Manitoba Hydro

REPORT ON

FUTURE PROJECTS FOR
HVDC CONVERTER STATIONS

Report No. HVDC 10-34E

HVDC ENGINEERING DEPARTMENT

HVDC DIVISION

POWER SUPPLY

PROVINCE OF MANITOBA
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Table of Contents

1. INTRODUCTION

The objective of this report is to identify long term future system improvements necessary to maintain the reliability and availability of the Nelson River HVDC system and minimize the operating and maintenance cost. This report is not intended to be a full justification but only to identify projects at a high level based on expected life and known operational issues.

Bipole I was started in 1971 and completed in 1976 as a mercury arc valve scheme. Even though the pole 2 valve groups were commissioned in the later years, the equipment related to pole controls, pole switchgear and dc filters for both poles was installed 1971. VG13 was operated as a pole 2 valve group for a number of years, in order to eliminate the ground current.

In 1992, the pole 1 mercury arc valves were replaced with thyristor valves. At the same time, valve group controls and valve cooling plants for pole 1 valve groups were replaced. The pole 2 mercury arc valves and cooling plant were replaced with thyristor valves in 2004. Pole 2 valve group controls were not changed out.

Bipole II, stage 1 valve groups were installed in 1978 and stage 2 valve groups were installed in 1984. Pole controls and the pole related equipment for both poles were installed in 1978.

Over time, the performance of various components of Bipole I and Bipole II has been deteriorating, resulting in increased life extension measures. The Electric Power Research Institute (EPRI) issued a report in 2007 on the Life Extension of HVDC Stations. This report provides an estimated lifetime of various components (Appendix A) based on a world wide survey of HVDC stations. These values are used in this report as a guide.

2. SCOPE

This report covers major components of Bipole I and Bipole II that would require replacement in next 20 years. Some of these items may already be included in the present financial plan. The report recommends an estimated date of replacement and an estimated cost (+/- 30%) of replacement for each element. This report does not include replacement of converter transformers, AC switchyard apparatus or wall bushings which are covered under separate programs. In this report Bipole II valve replacement is assumed to be completed after Bipole III is in-service in 2018-19. However, should Bipole III development be delayed beyond 2018, it would be prudent to revisit the timing of Bipole II valve replacement.

3. CRITERIA

The following points were considered in determining the need and the timing for equipment replacement;

3.1 Equipment Age

If the life time of equipment, as defined in the EPRI report is exceeded by more than five years, the equipment is considered to have exceeded its life time and should be considered for replacement taking other factors into account.

3.2 Timing

The replacement date for some of the equipment has been selected such that outages required for replacement can be accommodated without limiting the transmission capacity and to keep the number of projects to a manageable number at any given time. Figures 1, 2 and 3 show the time schedule for various projects.

3.3 Lack of Spares

The HVDC system includes equipment which is highly complex and experiencing accelerated technological change. For example Bipole II thyristor valves were built with thyristors rated at 3.2 kV and 1200A where as today's thyristors are rated at 8 kV and 4000A. With the rapid change in technology it becomes difficult to maintain the old equipment since spare parts are no longer available or the cost of replacements parts is extremely expensive.

3.4 Lack of Technical Resources

As the equipment ages and technology changes the required technical resources are no longer available from the supplier or in-house. It has become more challenging to maintain or repair the equipment resulting in reduced reliability and availability.

3.5 Performance

As the intent of this report is to identity long term requirements, the present equipment performance is considered and extrapolated to when the actual date of replacement is to be considered.

4. BIPOLE I

The equipment related to Bipole I is listed in Table1.

4.1 Frequency Based Current Control (FBCC)

Reason:

This circuit was custom built in 1980 and has exceeded it lifetime. The circuitry uses outdated technology. It can no longer be repaired as the spare parts are not available and the technical knowhow and the tools required for reprogramming are no longer available.

A similar circuit would be required for Bipole III and it would be beneficial to develop a system now which can then be used for Bipole III. This approach would result in updating the technology and would make all three bipoles the same.

Proposed in Service: 2012

Cost: $200,000

4.2 Pole 1 Cooling Controls

Reason:
The equipment is an analogue control system installed in 1992, with an expected life of 15 years. The equipment has exceeded its expected lifetime and is starting to have problems. For example, it is no longer possible to communicate with the PLC and as a result troubleshooting is very difficult if not impossible.

Since the need is urgent, the replacement should be carried out at the same time as the replacement of the Bypass Vacuum Switch (BPVS). The development of the software can start immediately in order to meet the in service date.

Proposed in service: 2012-2013

Cost: $1,500,000

4.3 Pole Transductors (High and Low voltage)

Reason:
The equipment has exceeded its lifetime and no spare parts are available. Once the BPVS's are replaced only pole and electrode transductors will be supplied from the MG sets. It would be possible to remove the MG sets after these transductors are replaced.

Proposed in Service: 2014

Cost: $12,000,000

4.4 Motor Generator Set Removal

Reason:

After the replacement of BPVSs and transductors in pole and valve groups the MG sets are no longer required.

Proposed in Service: 2014

Cost: $4,000,000

4.5 AC Filter Protections

Reason:

The protection uses old electromechanical relays which have exceeded their lifetime. Spare parts and technical resources are no longer available. These relays should be replaced with latest technology relays.

Proposed in Service: 2015

Cost: $2,000,000

4.6 Transformer Protection (Converter Transformer and station transformers)

Reason:

The protection uses old electromechanical relays which have exceeded their lifetime. Spare parts and technical resources are no longer available. These relays should be replaced with latest technology relays.

Proposed in Service: 2015

Cost: $4,000,000

4.7 DC Filter Protection

Reason:

The protection uses old electromechanical relays which have exceeded their lifetime. Spare parts and technical resources are no longer available. These relays should be replaced with latest technology relays.

Proposed in Service: 2015

Cost: $1,000,000

4.8 Special Protection Systems Controls

Reason:

The Special Protection Systems are digital controls and reaching end of life. The expected life of digital controls is 15 years. The technical resources and spare parts will not be available.

Controls included in this section include; allocators, reduction controllers, six-pulse PLC, SCADA PLC and SUVC.

The best time to replace these controls is at the same time as Bipole III.

Proposed in Service: 2016-17

Cost: $5,000,000

4.9 Communication System

Reason:

At present the CODEC cards are used for the interface between the main communication system and the HVDC controls. These cards were custom designed by Manitoba Hydro. The equipment has exceeded its life time. There is a concern that these cards will not be repairable in future.

These cards should be replaced at the same time when Bipole I controls are replaced.

Proposed in Service: 2020-21

Cost: $6,000,000

4.10 Pole 2 Cooling Controls

Reason:

The equipment was installed in 2004 and would exceed its life time in 2019. By that time the technology used will also become obsolete and it would not be possible to maintain the controls.

Proposed in service: 2022

Cost: $1,500,000

4.11 Bipole I DC Disconnects and high speed switches

Reason:
The dc disconnects and switches were installed in 1974 and have reached their estimated lifetime. These disconnects have had lots of operations during this period, they are starting to breakdown and the spare parts are not available.

Breakdown of any of these disconnects requires a (10-16 hours) pole outage to repair.
The best time to replace these disconnects is immediately after Bipole III, prior to Bipole II valve replacement and before Conawapa comes on line. This work can be done at the same time as the replacement of pole controls.

Proposed in Service: 2021-22

Cost dc disconnects: $20,000,000
Cost high speed switches: $15,000,000
Total: $35,000,000

4.12 Bipole I Control Desk

Reason:

The control desk was installed in 1973 and is 36 years old. The switches and the indicating lights on the desk have been failing and the spare parts are difficult to find. The control desk should be replaced with an HMI console at the same time when the Bipole I pole and bipole controls are replaced.

Proposed in Service: 2021-22

Cost: $3,000,000

4.13 Bipole and Pole Controls

Reason:

The Bipole I controls are of analog technology and are close 40 years old. The expected life of analog controls is 25 years. The technical resources and spare parts will not be available soon.

Assuming that Bipole II controls will be replaced after Bipole III, Bipole I controls should be replaced with the same controls as Bipole II. This will ensure that the same technology is used in Bipole I and Bipole II and will make maintenance, operation and staff training easier.

The best time to replace these controls is immediately after Bipole II controls are replaced and before Conawapa comes on line. This will reduce the cost of outages required for replacing the controls. It will be necessary to order Bipole I and Bipole II controls at the same time.

Proposed in Service: 2021-22

Cost: $15,000,000

4.14 Pole 1 and Pole 2 Valve Group Controls

Reason:

Pole 2 valve group controls are of analog technology and are already 35 years old. The expected life of analog controls is 25 years. The technical resources and spare parts will not be available soon.

Although pole1 valve group controls will only be 27 years old in 2020, it is recommended that these controls be replaced with the same technology as pole 2 and Bipole II.

Assuming that Bipole II controls will be replaced after Bipole III, Bipole I controls should be replaced with the same controls as Bipole II. This will ensure that we have the same technology in Bipole I and Bipole II and will make maintenance, operation and staff training easier.

The best time to replace these controls is immediately after Bipole II and before Conawapa comes on line. This will reduce the cost of outage required for replacing controls.

Proposed in Service: 2021-22

Cost: $15,000,000

4.15 Pole 1 Thyristor Valve Replacement

Reason:

The pole 1 thyristor valves were installed in 1992. The expected lifetime of thyristor valve is 30 years. Assuming the lifetime can be extended by another five years, the valves would need to be replaced by 2027.

Proposed in Service: 2027

Cost: $100 million

5. BIPOLE II

The equipment related to Bipole II is shown in Table 2.

5.1 Valve Hall Air Handling

Reason:
The equipment has exceeded its expected lifetime of 20 years. The other important reason for replacement is to address environmental concerns by replacing the existing refrigerant condensers with environmentally friendly equipment.

The in service date is dictated by the deadline to meet the environmental requirements.

Proposed in service: 2015

Cost: $11,000,000 (based on 2005 CPJ)

5.2 Frequency Based Current Control (FBCC)

Reason:

This circuit was custom built in 1980 and has exceeded it lifetime. The circuitry uses outdated technology. It can no longer be repaired as the spare parts are not available and the technical knowhow and the tools required for reprogramming are no longer available.

A similar circuit would be required for Bipole 3 and it would be beneficial to develop a system now which can then be used for Bipole 3. This approach would result in updating the technology and would make all three bipoles the same.

Proposed in Service: 2012

Cost: $200,000

5.3 AC Filter Protections

Reason:

The replacement of Bipole 2 AC filter protection was recommended in the Bipole 2 Outage Reduction report HVDC 01-09E. The timing for this work could be tied to any decision on adding additional relay buildings at Dorsey.

Proposed in Service: 2015

Cost: $4,000,000

5.4 DC Filter Protection

Reason:

The equipment has exceeded its expected lifetime of 30 years and needs upgrading. The replacement is recommended at the same time Bipole 1 Dc filter protection is replaced.

Proposed in Service: 2015

Cost: $2,000,000

5.5 Thyristor Valves, Valve Controls and DC Controls

Reason:

The equipment has exceeded its expected lifetime of 30 years. The equipment has required continuous repairs for last 15 years and the spare parts are not available. A comprehensive report has been prepared which justifies the replacement of the thyristor valves. The scope of the work includes valves, valve controls, valve cooling plant and the dc controls.

Proposed in service: 2020

As per HVDC report # HVDC 10-16E

Cost: $180,000,000

5.6 Paralleling Controls

This item is included separately as it requires outages and testing with Bipole 1 equipment. The main paralleling controls are located in Bipole 2 DC control.

Reason:

When the Bipole 2 DC controls are replaced the paralleling controls would also have to be replaced. The commissioning of these controls will require outages on Bipole 1 and Bipole 2.

The existing paralleling controls require that the healthy line pole must be in service before the paralleling can proceed. This limits the ability to parallel if the pole with healthy line switches off. The new controls sequences should be modified to allow paralleling with either pole in service.

Proposed in Service: 2020

Cost: $6,000,000

5.7 Communication System

Reason:

At present the CODEC cards are used for the interface between the main communication system and the HVDC controls. These cards were custom designed by Manitoba hydro. The equipment has exceeded its life time. There is a concern by being able to repair these cards in future.

These cards should be replaced at the same time when Bipole II controls are replaced.

Proposed in Service: 2020

Cost: $6,000,000

5.8 Bipole II Control Desk

Reason:

The control desk was installed in 1976 and is 36 years old. The switches and the indicating lights on the desk at Dorsey have been breaking and the spare parts are difficult to find.

The mimic board at Hendy is also starting to have problems. There is a lack of technical resources and spare parts available to repair the interface to the mimic board and the mimic board itself.

The control desk at Dorsey and the mimic board at Henday should be replaced with an HMI console at the same time when the Bipole 2 pole controls are replaced.

Proposed in Service: 2020

Cost: $3,000,000

5.9 DCCTs and Voltage Dividers

Reason:

The DCCTs and Voltage Dividers were installed in 1976. Although the expected lifetime of 30 years will be reached in 2006, it is anticipated that DCCTs and voltage dividers would not need replacement till 2028.

Proposed in Service: 2028

Cost: $20,000,000

5.10 DC disconnects and High Speed Switches

Reason:

The dc disconnects and high speed switches were installed in 1976. Although the expected lifetime of 35 years will be reached in 2011, it is anticipated that these disconnects would not need replacement until 2028.

Proposed in Service: 2028

Cost dc disconnects: $20,000,000
Cost high speed switches: $15,000,000
Total: $35,000,000

6. SYNCHRONOUS CONDENSERS

6.1 Joint Var Controller

Reason:

The Dorsey Joint Var Controller (JVC) was installed in 1989. The supplier no longer supports the existing hardware and software. The equipment has exceeded its expected life time of 15 years. The JVC at Dorsey has many custom built functions which are not available in off the shelf JVC's. A considerable amount of Manitoba Hydro engineering time was spent in helping the supplier develop all the features.

A JVC will also be required for Riel station. It is recommended that new JVC be developed by the HVDC Engineering Dept for Dorsey and Riel. Having the same technology at both stations will improve upon the ability to maintain and repair the equipment.

The new JVC can be installed at Dorsey first and the software can be fully commissioned. This would result in a smooth installation at Riel. It would also result in cost reduction for Riel JVC.

Proposed in Service: 2015
Cost: $1,000,000

6.2 ASEA Start/Stop Controls

Reason:

The ASEA synchs were installed in 1976. Over the last five years the performance of the start/stop controls have deteriorated and have resulted in either forced outages or extension of planned outages. The controls are now 35 years old and have exceeded their life expectancy of 25 years. Similar controls for the English Electric synchs were replaced in 1995.

The start/stop controls should be replaced during the major refurbish outages planned in the near future.

Proposed in Service: SC23Y - 2013
SC21Y - 2014
SC22Y - 2015

Cost: Total for 3 synchs $10,500,000

6.3 ASEA Excitation systems

Reason:

The ASEA synchs were installed in 1976. Over the last five years the performance of the excitation systems have deteriorated and have resulted in either forced outages or extension of planned outages. The exciters are now 35 years old and have exceeded their life expectancy of 25 years. Similar exciters for the English Electric synchs were replaced in 1995.

The excitation systems should be replaced during the major refurbish outages planned in the near future.

Proposed in Service: SC23Y - 2013
SC21Y - 2014
SC22Y - 2015

Cost: Total for 3 synchs $ 6,000,000

6.4 ASEA Protection Systems

Reason:

The protection uses old electromechanical relays which have exceeded their lifetime. Spare parts nd technical resources are no longer available. These relays should be replaced with latest technology relays.

Proposed in Service: SC23Y - 2013
SC21Y - 2014
SC22Y - 2015

Cost: $2,000,000

6.5 EE Start/Stop Controls

Reason:

The English Electric synchs start/stop controls were replaced in 1995. The expected lifetime of these controls is 15 years. Replacement should be considered during the next major refurbishment outage.

Proposed in Service: SC11Y - 2016
SC12Y - 2017
SC13Y - 2018

Cost: Total for 3 synchs $10,500,000

6.6 EE Protection Systems

Reason:

The protection uses old electromechanical relays which have exceeded their lifetime. Spare parts and technical resources are no longer available. These relays should be replaced with latest technology relays.

Proposed in Service: SC11Y - 2016
SC12Y - 2017
SC13Y - 2018

Cost: Total for 3 synchs $2,000,000

6.7 MIL Static Frequency Controllers (SFC)

Reason:

The SFCs for MIL synchs were installed in 1988. The SFC consists of a digital programmable device which has been outdated for almost 10 years. The SFCs are now 23 years old and have exceeded their life expectancy of 15 years. There is no support to repair these units in terms of spare parts and technical resources from the original supplier.

It is recommended that the SFC controls for MIL should be the same as for the Riel synchs. It can be specified as an additional option to Bipole III synchs. This would have the advantage of having the same technology at Dorsey and Riel.

Proposed in Service: SC7Y -2019
SC8Y - 2020
SC9Y -2021

Cost: Total for 3 synchs $ 6,000,000

6.8 Excitation System for MIL Synchs

Reason:

The excitation system for MIL synchs were installed in 1988. The system is now 23 years old and with an expected life of 30 years.

The change out should be coordinated with a mechanical overhaul outage.

Proposed in Service: SC7Y -2029
SC8Y - 2030
SC9Y -2031

Cost: Total for 3 synchs $10,500,000

6.9 Synchronous Condenser Overhaul

Reason:

The stator and rotor windings of the synchronous condensers must be inspected for tightness every 10 years.

Based on the previous years of overhaul of various synchronous condensers the year of next overhaul is as following.

Proposed in Service: SC23Y- 2013
SC21Y - 2014
SC22Y - 2015
SC11Y - 2016
SC12Y - 2017
SC13Y - 2018
SC7Y - 2019
SC8Y - 2020
SC9Y - 2021

Table 1 - BIPOLE I 1 PROJECTS

Project number (P:)	Project	Time Frame		Cost [$ Millions]
		Start	End (ISD)	
	Frequency Based Current Controller	2012	2012	0.2
12688	Pole 1 Cooling Controls	2011	2013	1.5
11165	Transductions (Pole)	2012	2014	12
	Motor Generator Set Removal	2013	2014	4
	AC Filter Protection	2013	2015	2
	Transformer Protection	2013	2015	4
	DC Filter Protection	2014	2015	1
	Special Protection Systems Controls	2016	2017	5
	Communication	2020	2021	6
12688	Pole 2 Cooling Controls	2020	2022	1.5
	Voltage Dividers	2020	2022	10
11170	DC Disconnects	2020	2022	35
	Bipole I Control Desk	2020	2022	3
	Bipole and Pole Controls	2020	2022	15
	Pole 1 and Pole 2 VG Controls	2020	2022	15
	Pole 1 Thyristor Valves	2025	2027	100

Table 2 - BIPOLE II PROJECTS

Table 2 -
Bipole II

Project number (P:)	Project	Time Frame Start	End (ISD)	Cost [$ Millions]	Age When Replaced
	Valve Hall Air Handling	2010	2011	4	32
	Frequency Based Current Controller	2011	2012	0.2	31
	AC Filter Protection (Siemens package) in Dorsey Zone Building	2013	2015	4	37
	DC Filter Protection	2014	2015	2	35
	Thyristor Valves, Cooling and Controls	2018	2020	180	37
	Paralleling Controls	2018	2020	6	37
	Communication	2018	2020	6	37
	Bipole II Control Desk	2018	2020	3	37
	DCCT's and Voltage Dividers	2027	2028	20	51
11170	DC Disconnects	2027	2028	35	51

Table 3 - SYNCRONOUS CONDENSERS

Project number (P:)	Project	Time Frame		Cost [$ Millions]	Age When Replaced
		Start	End (ISD)		
	Joint VAR controller	2014	2015	1	26
	ASEA SC23Y START/STOP	2012	2013		37
	ASEA SC21Y START/STOP	2013	2014	10.5	38
	ASEA SC22Y START/STOP	2014	2015		39
	ASEA SC23Y EXCITATION	2012	2013		37
	ASEA SC21Y EXCITATION	2013	2014	6	38
	ASEA SC22Y EXCITATION	2014	2015		39
	ASEA SC23Y PROTECTION	2012	2013		37
	ASEA SC21Y PROTECTION	2013	2014	2	38
	ASEA SC22Y PROTECTION	2014	2015		39
	EE SC11Y START/STOP	2015	2016		21
	EE SC12Y START/STOP	2016	2017	10.5	22
	EE SC13Y START/STOP	2017	2018		23
	EE PROTECTION SC11Y	2015	2016	-	21
	EE PROTECTION SC12Y	2016	2017	2	22
	EE PROTECTION SC13Y	2017	2018	-	23
	MIL SC7Y SFC	2018	2019		31
	MIL SC8Y SFC	2019	2020	6	32
	MIL SC9Y SFC	2020	2021		33
	SC7Y SFC	2028	2029	-	41
	SC8Y SFC	2029	2030	6	42
	SC9Y SFC	2030	2031	-	43
	MIL SC7Y EXCITATION	2028	2029		41
	MIL SC8Y EXCITATION	2029	2030	6	42
	MIL SC9Y EXCITATION	2030	2031		43

Bipole I	YEAR																
PROJECT	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
FBCC		■															
Pole 1 Cooling Controls	■	■	■														
Transductors (Pole)		■	■	■													
Mg Set Removal			■	■													
Ac Filter Protection			■	■	■												
Transformer Protection			■	■	■												
Dc Filter Protection				■	■												
Special Protection Systems Controls						■	■										
Communication System										■	■						
Pole 2 Cooling Controls										■	■	■					
Dc Disconnects										■	■	■					
Bipole I CONTROL DESK										■	■	■					
Bipole And Pole Controls										■	■	■					
VG Controls										■	■	■					
Thyristor Valve Replacement															■	■	■

Figure 1 - Time schedule for Bipole I projects

BIPOLE II							YEAR											
PROJECT	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
VALVE HALL AIR HANDLING	■																	
FBCC	■	■																
AC FILTER PROTECTION			■	■	■													
DC FILTER PROTECTION				■	■													
THRYISTOR VALVES, COOLING AND CONTROLS								■	■	■								
PARALLELING								■	■	■								
COMMUNICATION SYSTEM								■	■	■								
Bipole II CONTROL DESK								■	■	■								
DCCTS + VOLTAGE DIVIDER																	■	■
DC DISCONNECTS																	■	■

Figure 2 - Time schedule for Bipole II projects

SYNCH CONDENSERS	YEAR																				
PROJECT	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
JOINT VAR CONTROLLER				■	■																
ASEA SC23Y START/STOP			■																		
ASEA SC21Y START/STOP				■																	
ASEA SC22Y START/STOP					■																
ASEA SC23Y EXCITATION			■																		
ASEA SC21Y EXCITATION				■																	
ASEA SC22Y EXCITATION					■																
ASEA PROTECTION SC23Y			■																		
ASEA PROTECTION SC21Y				■																	
ASEA PROTECTION SC22Y					■																
EE SC11Y START/STOP						■															
EE SC12Y START/STOP							■														
EE SC13Y START/STOP								■													
EE PROTECTION SC11Y						■															
EE PROTECTION SC12Y							■														
EE PROTECTION SC13Y								■													
SC7Y SFC									■												
SC8Y SFC										■											
SC9Y SFC											■										
SC7Y EXCITATION																			■		
SC8Y EXCITATION																				■	
SC9Y EXCITATION																					■

Figure 3 - Time schedule for Synchronous Condenser Projects

Appendix A - Abstract from EPRI Report 1013976 "Life Extension Guidelines of Existing HVDC Systems" Published in 2007

Utility Information

The guideline preparation followed these steps:

List of existing HVDC stations

Surveys were prepared and sent to utilities around the world to identify the known HVDC converter stations currently in service in the world. They were also used to gather data on what types of life extension activities have been undertaken or planned. These life extension activities were tabulated by year commissioned and major system.

The results of this survey activity indicated most converter stations older than 10 years are undergoing some form of life extension upgrade.

CIGRE HVDC System Performance Data

A review of published Comité International des Grands Réseaux Electrique (CIGRE) reliability and performance data was accomplished and summarized by age of station. The Energy Availability, Energy Utilization, Forced and Scheduled Energy Unavailability, Thyristor Cell Failure Rates and Forced Outage Statistics were reviewed and tabulated. The following are the summary observations:

The average energy availability (EA of HVDC systems, as a function of age, tends to rise after the first ten years of operation and remain relatively constant. The overall average EA is approximately 94.3%.

The average energy utilization of HVDC systems as a function of age tends to rise significantly for the facilities greater than twenty years of age indicating a high value is placed on their use.

Forced energy unavailability tends to improve with age perhaps indicating improved diagnostics as HVDC systems age.

Scheduled energy unavailability increases for those facilities greater than twenty years of age, perhaps indicating a higher level of maintenance is required for older HVDC systems.

Thyristor cell failure rates tend to rise significantly for those facilities greater than twenty (20) years of age. The total number of forced outage events between 1993 and 2004 is greatest for ac equipment (AC-E) and least for thyristor valves (V).

Component Lifetimes

Expected component lifetimes were determined through a review of both published information and experience of the project team members. It should be noted, these values represent an average and there can be wide ranges for lifetimes, particularly with thyristor valves and converter transformers (see Table 1-1).

Table 1-1 - Component Lifetimes

Component	Expected Lifetime (Years)
Capacitor Banks (AC Filter and Reactive Compensation)	25
Air Core Reactors (AC Filter and Reactive Compensation)	25
Oil Filled AC Filter Reactors (AC Filter and Reactive Compensation)	35
AC Filter Resistors	40
AC Power Circuit Breakers	35
Interrupting Switches	20
Circuit Switchers	25
Disconnecting Switches	35
Surge Arrestors (AC)	35
Line or Wave Traps	20
Bus, Insulators, Structures	50
AC Controls and Protection	15
Instrument Transformers	30
Valve Hall Cooling and Fire Protection Systems	20
Thyristor Valve Cooling Systems (Wet Surface Cooling Tower)	15

Thyristor Valve Cooling Systems (Dry Surface Cooling Tower)	20
Converter Transformers	40*
Civil Works (Grading, Concrete, Steel, Structures, Roads, Buildings)	50
Auxiliary Power Equipment (Batteries)	15
Auxiliary Power Equipment (Battery Chargers)	20
Auxiliary Power Equipment (Station Service Transformers)	40
Thyristor Valves	30 *
HVDC Controls and Protection (Analog)	25
HVDC Controls and Protection (Digital)	15
UPS Power Supplies	10
Digital Fault Recorder/Sequence of Events Recorder	15
SCADA/RTU	10
Communication Systems	10
DC Smoothing Reactors (Air Core)	25
DC Smoothing Reactors (Oil Filled)	35
DC Switching Equipment	35
Ground Electrode	40
DC Surge Arrestors	35
DC Filters	20
Wall Bushings	35
DC Instrumentation	30
DC Buswork, Insulators, Structures	50

*It should be noted there are many converter transformers and thyristor valves that have experienced early failures and have much shorter lifetimes.

Please refer to the Interim Report - E.Pl I 'Life Extension Guidelines of Existing HVDC Systems" Technical Update 101251. March 2007.