Stakeholder Comments Template

Variable Operations and Maintenance Cost Review Working Group – Hydro Resources

This template has been created for submission of stakeholder comments on the VOM Cost Review working group for Hydro resources that was held on July 19, 2019*.* The workshop, stakeholder meeting presentations, and other information related to this initiative may be found on the initiative webpage at: http://www.caiso.com/informed/Pages/StakeholderProcesses/VariableOperations-MaintenanceCostReview.aspx.

Upon completion of this template, please submit it to initiativecomments@caiso.com. Submissions are requested by close of business on **August 2, 2019.**

Note: Upon submission, please indicate if you would like your comments to be confidential.

Submitted by	Organization	Date Submitted
Daniel Kirschbaum	*Seattle City Light*	*7/29/19*

Please provide your organization's comments on the following topics and questions.

1. **Appendix A to this template contains a list of maintenance activities for Hydro resources. What maintenance activities are missing from this list that should be included for consideration?**

   SEE BELOW in APPENDIX A

2. **Appendix A also allocates the maintenance activities to three cost components (Major Maintenance [green], Other Maintenance – Variable [yellow], Other Maintenance – Fixed [red]). Please review and note whether you disagree with our proposed allocation and why.**

   SEE BELOW in APPENDIX A

3. **Please provide any comments or updates you may have to the definitions of Major Maintenance Costs, Variable Operations Costs, and General and Administrative Costs, if any, listed in the July 2, 2019 report found on the stakeholder initiative website.**

Comments to specific questions in the CAISO presentation

Goal #1 – Definitions

- Major Maintenance Costs (MM)– present maintenance practices based on existing utility operations. This is based on a utilities hour and starts based maintenance, <u>including end of life Capital expenditures to replace worn out equipment.</u> Major Maintenance costs cover the existing hours of operation cost and cost per start. This is based on the past XX-years of operating profile that has been used to determine a utilities present maintenance plan. A general practice with regards to Major Maintenance is to review the type and amount of maintenance every XX-years to determine if it is too much or not enough based on forced outages and other failures.
  - Questions for CAISO – how often can a utility change the values in the MMA template?
- Variable Operations Costs (VO) – Costs that are incurred due to changing the operating profile of generating equipment – example, increasing load variations/load swings will increase wear on Mechanical and Electrical equipment increasing the maintenance cycles and reducing the mean life between replacements (increased CIP costs). The VOM adder covers these costs.

Discussion – Hydro equipment is designed to be long lived and robust. Changes in maintenance due to increased load swings will take many years to present themselves as increased forced outages and changes to the maintenance program.

Goal # 2 – differentiating between Major and Minor Maintenance

Other Maintenance (OM)

- Other Maintenance – Fixed – SCL did not include in the MMA template, our general inspections and measurements <u>that we take during every outage</u> – examples not in MMA
  - Governor - oil filtration, greasing pump bearings, cleaning filters, checking instruments and level switches, timing checks, Pilot valves clean calibrate – accumulator/sump inspections
  - Bearings oil filtration and oil samples – oil vapor seal inspections and replacement – bearing clearance checks
  - Turbine – clearance checks – gates checks – cavitation checks and reports, Vibration readings during operation
  - Generator – cleaning, inspections, air cooler cleaning, relay checks, meter checks
  - Fire Suppression system testing – NFPA testing

    - Exciter checks, cleaning for flash over, meggar, brush replacement
    - GSU oil samples, cleaning
    - Voltage regulator – field CB maintenance
    - Working grounds inspections and testing
    - NERC/WECC power system stabilizer testing
- Other Maintenance – Variable – I can't think of anything specific here. Variable maintenance would be determined by something being out of specification during normal fixed maintenance. Examples would be
    - Extra oil analysis due to poor sample results.
    - Unexpected cooler cleaning due to high differential temperature results.

In general, "other maintenance – variable" would almost be considered corrective maintenance due to some finding during "other maintenance – fixed". If load swings increased component wear and issues were identified during our "other maintenance – fixed" and extra unplanned outage might be required to do corrective maintenance, such as replacing a linkage bushing for example.

4. **Please provide any comments or updates to the categories/sub-categories of generation technologies for VOM adders. Should the categories currently found in the CAISO BPM for Market Instruments be further disaggregated into sub-categories (e.g. Solar PV and Solar Thermal)?**

5. **Please offer your feedback on structure of this stakeholder initiative and working groups.**

Additional comments

Please offer any other feedback your organization would like to provide on the topics discussed during the working group.

Seattle City Light (SCL) Comments – Daniel Kirschbaum Mechanical Engineering Supervisor

It is SCL's understanding that the MMA template will compensate hydro utilities by providing a $/operating hour and $/start reimbursement to cover operating hours and starts based Major Maintenance. Within the MMA template SCL has provided the equipment types that require

Major maintenance based on hours of operation and number of starts. It is SCL's understanding that an increase in hours of operation or starts to support EIM will be compensated via this mechanism.

SCL Engineering believes the key word in the VOM is "Variable". For example, how would operation within the EIM be different than how we operate now. We do follow our load now, but it is generally predictable and the load changes are gradual. SCL has studied our existing load swings (i.e. variable operations) in preparation for EIM participation. SCL used a change in load of 5-25% of the maximum unit output as our definition of a minor load swing and we use >25% change in load as the definition of a major load swing.

SCL has communicated and been present at utility conferences where EIM operations have been discussed. In general, we have learned that after entering the EIM the number of extra starts is not that great, but the load following (i.e. variable operations) increases dramatically. Therefore, SCL is expecting once we enter the EIM system that we will be performing more rapid load changes to support the "system". These increased load swings ("Variable Operations") have a cost. A brief review of equipment and effects:

1. Mechanical equipment
    a. Wicket gates must change position to adjust load – wear components
        1. Wicket gate bushings and seals
        2. Wicket gate linkages
        3. Wicket gate journals
        4. Seals
        5. Operating ring bushings
        6. Servomotor cylinder/piston rings and seals
        7. Governor pumps and main distributing valve
    b. Alternating stress on components – life reduction due to fatigue.
        1. Possible increase in runner cavitation depending on operating points
        2. Possible decrease in runner life due to fatigue and cracking
        3. Alternating stress on Shafting and bearings – decreased life.
2. Electrical equipment
    a. Thermal growth of winding (stress between copper conductor and insulations – different thermal growth rates – decreases winding life.
    b. Core and frame expansion and contraction – increases looseness over time
    c. Field winding temperature variation
    d. Cyclic stress in the end winding supports
    e. Mechanical abrasion of the winding in the core slot

f. Alternating stress on components – life reduction due to fatigue.

1. Poles bodies dovetail/hammerhead connection to rim – reduced fatigue life
2. Rotor spider – reduced fatigue life

This being said – how would these costs be recovered – trying to recover a per load variation could be very difficult – how large a load swing is worth how much? But in SCL opinion some type of VOM adder is necessary to recover these effects.

As a separate exercise SCL has calculated a load variation cost for the electrical equipment only not the mechanical equipment, but it is based on our size units and is based on Engineering judgements of life reduction caused by load swings ("Variable Operations").

Over the past few years in preparation for entering the EIM, SCL has been asking hydro Original Equipment Manufacturers (OEM) what the past design practices and guidelines were for equipment that was designed in the 1950's and 1960's. The responses indicate that in the past hydro was in general considered a base load type unit and were not designed for daily starts and stops.

Recent examples of SCL experience

Example # 1 – Rotor Spider Pole Body replacement

SCL in preparing for 3 large unit rewinds – the specification was written for the unit to operating 40 years with 2 starts per day. A number of OEM's reviewed and bid on the rewind specification. Due to the requirement of 2 starts per day and a 40 year life the OEM's were forced to perform a Fatigue life assessment using Fracture Mechanics methods (Either ASME BPVC Section VIII – Division 2 or via the German Standard FKM- Guideline) – the existing rotor spider and Pole body end plates could not pass the requirement and SCL is spending large dollars replacing the spider on 3-170MVA units and all the pole bodies. These are of course mostly Start-Stop related issues, but load variation was also evaluated and do contribute to life reduction.

The cost of one rotor spider replacement is $730,000

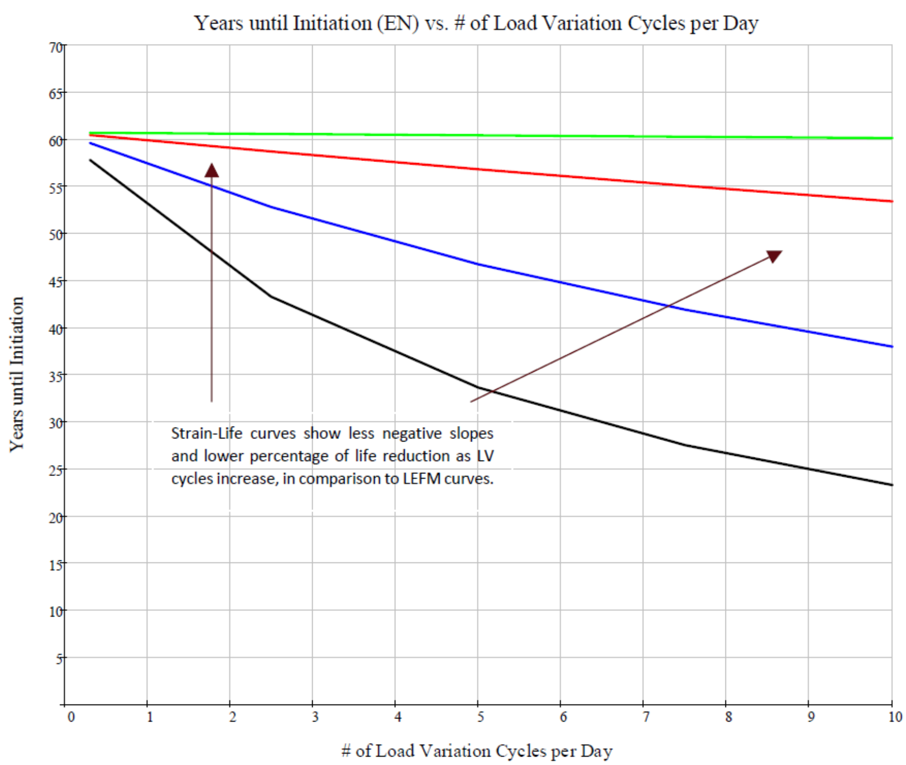
The cost of the pole body replacements for one unit is $910,000

Example # 2 – Rotor Ledge Cracking

During a generator rewind, cracks were found in the generator spider rim ledge. This rim ledge holds the rim iron and poles as part of the generator rotating equipment. This failure was caused by start stop issues. The emergent repair cost was large put were discovered early enough that the delays to completion of the rewind were minor. This type of failure during operation would have taken the unit out for 6 months or more. This failure occurred on a unit commissioned in 1986 which has about 200 starts per year on average. For additional details go to the NHA OpEx website (www.hydroexcellence.org and search rotor) – SCL has written up the incident for other utilizes to learn from in 2 papers.

Example # 3 – Turbine Shaft FEA study to determine EIM effects

SCL commissioned an FEA analysis using fracture mechanics analysis of turbine shafts for our Boundary units (1-4) by EME Power Engineering Solutions to determine the remaining shaft life, and the effects of increasing load variations (LV). In the below graphs from this report a 100% load variation is considered to be from speed-no-load (SNL) to 100% load. The load variations are studied parametrically as possible frequencies from 114/year to 10/day, at load variation levels of 25%, 50%, 75%, and 100% of full load. As can been seen increasing the LV both reduced the time to crack formation via strain life (EN) analysis and greatly reduces the life to failure using Linear Elastic Fracture Mechanics (LEFM) methods once a 1/16" crack is produced. These graphs are based on the present shaft life (at 60 years of operations) indicating between 60 years (25% LV) to 23 years (100% LV at 10/day) of remining operations until we would expect a crack initiation. This indicates that large load variations on hydro units do reduce large components life and require some kind of compensation method.



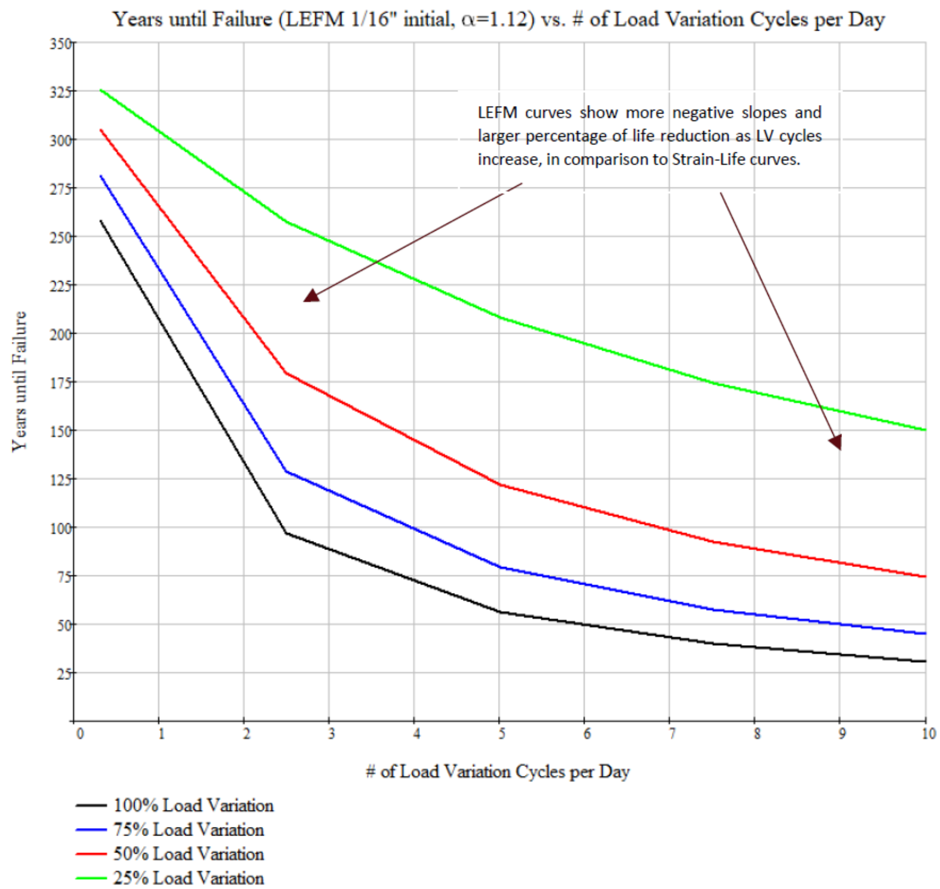


Figure 23. Infinite edge crack LEFM plot showing sensitivity to LV cycle increase.

swings will increase wear on Mechanical and Electrical equipment increasing the maintenance cycles and reducing the mean life between replacements (increased CIP costs). The VOM adder covers these costs.

Discussion – Hydro equipment is designed to be long lived and robust. Changes in maintenance due to increased load swings will take many years to present themselves as increased forced outages and changes to the maintenance program.

SCL is providing these comments for Working Group # 4 review and discussion with CAISO.

Appendix A:

Cost Component Allocation		
Major Maintenance	Other Maintenance - Variable	Other Maintenance - Fixed

Maintenance Activity	Please note if you disagree and why
Inspections, Repairs and Overhauls, and Replacements:	
1) Bearings and Bushings	This should be Major Maintenance - GREEN
2) Communication Systems	
3) Distributed Control Systems	
4) Exciter Water Wheels and Turbines	
5) Generator Cooling System	This should be Other Maintenance – Fixed - RED
6) Generator Field Rewinds	Under Generator you should add - Stator Winding – Stator Core – Rotor Spider – Rotor Poles – Generator testing
7) Lubricating Systems	
8) Main Penstock Valves and Appurtenances	
9) Main Turbines and Water Wheels	
10) Plant Electrical Systems	
11) Runner Seals	
12) Servomotors	Add Governors – Main Distributing valves - Pumps
13) Shaft Sleeves and Seals	
14) Valves	
15) Wicket Gate Seals	Add Bushings

Other	
16) Balance-of-Plant	

Materials	
17) Instruments	
18) Safety Equipment	
19) Shop Supplies	
20) Tools	