tube failure	Poor performance of bearing in the long run	Installation of moisture detector in bearings suggested
8.	Excessive carbon brake dust/oil vapor deposition on stator/rotor windings and brake track surface	1. Bearing vapor seal non – performance 2. Brake dust collector not in service 3. Carbon brush bedding on slipring not done properly or incorrect brush material,spring pressure	1. Winding Insulation Deterioration 2. Increase in brake duration 3. Sparking at slip rings	1. Periodic Cleaning is required at slipring area/rotor inter polar joints, stator overhang winding
9.	Faster wear of brake shoes/grooving in brake track	1. Higher speed/pressures of brake application than necessary 2. Incorrect material of brake shoes/pads	Frequent replacement of brake shoes and forced shut down	Generator manufacture guidelines to be followed
10.	Shifting of rotor lead or cover plates Between the arms of rotor hub	1. Improper tightening/locking of fasteners 2. Non-butting of plates against stopper		Inspection of rotor after over speed is mandatory
11.	Periodic enlargement of	1. Rotor swings during operation in grid	Increase in vibrations	

	guide bearing clearances	2. Improper locking/doweling of bearing house		
12.	Flooding of power house/submergence of Generator/ Control panels etc.	1. Breakdown of cast iron valve during operation used for CW tapping from penstock 2. Break down of PH wall during water release from opening of adjacent bypass gate 3. Unforeseen reasons like heavy rains entering PH or retaining wall collapse on downstream side during erection stage	1. Complete disruption of ongoing works 2. Great efforts required for dewatering of PH 3. Re-conditioning or replacement of submerged parts 4. Generator and control panels dry out and recommissioning	1. Use cast steel valve instead of cast iron valve 2. When required open farthest bypass gate from the PH wall 3. Contact manufacturer for guidelines for restoration
13.	Excessive foaming sludge formation of governor oil	1. Mixing of 2 groups of oil	1. Malfunctioning of governing system	Use same oil type for top up
14.	Repeated failure of shear pins of guide vanes	1. Excessive lifting of regulating ring due to faulty erection of GA system 2. Foreign matter lodged between GV^Sduring stopping 3. Excessive deflection/tilting of top cover	1. Forced downtime for restoration of normalcy	Intake gate falling may be required if speed doesn't fall sufficiently to apply brake
15.	Excessive water leakage through GV bush housings	1. Inadequate sealing 2. Inadequate greasing inside the bushes	1. Flooding in turbine pit requiring additional DW pumps 2. Danger of Water/Moisture ingress in turbine bearing 3. Unpleasant view of turbine pit space	Care is required for proper fitting of cup seals and 'O'rings during erection
16.	Excessive closing time of servo motors in the damping zone during load throw or upon stop command for normal stopping	Mismatch of holes of throttle device and servomotor piston rod, due to some turning of the latter	1. Load throw process gets disturbed 2. Emergency closing signal may get generated on 'GV^S fail to close in preset time', Causing more complications like intake gate falling etc.	1. Problem must be attended as soon as possible 2. Proper locking of piston rod must be ensured in correct position.
17.	Internal oil leakage in the governing system	1. Conicity in servomotor cylinder 2. Excessive clearance due to wear between piston and cylinder of servomotor(s)	1. Frequent loading/unloading or start/stop of OPU pump motor 2. Heating of oil/pipes/motor	
18.	External oil leakage from the governing system	1. Kaplan runner trunnion seal damaged 2. Servomotor shaft chevron packing failure	1. Oil loss in TRC or turbine pit 2. Water entry in governor oil system leading to its mal-functioning	1. Periodically check for floating oil in TRC 2. Chance of runway speed due to governor failure
19.	Continued loss of metal from runner/stay vanes	1. Excessive cavitationdamage from part load operation or other reasons	1. Forced shut down for repairs 2. Possibility of higher vibrations, lower efficiency	1. Repair by weld deposit of same material or by

	etc. during operation	2. Erosion/corrosion damage from silt		application of polymer coatings
20.	Non performance of bearings	1. Bracket shifting or sinking of foundations 2. Excessive temperatures 3. Deterioration of oil quality	1. Major problems likely in long term requiring prolonged shutdown	1. Periodic Centrifugal/electrostatic cleaning of oil and testing is suggested
21.	Turbine shaft working seal failures leading to water escape (main seal)	1. Clean Cooling water unavailable to seal 2. Excessive runner top cover pressure 3. Material selection incorrect with respect to surface velocity requirement 4. Inadequate spring pressure	1. Loss of energy generating water 2. Chance of flooding of turbine guide bearing and pit increased	1. Signaling of CW failure to seal should be acted upon immediately
22.	Turbine shaft isolation seal failure (Air inflated repair seal)	1. Joint failure in rubber ring 2. Insufficient air pressure for expansion of rubber ring to make proper contact all around with the shaft	1. Even for smallest work in main seal, dewatering of DT will become necessary	1. Periodic gap checking after/before inflation should be done
23.	Dewatering/Drainage problems of turbine DT and PH	1. Choking of rather long pipes of systems by mud etc. causing tripping of pump motors 2. Excessive leakage from dropped down DT gate 3. Excessive leakage from the closed penstock gate (which is let into DT during dewatering).	1. Delay in dewatering causes increased shut down duration or delays in erection schedule of new units	1. Repeated switch ON of dewatering pump motor should clear the pipes of mud 2. Services of divers may be required to plug leakage from DT gate
24.	In single PB start, machine over speeds	1. GCB interlocking contact in start circuit closed inadvertently	1. Requires restart after trouble shooting	Over speed protections must be effective
25.	Machine not starting in auto governing	1. Starting Interlocks not through 2. ESV not reset or mal-functioning 3. Governor malfunctioning (Mechanical/Electrical)	1. Requires restart after trouble shooting	
26.	Machine not starting even in manual governing mode	1. Governor MSV jammed due to ingress of mud 2. Inadequate water pressure in spiral 3. Generator brake ON 4. HS lube pump off 5. Mechanical problem in governor limiter mechanism	1. Restart after trouble shooting 2. Clean governor oil and flush the sump and pipes to remove mud and sludge etc.	1. Periodic cleaning of governor oil sump is suggested 2. Brake ON/ OFF status should be physically checked before starting
27.	Machine stopping after load throw	1. Micro switch for detection of MSV movement in closing	1. Repeat load throw after trouble shooting	1. Machine must run in no load excited after

	instead of continuing to run on no load	direction malfunctioning in HMC of governor.		successful load throw
28.	GCB tripping immediately after synchronizing	1. Protection PT secondary voltage absent which initiates backup impedance protection	1. In trouble shooting, malfunctioning of PT secondary sliding contacts may be found. 2. Operation of some electrical fault protection.	A look at control room annunciations would provide the clue
29.	Machine stopping or over-speeding unnecessarily on some faults	1. Wrong tripping logic adopted for faults in design	1. Review logic 2. Un necessary effort for restarting 3. Loss of water energy due to no load run involved for restarting	A commonly agreed tripping logic at design stage is necessary
30.	Over voltage tripping during field flashing in auto (manual ok)	1. Excessive control voltage build-up during the process in AVR card	1. Adjust control voltage limiting circuit in AVR card	In new machine field flashing in manual mode must be proved at first
31.	Stator E/F in a machine during operation	1. Unclean external connected equipment like generator terminals/bus duct insulators/XLPE cable connection to main transformer etc.	2. Loss of generation during the period of down time 3. Cleaning alone may solve the problem which should be first undertaken before any other measure.	After successful final acceptance HV test before commissioning, no likelihood of winding failure for 25 years is expected.
32.	Inadvertent application of brake in a running machine	1. No clear marking of unit number in a multi unit PH 2. Malfunctioning of auto braking system	1. Extensive damage to brake track and pads 2. Lowering of IR (insulation resistance) of generator windings from brake dust laden fumes of oil.	1. Unit number must be reliably marked on panels, turbine pit, generator barrel etc. 2. Manual braking may be preferred
33.	Inadvertent closing of governor main oil valve during operation in grid	1. Malfunctioning of control circuits of motorized valve 2. Wrong operation by operator say in case of LT supply failure in the power house.	1. Likelihood of machine going to runaway speed if GCB trips during this time	1. Manually operated valve is preferable
34.	Generator over voltage tripping during field flashing both in auto and manual modes	1. Dirt/Dust accumulation in thyristors over a long period	1. Cleaning of Thyristors and checking for their healthiness	1. Periodic cleaning of excitation panels is necessary
35.	Abnormal noise and sparking at the time of GFB tripping on load	1. Pulses from pulse generating card not moving in inverter mode	1. Check the circuit and the card	1. Harmful to long life of GFB from such sparking
36.	Jerky/erratic behavior of GA together with jerks in governor oil	1. Contamination of governor oil 2. Flapper of EHT of governor not in center or its looseness	1. Forced shutdown to attend the problem 2. Reduction in life expectancy of equipments	Periodic oil cleaning and testing in

	pressure gauge during operation			Certified Lab is necessary
37.	Sudden noisy operation of OPU pumps of governor	1. Choking of filters in the sump tank of governor	Thoroughly clean the filters one by one, periodically	Periodic maintenance is essential

III. Conclusion

The construction of hydro power stations and units being a highly tailor made effort at every stage from concept to commissioning, it is but quite natural to face some unforeseen problems during operation and maintenance, some of which have been brought out in this article, on a holistic basis to cover not only the mechanical side of turbine, generator, governing systematic, but also of their electrical side, including the excitation and protections part. This will make aware all concerned about various problems faced at severalhydro stations in the past over many years and their repercussions on performance/life expectancy etc. along with brief analysis and suggestions for avoidances. Needless to say, everybody's objective is to achieve minimum or no forced outage for maximum availability of equipment for generation of electricity for greater good of the nation. For this, it would be highly desirable on the part of owner of PH not to move those operation and maintenance engineers who were associated with erection/commissioning –activities, at least up to first capital maintenance.

For effective maintenance, well defined maintenance schedules of daily, weekly, monthly yearly intervals and capital maintenance should be prepared based on Operation and Maintenance manuals of suppliers as well as experience of other similar units elsewhere, which should be religiously followed. This can be done in such a way that not more than 5 to 8% of total generation time is spent for it as a guideline. Of all the problems, excessive vibrations are the most harmful for the machine as these cause fatigue stress on various components, resulting in reduced life expectancy, low performance level and dissipation of energy. It is therefore necessary to periodically monitor vibration condition of the units and to reduce these as for as possible.

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