Q. Please provide a copy of the analysis or evaluation that resulted in the decision to procure four spare 4kV motors for the Holyrood generating station.

A. Please see PUB-NLH-455 Attachment 1.

Critical Spare Evaluation for 4160 V Motors

Holyrood Thermal Generating Station

September 5, 2014, Revision 1

newfoundland labrador hydro
a nalcor energy company

Summary

This report covers the evaluation process for the selection of critical spares for the 4160 volt motors at the Holyrood Thermal Generating Station (HTGS). Procurement of these critical spare motors ensures that in the event of a motor failure like that of December 26, 2013, the units are able to return to service in a more timely and cost effective manner while minimizing the impact to the people of Newfoundland and Labrador.

The report details the evaluation process used, starting with asset criticality and an analysis of available 4160 volt motors available on the market. Emphasis is placed on the most critical assets first as those assets present the greatest risk to generation.

TABLE OF CONTENTS

1 Background

The de-rating of Unit 3 at the Holyrood Thermal Generating Station, from 150 MW to 50 MW, due to the failure of the East Forced Draft (FD) Fan motor on December 26, 2013 was a key aspect of the of generation unavailability leading into January 2014. The current N -1 criteria allowed for the largest generating unit on the island to be unavailable for up to 356 days without affecting customers. Despite the expedited repair of the FD fan motor, the loss of generation contributed to the generation unavailability in January 2014 highlighting that the exiting N -1 criteria should be reviewed.

For the purpose of the 4160 volt spare motor evaluation it is expected that all three units at the HTGS must be available from December 1 through March 31.

2 Asset Criticality

Starting in 2013, the Holyrood Thermal Generating Station performed a complete assessment of Asset Criticality for all plant equipment. This process was developed by the Long Term Asset Planning (LTAP) departments and adapted throughout all LOB's by the LTAP departments. At Holyrood, ranking of the equipment was completed by a team of engineering, maintenance and operations personnel from the HTGS. Each asset was ranked using the seven equipment factors which can be found in Appendix A and are as follows:

- Health and Safety;
- Output (Unit Capacity derating/outage – time and impact);
- Quality of Desired Output;
- Utilization;
- Alternatives;
- Environment; and
- Time to Effect.

Each of the factors are multiplied together to calculate the total Equipment Score for an asset. The results for the HTGS are shown below in Figure 1.

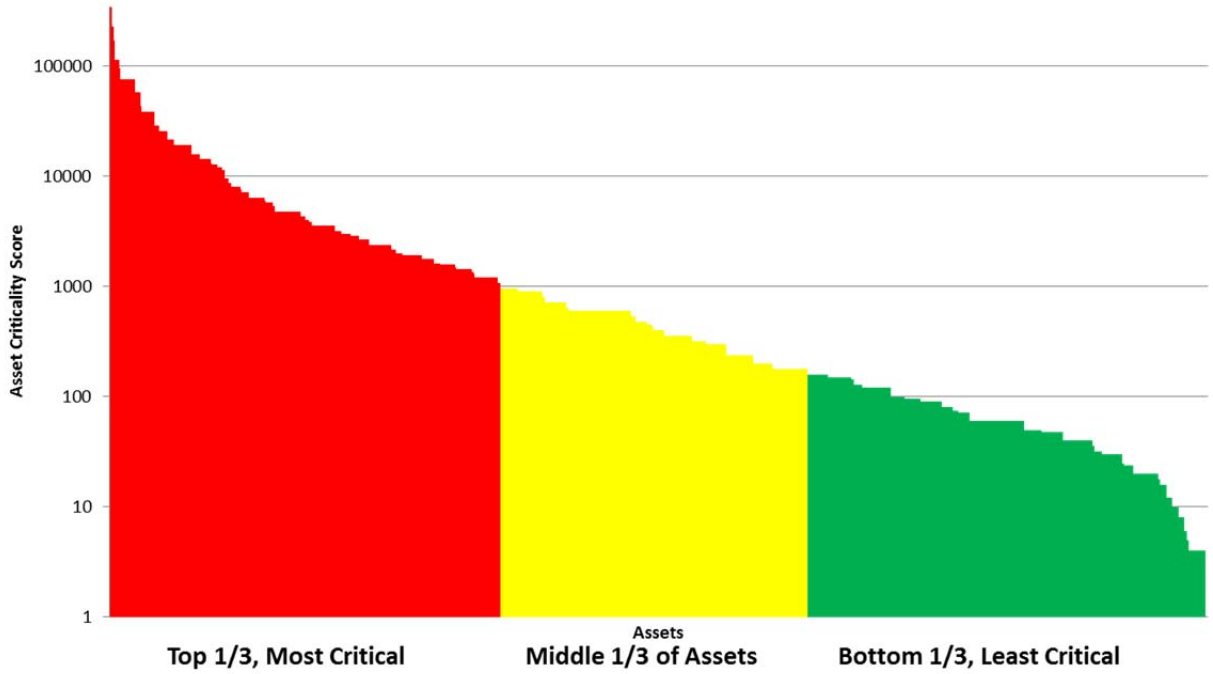

Figure 1: HTGS Asset Criticality

Figure 2 shows the ranking of the 4160 volt motors that are the basis of this report.

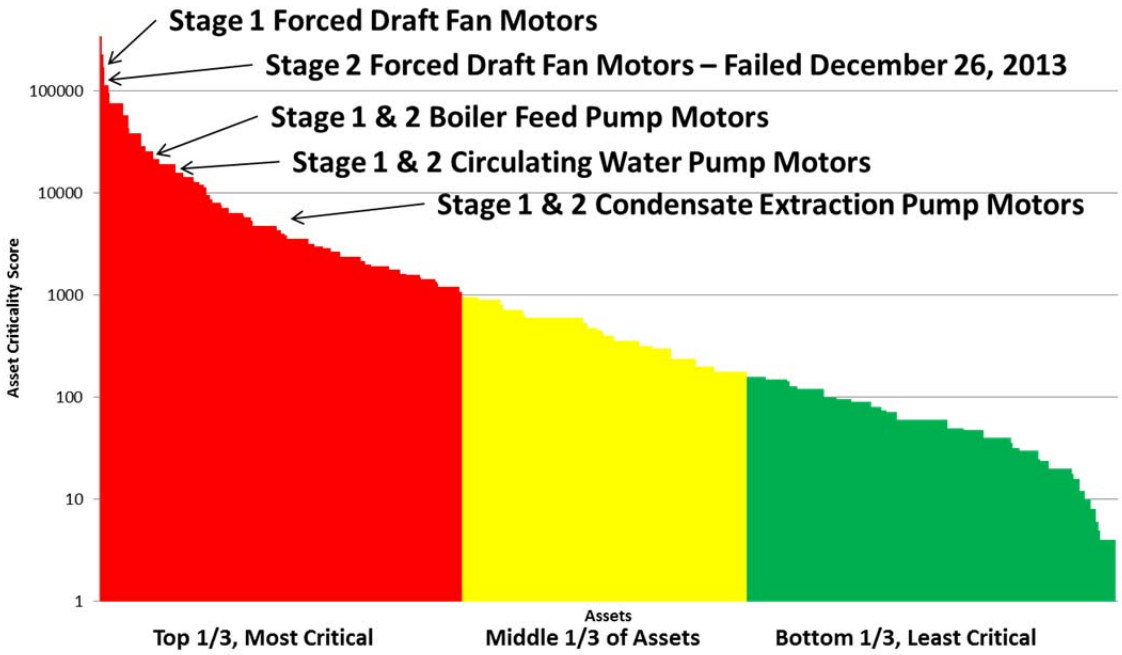

Figure 2: 4160V Motor Criticality

Figure 2 highlights the criticality of the 4160 volt motors, in particular the FD Fan motors and the Boiler Feed Pump motors which are in the top 5% most critical assets at the HTGS.

3 Availability of 4160 Motors

Quotations were requested from original equipment manufacturers for each of the 4160 volt motors, complete with motor information, delivery times, costs and if the motor was a direct drop in replacement. A tabulated list of the results is shown below in Figure 3.

Stage 1: Units 1 & 2

Motor	HP	RPM	Installed Frame	Enclosure	Manufacturer	Drop in Replacement	Delivery	Cost New	Cost Refurbished	Notes	Criticality Ranking
Extraction Pump	400	1800	5008VP	WP-I	US Electric	Yes	12-14 Wks	$58,630.00		OEM	5
					WEG	Yes	18 Wks	$38,735.00			
FD Fan	1500	1200	450C	WP-II	ABB	Yes	17 Wks + Shipping (Finland)	$151,416.00		Includes adapter plate, OEM	1
					US Electric	Yes	14 Wks	$99,850.00		Includes adapter plate	
					WEG	Yes	22 weeks	$99,335.00			
CW Pump	300	600	687UP	WP-I	US Electric	Yes	13 Wks	$115,365.00		5813PZ Frame, OEM	4
Unit 1 Boiler Feed Pump	3000	3600	500	WP-II	ABB	Yes	17 Wks + Shipping (Finland)	$235,775.00		Shipping not included in price, OEM	3
					ABB	No	4-5 Wks	$219,485.00		3100 HP, Mounting feet dimensions are different, AMI 500L2W BSH	
					WEG	Yes	22 weeks	$131,355.00			
Unit 2 Boiler Feed Pump	3000	3600	500	WP-II	Teco Westing House	Yes	36-38 Wks	$130,280.00		OEM	3
					Westinghouse	No	4-6 Wks		$128,260.00	5014 Frame, OEM	
					WEG	Yes	22 weeks	$131,355.00			

Stage 2: Unit 3

Motor	HP	RPM	Installed Frame	Enclosure	Manufacturer	Drop in Replacement	Delivery	Cost New	Cost Refurbished	Notes	Criticality Ranking
Extraction Pump	350	1800	VEFLoSN-KK	IP22	Hitachi	Yes	10 Mths + Shipping (Japan)	$159,310.00		Shipping not included in price, OEM	5
					US Electric	Yes	12 Wks	$62,125.00		Adapter plate included	
FD Fan	1500	1200	R885E	WP-I	Canadian Westing House	Yes	8 Wks		$104,485.00	Reengineered 1250 HP -> 1500 HP	2
					Siemens	Yes	6 Wks	$138,990.00		Adapter plate 5812S -> R885E, c/w cooler,	
					Teco Westinghouse	Yes	--	$131,320.00		560 (R885E) Frame, OEM	
					WEG	Yes	18 weeks	$99,335.00			
CW Pump	400	600	VEFSN-KK	IP22	Hitachi	Yes	10 Mths + Shipping (Japan)	$234,450.00		Shipping not included in price, OEM	4
					US Electric	Yes	12-13 Wks	$166,590.00		Adapter plate included	
Boiler Feed Pump	2350	3600	TFLW-KK	IP44	Hitachi	Yes	10 Mths + Shipping (Japan)	$262,775.00		Shipping not included in price, OEM	3
					US Electric	No	28 Wks + Shipping (USA)	$140,510.00		Does not include adapter plate	
					WEG	Yes	22 weeks	$129,708.00			

Figure 3: Available 4160V Motors

3.1 Option 1: Purchase Spare 9 Motors

Purchasing spare motors for each of the applications offers the lowest risk to production in the event of a motor failure. Turn around time for replacement of a failed motor with a spare on hand is approximately 7 days or less, depending on location. From the available motors, only those which were drop in replacements were considered as well as motors which could be obtained for the 2015 winter operating season. The selected motors are shown below in Figure 4:

Stage 1: Units 1 & 2

Motor	HP	RPM	Installed Frame	Enclosure	Manufacturer	Drop in Replacement	Delivery	Cost	Priority Ranking
Extraction Pump	400	1800	5008VP	WP-I	**WEG**	**Yes**	**18 Wks**	**$38,735.00**	5
FD Fan	1500	1200	450C	WP-II	**US Electric**	**Yes**	**14 Wks**	**$97,850.00**	1
CW Pump	300	600	687UP	WP-I	**US Electric**	**Yes**	**13 Wks**	**$115,365.00**	4
Unit 1 Boiler Feed Pump	3000	3600	500	WP-II	**WEG**	**Yes**	**22 weeks**	**$131,355.00**	3
Unit 2 Boiler Feed Pump	3000	3600	500	WP-II	**WEG**	**Yes**	**22 weeks**	**$131,355.00**	3

Stage 2: Unit 3

Motor	HP	RPM	Installed Frame	Enclosure	Manufacturer	Drop in Replacement	Delivery	Cost	Priority Ranking
Extraction Pump	350	1800	VEFLoSN-KK	IP22	**US Electric**	**Yes**	**12 Wks**	**$62,125.00**	5
FD Fan	1500	1200	R885E	WP-I	**Siemens**	**Yes**	**6 Wks**	**$138,990.00**	2
CW Pump	400	600	VEFSN-KK	IP22	**US Electric**	**Yes**	**12-13 Wks**	**$166,590.00**	4
Boiler Feed Pump	2350	3600	TFLW-KK	IP44	**WEG**	**Yes**	**22 weeks**	**$129,708.00**	3

Total Cost: $1,012,073.00

Figure 4: Option 1

The boiler feed pump motors for Unit 1, Unit 2 and Unit 3 are of a different make, ABB, Westinghouse and Hitachi respectively, and as such have different mounting arrangements.

3.2 Option 2: Source and Secure Most Common Spare Parts

Purchasing spare motor parts for the most common, repairable, motor failures offers the highest risk to production in the event of a motor failure. Manufacturers will not release coil information as it is confidential, making spare coils unavailable, with the exception of the Stage 2 FD Fan motor. As part of the rebuild of that FD Fan motor, Siemens reverse engineered coils to complete the rewind allowing spare coils for the application to be purchased. Turn around time with spare coils, bearings and leads are approximately 1-2 weeks, 3-4 weeks without spare coils. A summary of the spare parts is shown below in Figure 5:

Stage 1: Units 1 & 2

Motor	HP	RPM	Installed Frame	Enclosure	Manufacturer	Bearings (each)	Leads (each)	Coils (each)	Total Cost	Priority Ranking
Extraction Pump	400	1800	5008VP	WP-I	US Electric	$665.00	$600.00		$1,265.00	5
FD Fan	1500	1200	450C	WP-II	ABB	$1,460.00	$2,000.00		$3,460.00	1
CW Pump	300	600	687UP	WP-I	US Electric	$805.00	$200.00		$1,005.00	4
Unit 1 Boiler Feed Pump	3000	3600	500	WP-II	ABB	$30,000.00	$2,000.00		$32,000.00	3
Unit 2 Boiler Feed Pump	3000	3600	500	WP-II	Westinghouse	$30,000.00	$2,000.00		$32,000.00	3

Stage 2: Unit 3

Motor	HP	RPM	Installed Frame	Enclosure	Manufacturer	Bearings (each)	Leads (each)	Coils (each)		Priority Ranking
Extraction Pump	350	1800	VEFLoSN-KK	IP22	Hitachi	$375.00	$600.00		$975.00	5
FD Fan	1500	1200	R885E	WP-I	Siemens	$860.00	$1,200.00	$18,000.00	$20,060.00	2
CW Pump	400	600	VEFSN-KK	IP22	Hitachi	$515.00	$600.00		$1,115.00	4
Boiler Feed Pump	2350	3600	TFLW-KK	IP44	Hitachi	$30,000.00	$2,000.00		$32,000.00	3

Total Cost: $123,880.00

Figure 5: Option 2

3.3 Option 3: Purchase Select Spare Motors and Parts

Based upon Asset Criticality and availability of spare parts, the most critical motors would be purchased as spares with spare parts for the remaining motors. This option focuses on minimizing unit outage time and maximizing generating capacity in concert with overall cost consideration. Spare motors would be purchased for the Stage 1 FD Fans as well as for each of the generating units Boiler Feed Pumps. The Stage 2 FD Fan motors have been recently refurbished with spare coils available. A summary is shown below in Figure 6:

Stage 1: Units 1 & 2

Motor	Spare Motor Manufacturer	Spare Motor	Spare Parts	Priority Ranking
Extraction Pump			$1,265.00	5
FD Fan	WEG	$99,335.00		1
CW Pump			$1,005.00	4
Unit 1 Boiler Feed Pump	WEG	$131,355.00		3
Unit 2 Boiler Feed Pump	WEG	$131,355.00		3

Stage 2: Unit 3

Motor	Spare Motor Manufacturer	Spare Motor	Spare Parts	Priority Ranking
Extraction Pump			$975.00	5
FD Fan			$20,060.00	2
CW Pump			$1,115.00	4
Boiler Feed Pump	WEG	$129,708.00		3

Total Cost: $516,173.00

Figure 6: Option 3

4 Recommendation

Based on the availability of 4160 volt motors, the asset criticality analysis and risk assessment of potential impact to the power system in the event of a motor failure, Option 3 is recommended. Option 3 focuses on the most critical motors for purchase while stocking spare parts for the remainder; factoring in equipment condition, spare part availability, and potential impact to generation. The recommended solution recognizes the importance of having the most critical motors in stock but balances the initiative in view of total cost.

APPENDIX A

Asset Criticality Factors

Equipment Factors		
FACTOR	**1 - Health and Safety**	
Level	Definition	Score
1	Minor	1
2	A medical treatment incident or minor damage to plant is foreseeable less than 2 hours D/T	2
3	A lost time incident or serious damage to plant is foreseeable 2 hours to 8 hours D/T	4
4	A disability or catastrophic damage to plant more than 8 hours D/T	6
5	Loss of life or plant incident that is reportable to Department of Labour more than 8 hr D/T	10
Explanation:- Covers both maintenance and operation. Can cover both people and plant.		

FACTOR	**2 - Output (Unit Capacity derating/outage - time and impact)**	
Level	Definition	Score
1	No effect	1
2	Reduced rate minor effect	2
3	Reduced rate serious effect or off between 10 mins and 2 hours	3
4	Off 2 hours to 8 hours	4
5	Off for more than 8 hours	8
Explanation:- Based on 100% unit availability requirement at all times.		

FACTOR	**3 - Quality Of Desired Output**	
Level	Definition	Score
1	No effect or Planned Shutdown	1
3	Controlled Shutdown	3
4	Trip/Under Frequency Load Shed	8
Explanation:- Do not chose the worst case but one that is reasonably foreseeable.		

FACTOR	**4 - Utilization**	
Level	Definition	Score
1	Used less than 33% of the time	1
2	Used between 33% and 66% of the time	2
3	Used more than 66% of the time	3
4	Used 100% of time	5
Explanation:- The percentage time when its functionality is required for continuous plant operation.		

FACTOR	**5 - Alternatives (Same as Loss Mitigation)**	
Level	Definition	Score
1	Standby or alternative route readily available	1
2	Standby or alternative route available but with minor difficulty	2
3	Standby or alternative route available with difficulty OR loss of unit capacity	3
4	No standby or alternative route available without extreme difficulty	4
5	No alternative	6
FACTOR	**6 - Environment**	
Level	Definition	Score
1	No effect	1
2	Minor local effect - can be contained on site eg noise/smell	2
3	More serious local / minor off-plant - liable to result in discharge to atmosphere or water course eg ammonia/fumes/oil	4
4	Reportable or exceeds consents - has potential for prosecution	6
5	More serious off-plant or off-site effect which involves outside services	10
Explanation:- Use reasonably foreseeable effects rather than worse case. Include dust, noise, gas, liquids etc. Use this factor where the effect on the environment is important. Include any effect caused while the equipment is breaking down, any knock off effect and any environmental effect due to the maintenance itself.		

FACTOR	**7 - Time to Effect**	
Level	Definition	Score
1	Negligible effect	1
2	More than 24 hours	2
3	Between 2 hours and 24 hours	3
4	Between 30 mins and 2 hours	4
5	Immediate	5
Explanation:- Sometime the effect of a breakdown is not felt immediately because buffer storage is provided.		

Asset Criticality Ranking for 4160 Volt Motors at HTGS

Stage 1: Units 1 & 2

Motor	Health & Safety	Output	Quality	Utilization	Alternatives	Environment	Time to Effect	Equipment Score
Extraction Pump	1	8	8	5	3	1	5	4800
FD Fan	6	8	8	5	4	6	5	230400
CW Pump	4	8	8	5	3	1	5	19200
Unit 1 Boiler Feed Pump	4	8	8	5	4	1	5	25600
Unit 2 Boiler Feed Pump	4	8	8	5	4	1	5	25600

Stage 2: Unit 3

Motor	Health & Safety	Output	Quality	Utilization	Alternatives	Environment	Time to Effect	Equipment Score
Extraction Pump	1	8	8	5	3	1	5	4800
FD Fan	6	8	8	5	3	6	5	172800
CW Pump	4	8	8	5	3	1	5	19200
Boiler Feed Pump	4	8	8	5	4	1	5	25600