Hydro Asset Planning

Condition and Risk Driven Investment Decisions

NW Hydro Operators Forum
Skamania, WA
May 23, 2008

Condition Assessment – hydroAMP Framework

The FCRPS measures the condition of major components that comprise the power train, generating plant auxiliaries, and other site components using hydroAMP, a framework developed by four organizations – Reclamation, the Corps, Bonneville and Hydro-Québec. HydroAMP employs a two-tiered methodology for deriving condition ratings.

- Tier 1 indicators rely on test results and/or inspections that are normally obtained during routine maintenance activities. These Condition Indicators are weighed together to compute an equipment Condition Index. The index ranges from 10 to 0 and equates to a Good, Fair, Marginal or Poor rating.

- Tier 2 indicators are used to further investigate abnormal Tier 1 results and rely on more in-depth, non-routine tests and inspections requiring specialized knowledge, diagnostic equipment or outages. Tier 2 results refine or adjust the Tier 1 Condition Index.

The criteria for scoring the Condition Indicators under Tier 1 and for adjusting the Condition Index as part of Tier 2 are detailed in equipment assessment guides. Currently, there are 11 hydroAMP assessment guides on the equipment identified below. The guides provide consistent techniques for evaluating component condition and refining methods.

HydroAMP ratings have been collected for FCRPS power train equipment since 2004. Results are stored in a central data repository and are updated at least annually. As a result, the FCRPS hydro program is able to identify the condition of the major components in all 209 generating units in the system.

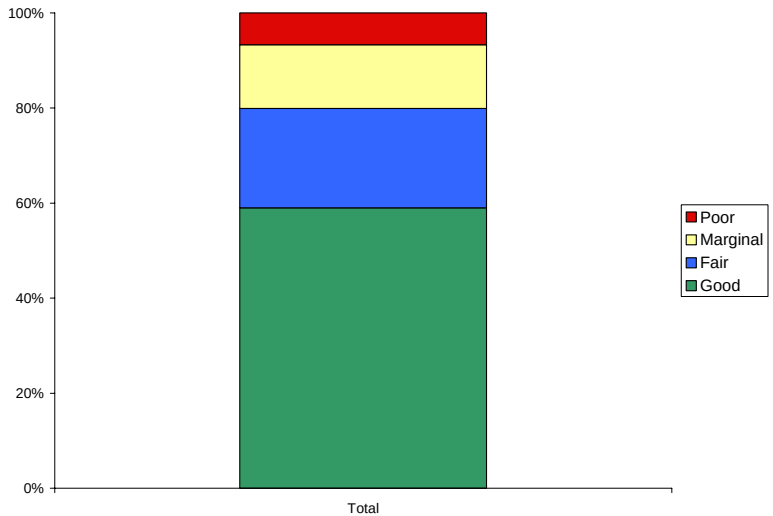
hydroAMP Equipment Assessment Guides

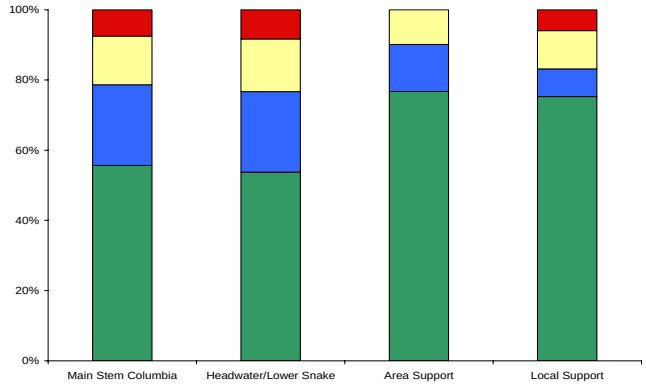
Power Train	Other
Generator Stator/Rotor	Battery System
Excitation System	Compressed Air System
Transformer	Emergency Closure Gate/Valve
Turbine	Crane
Circuit Breaker	Surge Arrester
Governor	

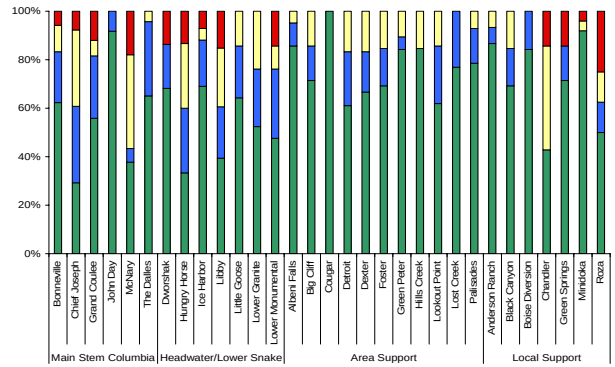
Current Condition – hydroAMP Ratings

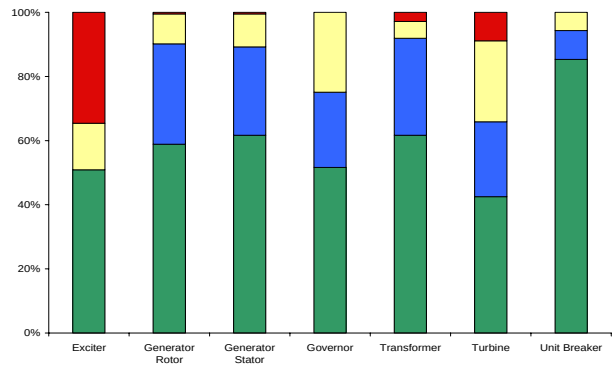
HydroAMP ratings have been collected for power train equipment since 2004. Results are stored in a central data repository and are updated at least annually. As a result, the FCRPS hydro program is able to identify the condition of the major components in all 209 generating units in the system.

Current condition profile shows that, system-wide, about 80 percent of equipment is in Good or Fair condition. Among strategic classes, Main Stem Columbia and Headwater/Lower Snake have the lowest overall condition ratings, with McNary having the lowest rating among all plants. Overall, unit breakers have the highest condition ratings, a result of a system-wide breaker replacement program that is now nearing completion. For other categories, roughly half of the equipment has a rating of Good, with all but exciters having an additional 25 percent of equipment rated as Fair.







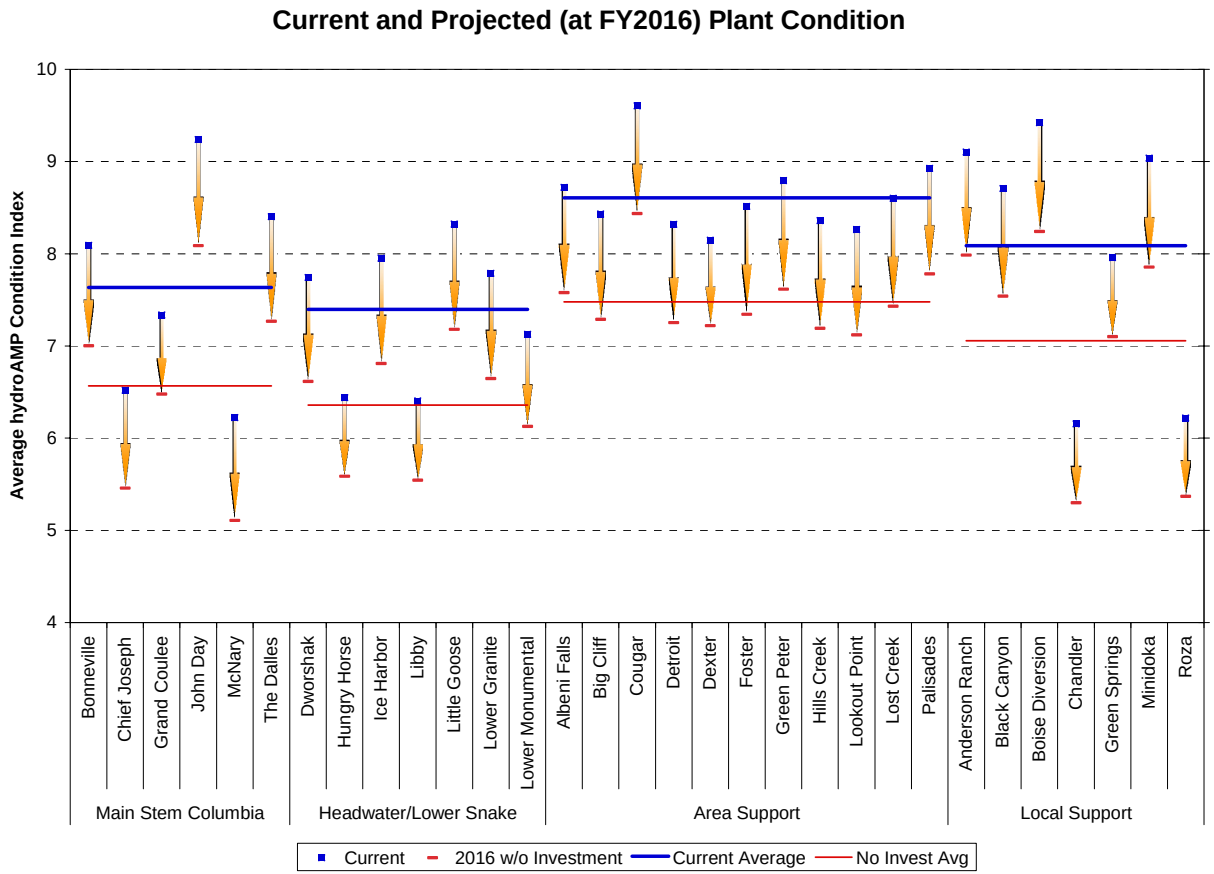


Condition – Change in Average hydroAMP Index w/o Investment

Current and historical hydroAMP data was studied using regression analysis to determine the rate at which hydroAMP ratings decrease over time. The analysis yielded degradation rates for each hydroAMP component type, which enabled the creation of projected hydroAMP ratings in the future if no investments are made to improve condition.

Current and projected condition ratings are shown on the figure to the right. Four items are shown on the chart:

- The current average hydroAMP condition index for all power train components at the plant (e.g., the average condition index for the 283 components at Grand Coulee is 7.3);
- The projected average hydroAMP condition index for each plant at the start of FY2016 if no investments are made to improve condition;
- The current average condition index for all power train components in each strategic class, and
- The projected average condition index in FY2016 by strategic class without investment.



Risk – hydroAMP Condition Index vs. Likelihood of Equipment Failure

HydroAMP is an important tool for evaluating performance risk of power train equipment. The FCRPS hydro program correlates a hydroAMP condition rating with the likelihood of the equipment failing to perform as expected within the planning window (FY2009 – FY2015). Equipment with a low condition index has a higher likelihood of failure than one with a higher condition rating. The correlation is shown below.

Likelihood	Condition Rating	Description
Almost Certain	0 to 0.9	Poor
	1 to 1.9	
Likely	2 to 2.9	
	3 to 3.9	Marginal
Possible	4 to 4.9	
	5 to 5.9	
Unlikely	6 to 6.9	Fair
	7 to 7.9	
Rare	8 to 8.9	Good
	9 to 10	

Risk – Current Profile of Equipment

To evaluate risk, the likelihood of failure is mapped against the associated consequence of not having a generating unit available to produce electricity. This risk map is segmented into a five-by-five grid; with five levels of likelihood and five levels of consequence. The consequence identified on the map is the value of the generation that would be lost from the time a piece of equipment fails – taking the generating unit out of service – until it is repaired or replaced and the unit is returned to service. Direct costs to repair or replace equipment are not included here, but are used later in evaluating the risk treatment. Consequences are characterized as insignificant if they are less than $10,000 to extreme if they exceed $10 million.

The risk map is further segmented into four levels of risk: High, Medium-High, Medium, and Low. The figure on the right summarizes the hydroAMP rating and lost generation consequence for FCRPS power train equipment and provides a basis for identifying risk mitigation strategies. The number preceding each equipment type listed in the grid corresponds to the number of equipment items. For example, five transformers on the system are in Poor condition and almost certain to fail by 2016 with an extreme (greater than $10 million) consequence.

Risk Map at FY2008

Likelihood	Insignificant < $ 10K	Minor $ 10K to $ 100K	Moderate $ 100K to $ 1 M	Major $ 1 M to $ 10 M	Extreme > $ 10 M	hydroAMP Index		
Almost Certain	6 Exciter	3 Exciter 2 Non-Power Train	55 Exciter 2 Turbine 9 Non-Power Train	6 Exciter 1 Transformer 3 Turbine 7 Non-Power Train	5 Transformer 3 Non-Power Train	0 to 0.9	Poor	
						1 to 1.9		
Likely	1 Non-Power Train	1 Governor 25 Non-Power Train	14 Exciter 1 Generator Rotor 4 Governor 4 Turbine 34 Non-Power Train	3 Exciter 1 Generator Stator 1 Transformer 12 Turbine 19 Non-Power Train	1 Transformer 4 Non-Power Train	2 to 2.9		
						3 to 3.9	Marginal	
Possible		2 Exciter 3 Generator Stator 8 Governor 23 Non-Power Train	13 Exciter 20 Generator Rotor 3 Generator Stator 40 Governor 1 Transformer 25 Turbine 7 Unit Breaker 79 Non-Power Train	1 Exciter 14 Generator Stator 5 Transformer 27 Turbine 32 Non-Power Train	2 Generator Stator 5 Transformer 18 Non-Power Train	4 to 4.9		
						5 to 5.9		
Unlikely	2 Generator Rotor	3 Generator Rotor 2 Generator Stator 32 Governor 5 Turbine 26 Non-Power Train	56 Generator Rotor 14 Generator Stator 18 Governor 7 Transformer 37 Turbine 19 Unit Breaker 26 Non-Power Train	6 Generator Rotor 43 Generator Stator 54 Transformer 8 Turbine 18 Non-Power Train	6 Transformer 21 Non-Power Train	6 to 6.9	Fair	
						7 to 7.9		
Rare	2 Exciter 5 Governor 2 Turbine 2 Unit Breaker	32 Exciter 34 Generator Rotor 2 Generator Stator 47 Governor 4 Turbine 34 Unit Breaker 7 Non-Power Train	64 Exciter 91 Generator Rotor 32 Generator Stator 51 Governor 1 Transformer 72 Turbine 127 Unit Breaker 2 Non-Power Train	13 Exciter 1 Generator Rotor 95 Generator Stator 7 Governor 128 Transformer 13 Turbine 17 Unit Breaker 15 Non-Power Train	3 Generator Stator 18 Transformer 3 Non-Power Train	8 to 8.9	Good	
						9 to 10		

Consequence

Risk Level	Low	Medium	Medium High	High

Proposed Long Term Plan – Large Capital Forecast w/ AFUDC

The proposed Large Capital Investment Program increases from past expenditure levels in order to address several issues:

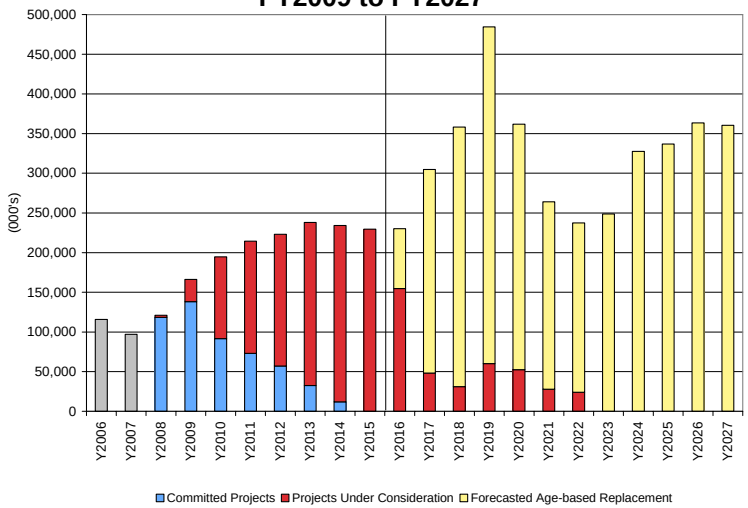
- Condition of FCRPS hydro equipment and associated performance risks;
- Significant increases in materials costs and orders for hydro generation equipment from a limited number of international suppliers; and,
- Devaluation of the US Dollar.

The large capital component of the Investment Program averaged $103 million per year from FY2003 to FY2007. The proposed plan for FY2009 to FY2015 totals $1.5 billion, averaging $214 million per year.

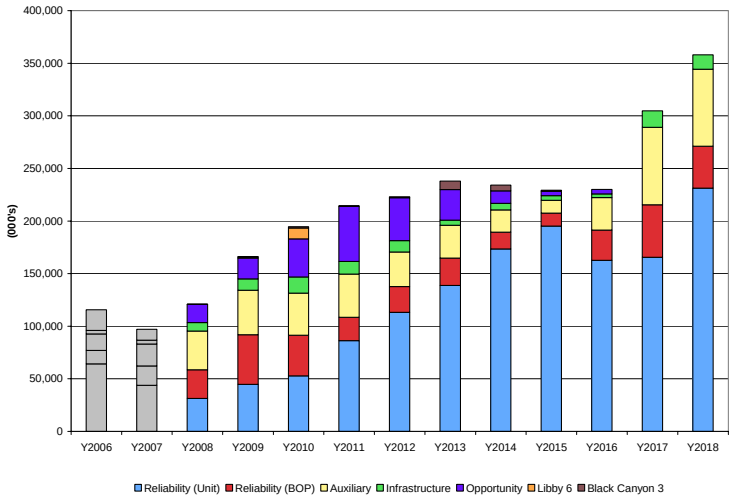
Over $500 million of the plan is for projects that are already committed. The remainder is for identified projects under consideration, driven by condition, risk, or economic opportunity. Known deficiencies and opportunities comprise all the spending over the FY2009 to FY2015 period. Forecasts for end-of-life, age-based equipment replacement are included in the spending outlook beyond FY2015 as the ability to forecast condition-related replacement decreases.

Funding requirements beyond FY2018 are expected to remain at or above the levels proposed in this plan. This projection is based on the forecast of age-related equipment replacement. While the accuracy of such long-term projections may be doubtful, they do illustrate that replacement of aging components is a question of "when", not "if", and that failure to address near-term condition issues will prolong the problem.

Large Capital Forecast
FY2009 to FY2027



Large Capital Forecast by Functional Category
FY2009 to FY2018



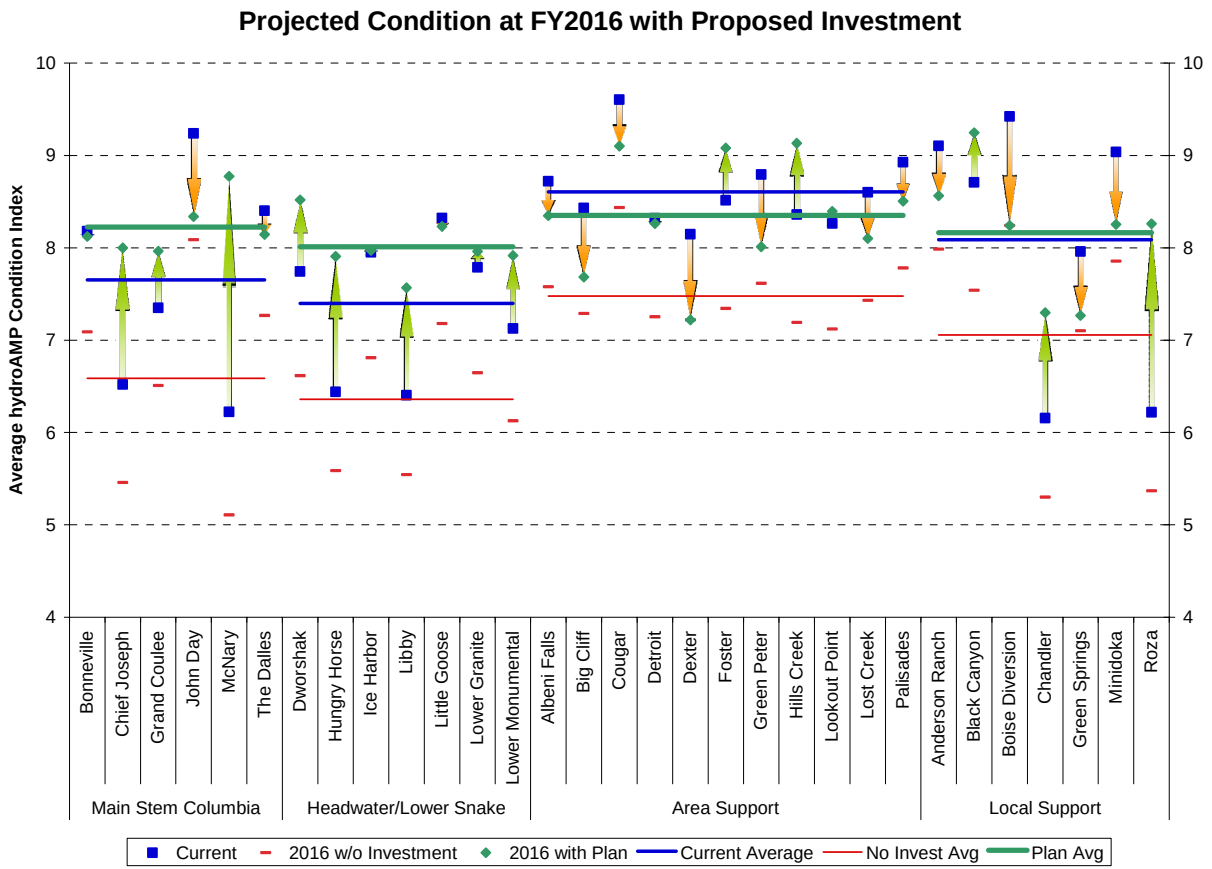
Proposed Long Term Plan – Average hydroAMP Index at 2016

The condition of the Main Stem class will improve from its current level under the proposed plan. The substantial investment that is proposed for Grand Coulee, Chief Joseph, and McNary will improve the condition of these facilities, though Grand Coulee and Chief Joseph still will be rated as Fair. The proposed plan will lead to additional condition improvements at Grand Coulee and Chief Joseph for work that will underway but not completed prior to 2016. The condition of Bonneville and The Dalles will be sustained. Condition of John Day will decrease but will remain in Good condition overall.

The condition of the Headwater/Lower Snake class will improve under the proposed plan. Hungry Horse and Libby will see the greatest improvement in hydroAMP ratings. The condition of other facilities will be sustained.

The condition of the Area Support class will decrease under the proposed plan but will remain in Good condition overall.

The condition of the Local Support class will remain constant. The proposed investment in Chandler and Roza, currently 4th quartile overall, will improve their conditions to Fair and Good, respectively. The condition of most other plants in this class will decrease but still remain Good.



Proposed Long Term Plan – Risk Profile at 2016

At 2016, the system risk profile is reduced significantly from that in 2008. This chart show that the proposed plan has the following effects:

- The proposed plan essentially eliminates risks to non-power train components.
- The number of high risk power train components will be significantly decreased by FY2016.
- In addition, some proposed work programs at Chief Joseph and Grand Coulee still will be underway in FY2016. This incomplete work is not reflected in the charts. As a result, the proposed plan will lead to additional reductions in risk in subsequent years.

Projected Risk Map at FY2016 with Proposed Investment

Likelihood	Insignificant	Minor	Moderate	Major	Extreme	hydroAMP Index	
	< $ 10K	$ 10K to $ 100K	$ 100K to $ 1 M	$ 1 M to $ 10 M	> $ 10 M		
Almost Certain	6 Exciter	3 Exciter	13 Exciter			0 to 0.9	Poor
						1 to 1.9	
Likely			3 Exciter 1 Generator Rotor 2 Governor 2 Turbine	1 Exciter 7 Turbine		2 to 2.9	
						3 to 3.9	Marginal
Possible		3 Generator Stator	8 Generator Rotor 2 Generator Stator 5 Transformer 11 Turbine 16 Unit Breaker	7 Generator Stator 8 Transformer 7 Turbine	4 Transformer	4 to 4.9	
						5 to 5.9	
Unlikely	2 Generator Rotor 2 Turbine	22 Exciter 11 Generator Rotor 3 Governor 7 Turbine 6 Unit Breaker	8 Exciter 62 Generator Rotor 20 Generator Stator 1 Governor 4 Transformer 32 Turbine 23 Unit Breaker	13 Exciter 6 Generator Rotor 35 Generator Stator 47 Transformer 5 Turbine	2 Transformer	6 to 6.9	Fair
						7 to 7.9	
Rare	2 Exciter 5 Governor 2 Unit Breaker 1 Non-Power Train	12 Exciter 26 Generator Rotor 4 Generator Stator 85 Governor 2 Turbine 28 Unit Breaker 83 Non-Power Train	122 Exciter 97 Generator Rotor 27 Generator Stator 110 Governor 95 Turbine 114 Unit Breaker 150 Non-Power Train	9 Exciter 1 Generator Rotor 111 Generator Stator 7 Governor 134 Transformer 44 Turbine 17 Unit Breaker 91 Non-Power Train	5 Generator Stator 29 Transformer 49 Non-Power Train	8 to 8.9	Good
						9 to 10	
	Consequence						

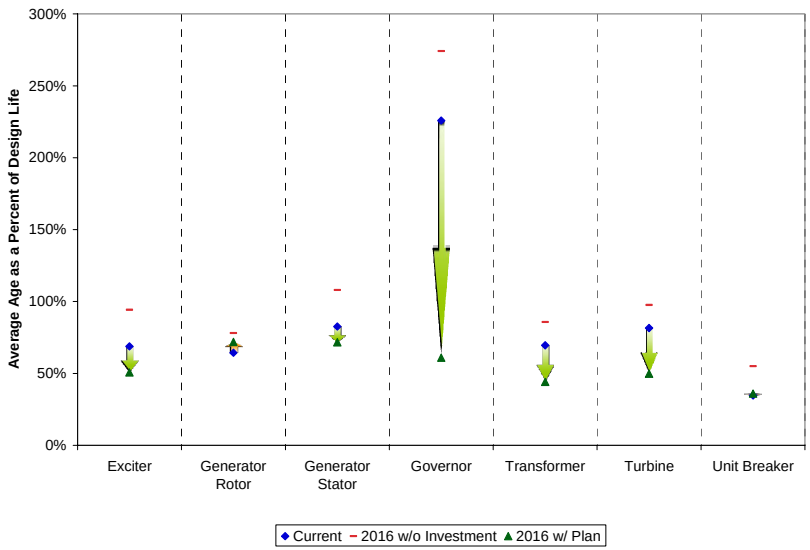
Risk Level	Low	Medium	Medium High	High

Proposed Long Term Plan – Age of hydroAMP Rated Equipment

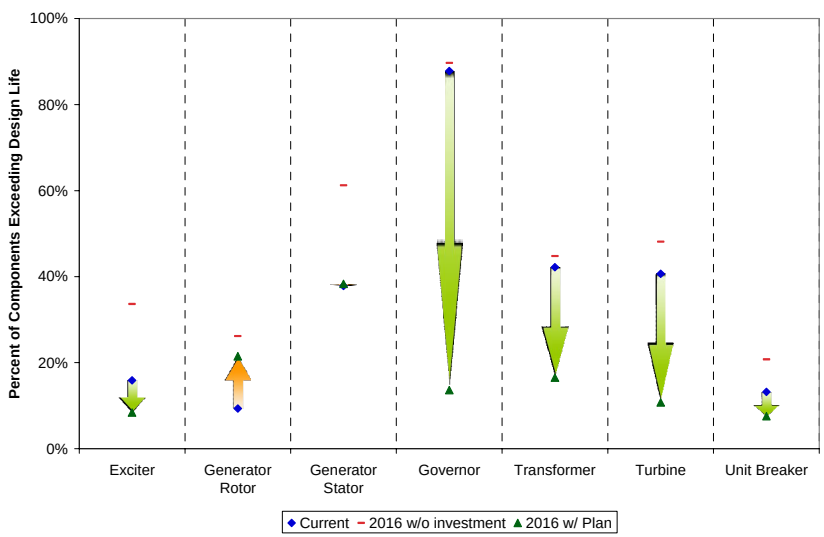
The average age of most hydroAMP rated equipment will decrease through the proposed plan. The most significant reduction in age profile will be for governors, which is the component type currently at the highest percentage of components exceeding design life. At FY2016, generator rotors, generator stators, and transformers will have the greatest percentage of components exceeding design life, each in excess of 20 percent of the asset base.

As a general assessment, for most plants the proposed plan will not have a significant impact on overall age profiles at FY2016. Consequently, the level of investment proposed (and as based on condition and risk needs) appears to be consistent with long-range funding required for age-based replacements, under an overall assumption that the age profile of the asset base should not worsen with time.

Projected Average Age of Power Train Components as a Percent of Design Life



Projected Percentage of Power Train Components Exceeding Design Life



Proposed Long Term Plan – System Cost of Production

Long-term pro forma statements have been created to demonstrate the financial impacts of the proposed plan on the FCRPS' cost of production and program net benefit. The analysis includes:

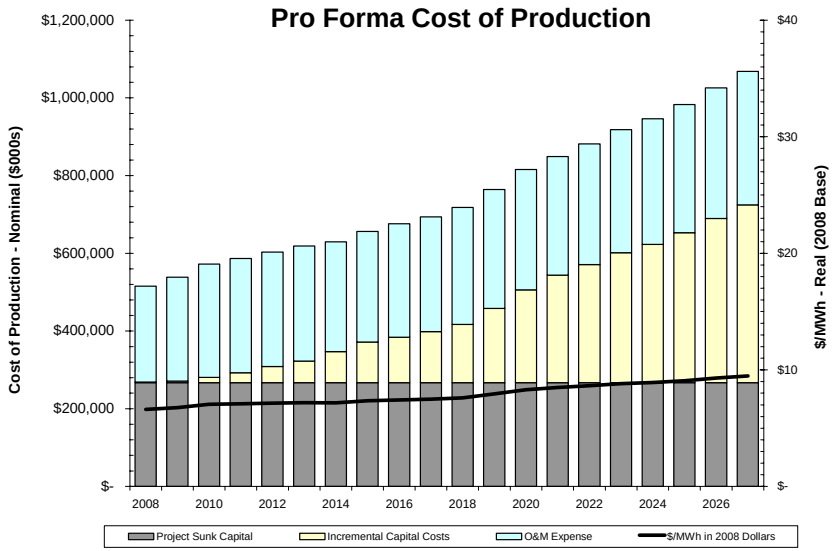
- O&M costs as proposed and forecasted for subsequent years;
- The impacts of proposed capital spending for condition/risk-driven projects and forecasted age-based replacements on finance charges and depreciation, and
- The 'sunk' finance charges and depreciation based on past investment.

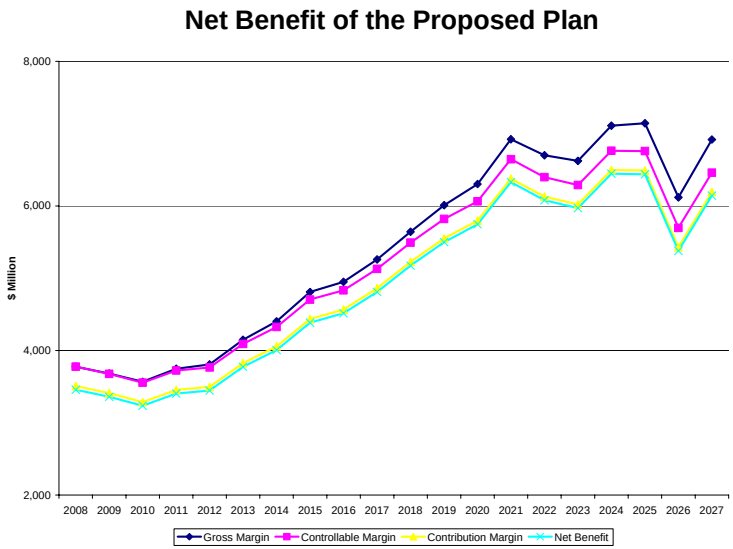
The analysis does not include any allocation of costs not directly attributable to Direct Funding programs. In addition:

- The cost of production chart calculates the unit cost of energy over time, shown in constant 2008 dollars, and
- The net benefit chart assumes energy from each plan is valued at long range forward energy price forecasts (Levelized $56/MWh in 2008$).

These charts show that the proposed plan has the following primary effects:

- The unit cost of production will increase slightly in real terms over the plan period (FY2009 – FY2015).
- Long range forecasts for the unit cost of production will continue to increase in real terms based on anticipated age-based replacements in FY2016 and beyond.
- The hydro system will continue to provide positive and increasing net benefit, provided that investment plans successfully maintain or improve reliability and sustain the economic value of generating assets. The plan has a net present value of $30 billion over 20 years.





Thank you

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