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PROTOCOL FOR REPORTING THE OPERATIONAL PERFORMANCE OF HVDC TRANSMISSION SYSTEMS

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Prepared by Working Group 04 of Study Committee 14

PREFACE

Recognising that the experience gained on HVDC transmission systems could be of value throughout the industry, CIGRÉ Study Committee 14 established Working Group 04, Performance of DC Schemes, with terms of reference which included an obligation to collect information on all systems in commercial service. It was considered that such information could be useful in the planning, design, construction and operation of new projects. It was also envisaged that the sharing of operational performance data could be of benefit to those concerned with the operation of existing HVDC links or those planning new HVDC links. It was clear that such reports were best prepared in accordance with a standardized procedure so that, with time, the accumulated data from several systems would establish a basis against which performance could be judged.

General information collected includes a system description, main circuit data and a simplified one-line diagram for each scheme. This descriptive information is compiled in a Compendium. The Compendium is revised biennially with the pages distributed to Regular Members of SC14. The Regular Members may be contacted to obtain the latest copy of the Compendium or revised pages as required. The Compendium or revised pages may also be obtained through the Chair or Secretary of WG 14.04. Furthermore, operational performance data is collected annually from each scheme in commercial operation. Performance data include reliability, availability and maintenance statistics. Reliability data are confined to failures or events which result in loss of transfer capability. Statistic are categorized in order to indicate which type of equipment caused the reduction in the transmission capacity. With the exception of recording thyristor failures, data on component failures not causing a loss of transmission capacity are not recorded. Reliability data on individual components such as capacitors, relays or circuit breakers is more appropriately kept by groups directly involved with each respective apparatus. Working Group 04 summarizes the performance statistics for all reporting schemes every two year in a CIGRÉ paper entitled “A Survey of the Reliability of HVDC Systems Throughout the World.”

As the equipment and techniques of HVDC transmission developed, for example, the replacement of mercury-arc valves by thyristor valves in new projects; it has been necessary to revise or supplement the procedure from time to time. This revision of the Protocol will provide more accurate data on scheduled or planned outages, reporting of system capacity and commutation failures summarized as follows:

a. Outages taken for major reconfiguration shall not be reported.

b. Scheduled outages will include work that may be postponed until a suitable time during light load periods - usually night or weekend. Outages of this type will include work on redundant systems such as the controls where there is the philosophy of the owner to schedule an outage for this activity.

c. Maximum capacity has been clarified to include capacity available through utilizing redundant equipment when system may be loaded over normal conditions.

d. Inverter end commutation failures during ac faults will be reported when ac bus voltage drops below 90 percent rather than 85 percent. Another category has been added to commutation failures related to control problems.

Scheduled equipment unavailability (SEU) has less significance than forced equipment unavailability (FEU) in comparing different systems since scheduled outages may be taken during reduced system loading conditions or when some reduction in power transfer capability is acceptable. Discretionary outages for maintaining redundant equipment are also considered within the SEU category. Accordingly, SEU is intended to be used mainly by owners over a long period of time for general comparison or for comparisons of their own needs, and not intended to be used for evaluating reliability of availability performance in RAM design or under RAM warranties.

This revised Protocol has been distributed to SC14 members for ballot last quarter, 1996 and was approved in March 1997. The Protocol will supersede the earlier issues and should be used for reporting 1996 performance and beyond.

Note:

General terms relevant to HVDC transmission with explanatory figures are to be found in the International Electrotechnical Commission publication 633, “Terminology for High-voltage Direct Current Transmission” to which reference should be made.

Please observe that the time should be given in “decimal hours” i.e. 6 h:30 min = 6.5 hours.

1. SCOPE OF REPORTING SCHEME

A separate report on the operational performance of each HVDC power transmission system or back-to-back interconnection in commercial service is to be prepared each year. These reports are to be made in accordance with this Protocol to ensure uniformity and comparability of the data. For an established system, the reporting period shall be from January to December. For a system in its initial calendar year of commercial operation, the report is to cover the period from the start of commercial operation to December of that year.

This protocol covers point-to-point transmission systems, back-to-back interconnections and multiterminal transmission systems. For point-to-point systems and back-to-back interconnections, i.e. two-terminal systems, statistics are to be reported based on the total transmission capability from the sending end to the receiving end measured at a given point. If, however, the two terminals are operated by different companies, are composed of equipment of different vintage or of equipment from different suppliers, statistics can be reported on an individual station basis if so desired by those responsible for reporting. In such a case the outage should only be charged to the originating station taking care not to report the same event twice. For distributed multiterminal systems, i.e. systems with more than two terminals, statistics are to be reported separately for each station based on its own individual capability. Multiterminal systems, incorporating parallel converters but having only two terminals on the dc line, e.g., the Pacific Intertie with the parallel Expansion, can be considered as either point-to-point systems or as multiterminal systems for purpose of reporting. Therefore, statistics for this special type of multiterminal system can be reported based on either total transmission capability or on individual station capability. If the convertors at one station use different technology, station statistics can be reported separately for each different type of capacity if desired. Multiple bipoles are to be reported individually. Special mention should be given in the text and in the tabulations to any common events resulting in bipolar outages.

From time to time older systems, for which further data is judged to be of only marginal value, will be specifically excluded from the reporting scheme.

2. PREPARATION AND DISTRIBUTION OF REPORTS

The preparation and submission of reports on national systems is the responsibility of the individual HVDC System Correspondents nominated by the Regular Member of Study Committee 14 for the country in question. For systems having different stations with different owners/operators, it is preferred that the Correspondents integrate their statistics into a joint report for that system before submission. In the case of international connections, the responsibility rests jointly with the separately nominated Correspondents.

One copy of each report is to be sent to the Convenor of Working Group 14 (WG)04 by the end of March in the year following the period covered by the report. These reports will be collected by the Convenor, copied and distributed to all Correspondents for their mutual information and to Working Group Members.

The Working Group will prepare each year, or as required, a paper summarizing the performance data from all the systems for presentation to the Study Committee at its meeting each year. To assist the proper interpretation of these data the Working Group will make available a Compendium of the main particulars of all HVDC systems.

Furthermore, the Working Group will from time to time, acting in accordance with the directions of the Committee, prepare a coordinating paper giving an analysis of the performance data collected for presentation to the CIGRÉ Conference in the name of the Study Committee.

3. DEFINITIONS

3.1 Outage Terms

3.1.1 *Outage* - The state in which the HVDC System is unavailable for operation at its maximum continuous capacity due to an event directly related to the converter station equipment or dc transmission line is referred to as an outage. Failure of equipment not needed for power transmission shall not be considered as an outage for purposes of this report. AC system related outages will be recorded but not included in HVDC system reliability calculations. For purposes of this report, outages taken for major reconfiguration or upgrading such as addition of converters shall not be reported.

3.1.2 *Scheduled Outage* - An outage, which is either planned or which can be deferred until a suitable time, is called a scheduled outage.

Scheduled outages can be planned well in advance, primarily for preventive maintenance purposes such as annual maintenance program. During such planned maintenance outage, it is usual to work on several different equipment, or systems concurrently. It is not necessary to allocate such outage time to individual equipment categories. Only the elapsed time should be reported in Table 2SS as “PM”.

Classified under the scheduled outage category are also outages for work which could be postponed until a suitable time (usually night or weekend) but cannot be postponed until the next planned outage. Equipment category code in Table 2SS should be used to identify the affected equipment. This includes discretionary outages based on operating policies, owner’s preference and maintenance of redundant equipment.

Note: If the scheduled outage is extended due to additional work which would otherwise have necessitated a forced outage, the excess period is counted as a forced outage.

3.1.3 *Forced Outage* - The state in which an equipment is unavailable for normal operation but is not in the scheduled outage state is referred to as a forced outage.

<u>Trips</u> - Sudden interruption in transmission by automatic protective action or manual emergency shutdown.

<u>Other forced outages</u> - In general other forced outages are unexpected HVDC equipment problems that force immediate reduction in capacity of HVDC stations or system but do not cause or require a trip. Also in this category are outages caused by start-up or de-block delays.

Note: In some cases the opportunity exists during forced outages to perform some of the repairs or maintenance that would otherwise be performed during the next scheduled outage. See clause 5.2, rule (f).

3.2 Capacity Terms

3.2.1 *Maximum Continuous Capacity Pm* - The maximum capacity (MW), excluding the added capacity available through means of redundant equipment, for which continuous operation under normal conditions is possible is referred to as the maximum continuous capacity.

For two-terminal systems reporting jointly, the maximum continuous capacity is referred to a particular point in the system, usually at one or the other convertor station. For multiterminal systems or two-terminal systems reporting separately, the maximum continuous capacity refers to the rating of the individual convertor station.

Note: When the maximum continuous capacity varies according to seasonal conditions, the highest value shall be used as the capacity for the purpose of reports prepared according to this Protocol.

3.2.2 *Outage Capacity Po* - The capacity reduction (MW) which the outage would have caused if the system were operating at its maximum continuous capacity (Pm) at the time of the outage is called the outage capacity.

For two-terminal systems reporting jointly, the outage capacity is referred to the same point in the system used for determining Pm. For multiterminal systems or two-terminal systems reporting separately, the outage capacity refers only to the individual convertor station.

3.2.3 *Outage Derating Factor ODF* - The ratio of outage capacity to maximum continuous capacity is called the outage derating factor.

$$ODF = Po / Pm$$

3.3 Outage Duration Terms

3.3.1 *Actual Outage Duration AOD* - The time elapsed in decimal hours between the start and the end of an outage is the actual outage duration. The start of an outage is typically the first switching action related to the outage. The end of an outage is typically the last switching action related to return of the equipment to operational readiness.

3.3.2 *Equivalent Outage Duration EOD* - The actual outage duration (AOD) in decimal hours, multiplied by the outage derating factor (ODF), so as to take account of partial loss of capacity, is called the equivalent outage duration.

$$EOD = AOD \times ODF$$

Each equivalent outage duration (EOD) may be classified according to the type of outage involved:

equivalent forced outage duration (EFOD) and,
equivalent scheduled outage duration (ESOD).

3.4 Time Categories

3.4.1 *Period Hours PH* - The number of calendar hours in the reporting period is referred to as the period hours. In a full year the period hours are 8760, or 8784 in leap years. If the equipment is commissioned part way through a year the period hours will be proportionately less.

3.4.2 *Actual Outage Hours AOH* - The sum of actual outage durations within the reporting period is referred to as the actual outage hours.

$$AOH = \Sigma\, AOD$$

The actual outage hour (AOH) may be classified according to the type of outage involved:

actual forced outage hours (AFOH) and,
actual scheduled outage hours (ASOH).

$$AFOH = \Sigma\, AFOD$$
$$ASOH = \Sigma\, ASOD$$

3.4.3 *Equivalent Outage Hours EOH* - The sum of equivalent outage durations within the reporting period is referred to as the equivalent outage hours.

$$EOH = \Sigma\, EOD$$

The equivalent outage hours (EOH) may be classified according to the type of outage involved:

equivalent forced outage hours (EFOH) and,
equivalent scheduled outage hours (ESOH).

$$EFOH = \Sigma\ EFOD$$
$$ESOH = \Sigma\ ESOD$$

3.5 Availability and Utilization Terms

3.5.1 *Energy Unavailability EU* - A measure of the energy which could not have been transmitted due to outages is referred to as the energy unavailability.

For two-terminal systems reporting jointly, the energy unavailability is calculated based on the same point in the system used for determining Pm. For multiterminal systems or two terminal systems reporting separately, the energy unavailability is calculated separately for each individual convertor station.

Energy unavailability % EU = (EOH / PH) x 100

Forced energy unavailability % FEU = (EFOH / PH) x 100

Scheduled energy unavailability % SEU = (ESOH / PH) x 100

3.5.2 *Energy Availability EA* - A measure of the energy which could have been transmitted except for limitations of capacity due to outages is referred to as energy availability.

For two-terminal systems reporting jointly, the energy availability is calculated based on the same point in the system used for determining Pm. For multiterminal systems or for two-terminal systems reporting separately, the energy availability is calculated separately for each individual convertor station.

Energy Availability % EA = 100 - EU

3.5.3 *Energy Utilization U* - A factor giving a measure of the energy actually transmitted over the system.

For two-terminal systems, the energy utilization is calculated based on the same point in the system used for determining Pm. For multiterminal systems, the energy utilization is calculated separately for each individual convertor station.

Energy Utilization % U = [(total energy transmitted)/(Pm x PH)] x 100

Total energy transmitted = energy exported + energy imported (expressed in MWh) both referred to the point at which Pm is defined.

Pm: Maximum continuous capacity in MW
PH: Period hours

3.6 Commutation Failure Performance Terms

3.6.1 *Recordable A.C. System Fault* - In this context, an a.c. system fault is one which causes one or more of the inverter a.c. bus phase voltages, referred to the terminals of the harmonic filter, to drop immediately following the fault initiation below 90 per cent of the voltage prior to the fault. Note also that in this context, ac system faults at, or near, the rectifier are not relevant and should not be included in this reporting. An exception to this rule is a special case where the network topology dictates that an ac fault near the rectifier also produces a simultaneous recordable fault at the inverter.

3.6.2 *Commutation Failure Start CFS(A)* - The initiation or onset of commutation failure(s) in any valve group immediately following the occurrence of an ac system fault, regardless of whether the ac fault is "recordable" as defined in 3.6.1 above. Do not include in here commutation failures as a result of control problems or switching events.

3.6.3 *Commutation Failure Start CFS(B)* - The initiation or onset of commutation failure(s) in any valve group as a result of control problems, switching events or other causes, but excluding those initiated by ac system faults under 3.6.2 above.

4. EQUIPMENT AND FAULT CATEGORY TERMS

Convertor station equipment is classified into major categories for the purpose of reporting cause of capacity reduction or convertor outages. Failure of equipment resulting in an outage or loss of convertor capacity is charged to the category to which the failed equipment belongs. Failures or outages of redundant equipment which do not result in a loss of converter capacity are not reported in this Protocol. The outage may be forced as a direct consequence of the failure or misoperation, or the outage may be scheduled due to maintenance requirements. Only scheduled outages classified as deferred are categorized according to equipment type. The major categories listed in the following sections are standard for CIGRÉ performance reports. In the interest of providing information which can be used to further describe problem areas and help improve designs, major categories are divided into subcategories. These subcategories are described in the following subsections and are summarized in Appendix B. System correspondents are to utilize these subcategories by appending the respective subcode to the major outage code when maintaining the outage log and in completing Table 2.

4.1 A.C. and Auxiliary Equipment AC-E This major category covers all ac main circuit equipment at the station. This includes everything from the incoming ac connection to the external connecting clamp on the valve winding bushing of the convertor transformer. This category also covers low voltage auxiliary power, auxiliary valve cooling equipment and ac control and protection. This category does not apply to capacity outages resulting from events in the ac network external to the convertor station. The following subsections give the different subcategories of equipment included in this category and contain examples of each type of equipment.

4.1.1 A.C. Filter and Shunt Bank AC-E.F - Loss of station capacity due to failure of passive and active ac filters, shunt compensation or PLC filters is assigned to this subcategory. Types of components included in this subcategory would be capacitors, reactors, and resistors which comprise the ac filtering or shunt compensation of the converter station.

4.1.2 A.C. Control and Protection AC-E.CP Loss of station capacity due to failure of ac protections, ac controls, or ac current and voltage transformers is assigned to this subcategory. AC protections or control could be for the main circuit equipment, for the auxiliary power equipment or for the valve cooling equipment.

4.1.3 Converter Transformer AC-E.TX Loss of station capacity due to failure of a converter transformer is assigned to this subcategory. Included in this subcategory is any equipment integral with the converter transformer such as tap changers, bushings or transformer cooling equipment.

4.1.4 Synchronous Compensator AC-E.SC Loss of station capacity due to failure of a synchronous compensator is charged to this subcategory. Included in this subcategory is anything integral or directly related to the synchronous machine such as its cooling system or exciter.

4.1.5 Auxiliary Equipment & Auxiliary Power AC-E.AX Loss of station capacity due to failure or misoperation of auxiliary equipment. Such equipment includes auxiliary transformers, pumps, battery chargers, heat exchangers, cooling system process instrumentation, low voltage switchgear, motor control centers, fire protection and civil works.

4.1.6 Other A.C. Switchyard Equipment AC-E.SW Loss of station capacity due to failure of ac circuit breakers, disconnect switches, isolating switches or grounding switches is assigned to this subcategory. Also included are other ac switchyard equipment such as ac surge arresters, buswork or insulators.

4.2 Valves V This major category covers all parts of the valve itself. The valve is the complete operative array forming an arm, or part of an arm of the convertor bridge. It includes all auxiliaries and components integral with the valve and forming part of the operative array. The valve category is divided into two subcategories.

4.2.1 Valve Electrical V.E. Loss of station capacity due to any failure of the valve except for those related to that part of the valve cooling system integral with the valve is assigned to this subcategory.

4.2.2 Valve, Valve Cooling V.VC Loss of station capacity due to any failure of the valve related to that part of the valve cooling system at high potential integral with the valve is assigned to this subcategory.

4.3 DC Control and Protection Equipment C-P This major category covers the equipment used for control of the overall HVDC system and for the control, monitoring and protection of each HVDC substation excluding control and protection of a conventional type which is included in "a.c. and auxiliary equipment." The equipment provided for the coding of control and indication information to be sent over a telecommunication circuit and the circuit itself is included. Devices such as disconnectors, circuit-breakers and transformer tap changers which may actually perform the control or protection action are excluded. The following subsections give the different subcategories of equipment included in this category and contain examples of each type of equipment.

4.3.1 Local Control and Protection C-P.L Loss of station capacity due to any failure of the control, protection or monitoring equipment of the local HVDC station is charged to this subcategory. Examples would include failures of the convertor firing control, current and voltage regulators, convertor and dc yard protections, valve control and protection, and local control sequences.

4.3.2 Master Control and Protection C-P.M Loss of station capacity due to any failure of the master control equipment is charged to this subcategory. The master control equipment is that used for interstation coordination of current and voltage orders, interstation sequences, auxiliary controls such as damping controls or higher level controls such as power control or frequency control.

4.3.3 Control and Protection Telecommunications C-P.T Loss of station capacity due to any failure of the equipment provided for the coding of control and indication information to be sent over a telecommunication circuit as well as the telecommunication circuit itself, e.g., microwave or PLC, is included in this subcategory.

4.4 Primary D.C. Equipment DC-E This major category covers all equipment at the HVDC substations except for that in the three categories "a.c. and auxiliary equipment", "valves" and "control and protection equipment". The following subsections give the different subcategories of equipment included in this category and contain examples of each type of equipment.

4.4.1 D.C. Filters DC-E.F Loss of station capacity due to failure to active and passive dc filters or dc-side PLC filters is assigned to this subcategory. Types of components included in this subcategory would be capacitors, reactors, and resistors which comprise the dc filtering of the converter station.

4.4.2 DC Smoothing Reactor DC-E.SR Loss of station capacity due to failure of the dc smoothing reactor is charged to this category.

4.4.3 DC Switching Equipment DC-E.SW Loss of station capacity due to failure of dc circuit breakers, dc commutating switches, dc disconnect switches, isolating switches or grounding switches is assigned to this subcategory.

4.4.4 DC Ground Electrode DC-E.GE Loss of station capacity due to problems with or failure of the ground electrode and its local termination or connecting equipment is charged to this subcategory.

4.4.5 DC Ground Electrode Line DC-E.EL Loss of station capacity due to failure of the ground electrode line or cable is charged to this subcategory.

4.4.6 Other DC Switchyard and Valve Hall Equipment DC-E.O Loss of station capacity due to failure of other dc switchyard and valve hall equipment is assigned to this subcategory. This subcategory includes valve and dc-side surge arresters, overcurrent diverters, buswork insulators, wall bushings and direct current and voltage measuring transducers.

4.5 Other O Loss of station capacity or extension of outage duration due to human error or unknown causes is assigned to this category. If, after an outage due to an event in another category, the outage duration is extended due to human error in maintenance or operation, the consequential extension in outage time is charged to this category.

4.6 DC Transmission Line TL Loss of transmission capacity due to faults on the dc transmission line, underground or submarine cable or cable terminal is charged to this category. This category covers auxiliaries associated with oil-filled cables but does not cover outages related to false operation of line protection. Only permanent dc line faults are classified as forced outages and coded as TL in table 1. Information about all dc line protection operations is included in table 3. Reference is also made to section 6.3.

4.7 External AC System EXT Loss of transmission capacity due to faults or events in the ac network external to the converter station is charged to this category. Examples would include ac network instability, ac overvoltage in excess of the convertor protective rating, short circuit level lower than the minimum design level, loss of ac outlet line(s) or loss of generation.

4.8 Severity Code Each forced outage is to be classified according to an outage severity code as follows:

Bipolar Total Outage	BP
Monopolar Total Outage	P
Convertor Total Outage	C
Other Capacity Reduction	RP

For reporting purposes, bipolar outage is one in which both poles are lost as a direct or immediate consequence of a single event. Since such bipole outages are of special significance, it is requested that a narrative discussion of every bipole outage be included in the discussion section of the report. The discussion should indicate whether both poles tripped simultaneously, and if not, the sequence of events involved. Overlapping pole outages due to different events or with a prior outage of the other pole should be reported as separate pole outages, not as a bipole outage. A convertor or valve group is the smallest switchable operating unit of capacity in the station. Overlapping convertor outages on the same pole due to different events or with prior outages of another convertor should be reported as two separate convertor outages rather than a pole outage. For stations not having series connected convertors, the convertor category does not apply. For stations having only a single dc circuit or monopole, the bipole category does not apply. If an outage affects multiple bipoles, each bipole should be reported separately but the event should be described in the annual report.

4.9 Restoration Code Each outage is classified according to a restoration code as follows:

Equipment causing outage is repaired or adjusted	R
Failed equipment is replaced by spare	S
No equipment failure, manual restart	M

5. INSTRUCTIONS FOR COMPILATION OF REPORT

5.1 General Instructions

The blank tables given in this Protocol, completed in accordance with these instructions, will form the basis of each annual report. It is recognized that these blank tables may not suit exactly each and every system, but since the comparison of performance of different HVDC systems is a central purpose of the reporting scheme, it has been determined that the standard blank tables must be used throughout. The effect is that the normalization of data in accordance with the Protocol is left with the HVDC System Correspondent who having the supporting information available is best able to carry out this task.

Also, it is appropriate to give information on innovative technical solutions which may be helpful to other HVDC System Correspondents.

The tables are to be augmented with an explanation of the major contributions of unavailability. The presentation of information or clarification of the data in the tables should be considered under the following topics:

Utilization State the reason for exceptionally high or low figures, e.g., low generator availability.

Availability Elaborate on major or abnormal factors influencing availability, e.g., special maintenance requirements, expansion or upgrade of equipment.

Reliability Give reasons behind exceptionally high outage rate, e.g., repetitive outage due to an intermittent control problem difficult to find and not initially corrected.

Severity of outage Comment on the relative frequency of valve group, pole or bipole outages. Elaborate on major outages especially bipolar outages.

When changes are made to a system, the details must be reported so that the Compendium of system particulars can be revised by the Working Group.

To ensure good reproduction of reports by the Convenor, original or clear masters should be submitted.

5.2 Instructions for Table 1 and Table 1 M/S

Section 1 For back-to-back and for two-terminal systems reporting in the preferred manner as a combined system, complete lines 1.1 and 1.2 with the substation names so as to indicate the direction of the energy flow and give the total energy in each direction in GWh. In the case of an HVDC back-to-back system, identify the direction of energy flow by using the names of the a.c. systems so connected. In the case of convertors operating in a multiterminal system or in a two-terminal system which is reporting separately, record station energy for both rectifier and inverter operation by completing one Table 1 M/S for each station.

Section 2 Calculate the Energy Utilization per cent in accordance with clause 3.5.3 and complete the line. For two-terminal systems, the preferred method of Energy Utilization is calculation based on a system basis whereas for multiterminal systems, Energy Utilization is calculated and reported separately for each station.

Sections 3, 4 and 5 In order to calculate the availability and unavailabilities for these sections, it is necessary to maintain a log of outages through the year. The system log can most conveniently be prepared by first preparing separate logs for each substation and for the transmission line. For two-terminal systems, these separate logs can then be merged into a single combined log for the system which eliminates the effects of concurrent outages. For multiterminal systems or two-terminal systems reporting separately, no combination of station outages is to be made. Care must be taken, however, that outages due to the other stations are so charged. The form of the log used is for the HVDC System Correspondent to determine but an example of a typical log is given as Appendix A for information only. The completed log is not to be submitted as part of the annual report.

The rules set out here must be applied when preparing the log and subsequently calculating the availability and unavailabilities:

(a) Record all outages in the log that cause a reduction in system capacity below the maximum continuous capacity.

(b) Indicate if the outage involves a total convertor (valve group), a total pole, or a total bipole or other capacity reduction by supplying the appropriate severity code as described in Section 4.8.

(c) Classify each outage as either a scheduled or a forced outage. For each scheduled outage record if the outage is scheduled according to the definitions given in Section 3.1.2.

(d) For each forced outage or scheduled outage, determine the primary cause of the outage and select the one most appropriate category from the seven major equipment and fault categories and associated subcategories given in Section 4, "Equipment and Fault Category Terms." All equipment in the HVDC system is included uniquely in one of these categories and subcategories.

(e) For each outage determine the outage derating factor, ODF. Calculate the equivalent outage duration (EOD) of each outage (clause 3.3.2).

(f) If during a forced outage the opportunity is taken to carry out some repair or maintenance that would otherwise be done during the next scheduled outage, record this as a scheduled outage with its own outage reference number. Record the equivalent outage duration (EOD) as zero, however, unless this scheduled outage increases the outage derating factor above that caused by the forced outage, or extends in time beyond the end of the forced outage. Should either of these events occur, calculate the outage derating factor and equivalent outage duration attributable to the scheduled outage.

(g) If during a forced outage a further forced outage occurs, record the new outage also. When determining the equivalent outage duration (EOD) of the new outage take into account only the extent to which the new outage increases the outage derating factor or extends in time the pre-existing outage.

At the end of the year when the outage log is complete, proceed as follows to calculate the numerical data required to complete sections 3, 4 and 5 of Table 1:

<u>Step 1</u> Group the outages into scheduled and forced. Group the forced outages according to the major outage categories and severity code.

<u>Step 2</u> Total the equivalent scheduled outage durations (ESOD) to obtain the equivalent scheduled outage hours (ESOH). Calculate the energy unavailability due to scheduled outages (clause 3.5.1) and complete line 4.1.

<u>Step 3</u> Total the equivalent forced outage durations (EFOD) to obtain the equivalent forced outage hours (EFOH). Calculate the energy unavailability due to forced outages (clause 3.5.1) and complete line 4.2. Break down the equivalent forced outage hours and forced energy unavailability into those due to substations and those due to the DC transmission line and complete lines 4.21 and 4.22.

<u>Step 4</u> Add the energy unavailability percent due to scheduled outages (line 4.1) to that for forced outages (line 4.2) and subtract from 100 to obtain the energy availability percent and complete line 3.

<u>Step 5</u> Record the number of forced outage events in each of the seven equipment and fault categories. Likewise total the equivalent forced outage durations (EFOD) for each of the seven categories to obtain the equivalent forced outage hours (EFOH) for each category. Record values in lines 5.11 to 5.15 and lines 5.2 and 5.3.

<u>Step 6</u> Total the number of events and equivalent outage hours for categories AC-E, V, C-P, DC-E and O (lines 5.11 to 5.15) to obtain the number of events and equivalent outage hours for line 5.1 substations.

Section 6 Transfer the number of commutation failure starts CFS(A) and recordable ac faults from Table 4 to complete line 6.

Section 7 Record the number of forced outage events in each of the four severity codes. Compute the forced energy unavailabilities (FEUC, FEUP, FEUBP, and FEURP) for each of the severity codes. The forced energy unavailabilities are calculated in accordance with Section 3.5.1 using the equivalent forced outage hours in Table 6 for each of the severity codes. Only the outage time due to the substations and dc line are to be used. Outages due to the external ac system are to be excluded. Total the number of events and the forced energy unavailabilities to complete Section 7. The total FEU should equal the value on line 4.2.

5.3 Instructions for Table 2 F and Table 2 S

5.3.1 Forced Outages Table 2 F

Record details of all forced outages that cause a reduction in system capacity. The log used to compile Table 1 data can additionally provide the input for Table 2 F. Appendix A gives an example of this. For two-terminal systems, either a common Table for both stations or separate Tables for each station can be provided as long as the same outage is not reported twice. For multiterminal systems, separate Tables are to be provided for each station.

Step 1 For each forced outage determine which of the five equipment and fault category codes and subcodes applies. Record code and subcode in first column. Record severity code and percent capacity reduction.

Step 2 Identify the failed equipment by a brief description, e.g. the code and subcode may be AC-E.AX while the description could be auxiliary power transformer. Record the forced outage type after the description (e.g. (DD) - delayed deblock).

Step 3 Record actual outage duration and whether the corrective measure was repair (R) or replacement by a spare (S).

5.3.2 Scheduled Outages Table 2 S

Record details of all scheduled outages that cause a reduction in system capacity. The log used to compile Table 1 data can additionally provide the input for Table 2 S. If the scheduled outage can be attributed to a certain category of equipment, supply the appropriate outage code. For two-terminal systems, either a common Table for both stations or separate Tables for each station can be provided as long as the same outage is not reported twice. For multiterminal systems, separate Tables are to be provided for each station.

Step 1 Record code in first column.

Step 2 Identify the maintained equipment by a brief description, e.g. the code may be AC-E.TX, while the description could be convertor transformer failed bushing. If the outage is for planned maintenance program use the code “PM.”

Step 3 Record actual outage duration and whether the corrective measure was repair (R) or replacement by a spare (S).

5.4 Instructions for Table 3

If the HVDC system includes one or more HVDC overhead line sections, and line protection is arranged to initiate auto-restart, perhaps at a lower pole operating voltage, for occurrences such as pollution or lightning induced flashovers, complete Table 3 as follows:

Step 1 Give each line protection event a unique number and record this together with the date and time using the 24 hour clock. Treat repeated operations of the protection within the reset time, usually some tens of seconds, as one event.

Step 2 Record the actual steady operating voltage and polarity, disregarding transients, of the affected pole immediately prior to the protection operation.

Step 3 Complete the event entry with the number of automatically attempted restart sequences, and whether or not the final automatic restart is successful. If the restart is unsuccessful, record the actual outage time. Give in a note any available information relevant to the cause of the protection operation and subsequent restoration if successful. If the dc system is multiterminal, indicate any automatic sectionalizing that takes place.

5.5 Instructions for Table 4

In order to complete Table 4 it is necessary to keep a log at each inverter substation to record information about a.c. system faults and any associated commutation failure starts. The rules set out here must be applied in the preparation of this log:

Determine if the a.c. system fault is recordable or not at the inverter as defined in clause 3.6.1. In order to decide if an a.c. system fault is recordable it is necessary to have at each inverter substation a fault recorder, with a prefault memory, initiated by a fall in a.c. bus voltage. When determining whether or not the voltage drops to or below 90 percent of the pre-existing voltage, consider only the fundamental voltage, i.e. disregard distortion. Take into account only reductions in voltage caused by phase-to-phase or phase-to-earth faults on the a.c. system.

Exclude the cases of temporary voltage reduction caused by other means such as normal switching of lines, transformers or reactive compensation, or faulty a.c. voltage regulating equipment.

At the end of the year proceed to complete tables as follows:

Step 1 Complete the first column of lines 1.1 and 1.2 with the substation names. In the case of an HVDC coupling system identify the two sides of the coupling by the names of the a.c. systems so coupled. For a multiterminal system, record data for each station.

Step 2 Count the number of recordable a.c. system faults during inverter operation at each substation and record the separate totals.

Step 3 Count the number of commutation failure starts, CFS(A), as defined in 3.6.2. A CFS may be determined by automatic recording for each converter unit or by inspection of the oscillographic records, but no more than one CFS(A) shall be attributed to each ac system fault.

Step 4 Count the number of commutation failure starts, CFS(B), as defined in 3.6.3.

5.6 Instructions for Table 5

Omit this table from reports on wholly mercury-arc valve systems.

Step 1 Complete the first column by listing separately the converter units at both substations or both sides in the case of coupling systems.

e.g. 1,2,3 and 4, or Pole 1 Norway, Pole 2 Norway, Pole 1 Denmark, Pole 2 Denmark.

Step 2 For each converter unit record whether it is a 6 or 12 pulse converter unit.

Step 3 Record the hours each converter unit is available, whether transmitting power or not.

Step 4 Record the number of thyristors failed in each converter unit. To provide uniformity in reporting, the short circuiting of a thyristor due to any cause shall be recorded as a thyristor failure. If two or more thyristors are used in parallel in a valve, record the short circuiting of the parallel connected thyristors as a single failure.

e.g. When 2 or more thyristors are used in parallel within a valve, record the short circuiting of the parallel thyristors as a single failure even though it might be known that 2 or more of the thyristors have in fact failed.

5.7 Instructions for Table 6

Table 6 summarizes the information contained in Table 2 FS. All forced outages are summed by outage classification and by subclassification as well as by severity code. Completion of Table 6 is an intermediate step in preparation for filling out Table 1.

6. GUIDELINES FOR INTERPRETATION OF EVENTS

6.1 Calculation of Outage Duration

Reported outage time should be the calendar time that the dc system or station is not available. The maintenance or forced outages often span several working days, possibly including weekends. The purpose of recording scheduled outage time is to develop a data base indicating the actual maintenance time. Therefore, clarification is needed on how “non-working” time is to be considered. If the system is made available but not operated during a portion of the non-working time, e.g. on a weekend, then such time should be excluded from the scheduled outage time. The key to computation of chargeable scheduled outage time is not whether or not work is performed, but whether or not the system is available for operation.

In some cases, outage duration may be longer than would normally be required. For example, there may be a period of low demand during which there is no economic loss due to unavailability of the dc link. This may permit the annual maintenance to be conducted on a more leisurely basis. Such extenuating circumstances should be noted in the discussion section of the report.

Similarly, lack of dc transmission resulting from scheduled outage of a generating plant which supplies the dc link should not be recorded as an outage of the dc system, provided that the dc system remains available for service. If maintenance is conducted on the dc link during such times, then the maintenance time should be reported as scheduled outage time.

6.2 External Events

Events external to the HVDC system which result in interruption of HVDC power transmission are not to be considered as outages of the dc system as long as the dc system operates as designed and is available for service after the event is over. For example, if the ac lines feeding the dc link open due to faults or if the ac system hosting the dc link goes unstable, the outage time is not recordable.

6.3 Protective Operation

Transient faults which are successfully cleared by correct operation of protection equipment do not constitute outages and should not be recorded in Table 2 F. Incorrect operation of protection equipment, either operation when not intended (false trip) or failure to automatically restart, would be reported as an outage, regardless of duration. Interruptions which require manual restart should be counted as forced outages if the system is designed to recover from such events.

7. PERFORMANCE OF SPECIAL CONTROLS

A number of dc systems are equipped with special supplementary controls, such as frequency control, damping control or runback, to help support the ac system. It is encouraged to include narrative comments regarding any significant positive or negative system aspects due to operation of such controls.

Operations of special controls when those operate to support the AC system shall not be counted as dc forced outages but shall be recorded as forced external AC outages.

OUTAGE LOG FORM

System: ____________________

Station: ____________________

Year: ____________________

	Outage Code *	
Outage due to faulty equipment	Forced:	Scheduled:
A.C. and Auxiliary Equipment	F.AC-E	S.AC-E
Valves	F.V	S.V
Control & Protection Equipment	F.C-P	S.C-P
Primary D.C. Equipment	F.DC-E	S.DC-E
Other	F.O	S.O
Transmission Line	F.TL	S.TL
External A.C. System	F.EXT	
Scheduled outage for planned maintenance:		S.PM

Outage Reference Number	Date & Time		Actual Outage Duration AOD	Outage Derating Factor ODF	Equivalent Outage Duration EOD	Outage Code	Severity Code BP,P,C	Description of Event, Equipment or Component Causing Outage	Repaired-R Spare-S Man Restart-M
	Start	Finish							

* See Section 4 or Appendix B for outage code subclassification for forced or for deferred scheduled outages.

APPENDIX A

AN EXAMPLE OF AN OUTAGE LOG

Care must be taken to not report the same outage twice. Therefore, only record an outage code for outages caused by the respective station. If the outage is caused by a remote station and leads to a consequential outage of the local station, the outage should be charged to the remote station. Exclude outages caused by remote stations in the preparation of Table 2 for the local station.

For single non-overlapping outages having a constant outage derating factor complete the log as follows:

Step 1 Assign the Outage Reference Number. This is a unique number given to each outage event at the start of the outage.

Step 2 Record the date and time at the start of the outage and subsequently the date and time at the end of the outage.

Record times to the nearest minute using the 24 hour clock.

Step 3 Determine and record the main cause of the outage using only one of the outage codes given at the head of the form. For forced outages and for deferred scheduled outages extend the outage code by appending the outage subclassification from Appendix B. For example, the primary cause of the outage can be indicated by "F.AC-E.AX" indicating a forced outage caused by AC equipment in the station auxiliaries.

Step 4 Calculate and record the Actual Outage Duration (AOD) which is the time elapsed between the start and end of the outage in accordance with clause 3.3.1.

Step 5 Describe the event, equipment or component causing the outage.

Step 6 Determine and record the restoration code to indicate if the restoration required equipment repair (R), replacement by spare (S) or just a manual restart (M).

Step 7 Determine and record the Outage Derating Factor (ODF) in accordance with clause 3.2.

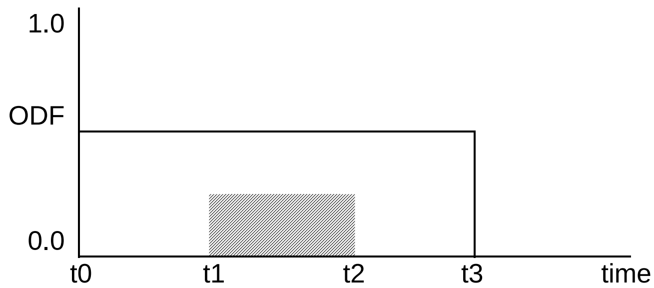
Step 8 Calculate and record the Equivalent Outage Duration (EOD) which is the product AOD x ODF.

For single non-overlapping outages having a variable outage derating factor and for overlapping outages, additional information must be recorded in order to calculate the correct EOD.

EXAMPLES OF APPLICATION OF RULE (d) of Clause 5.2

Scheduled Outage during a Forced Outage.

Case 1 Scheduled outage does not increase ODF or extend outage duration.

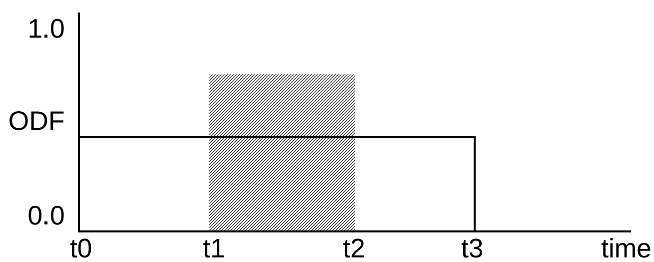


t0 - forced outage due to AC-E starts ODF = 0.5
t1 - scheduled outage starts ODF = 0.25
t2 - scheduled outage ends
t3 - forced outage ends

AOD = t3 - t0
ODF = 0.5
EOD due to AC-E = 0.5 (t3 - t0)

Scheduled outage does not contribute to unavailability.

Case 2 Scheduled outage increases ODF.



t0 - forced outage due to TL starts ODF = 0.5
t1 - scheduled outage starts ODF = 0.75
t2 - scheduled outage ends
t3 - forced outage ends

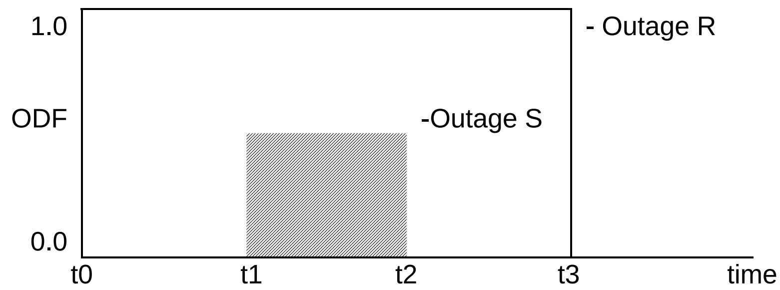
AOD due to TL = t3 - t0
ODF due to TL = 0.5
EOD due to TL = 0.5 (t3 - t0)

AOD due to scheduled outage = t2 - t1
Excess ODF due to scheduled outage = 0.75 - 0.5 = 0.25
EOD due to scheduled outage = 0.25 (t2 - t1)

Scheduled outage contributes to unavailability.

EXAMPLES OF APPLICATION OF RULE (e) of Clause 5.2

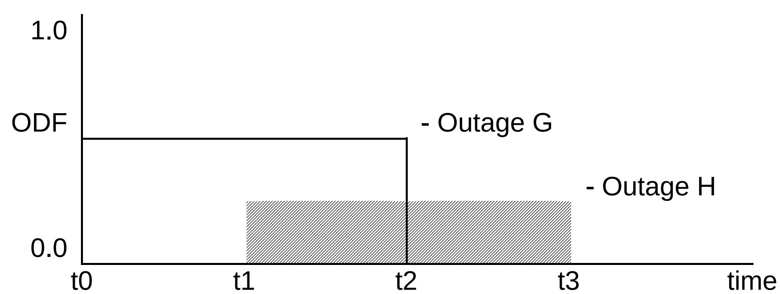
Case 1 Second outage does not increase ODF or extend outage duration.



t0 - forced outage due to TL starts - outage ref. R ODF = 1.0
t1 - forced outage due to DC-E starts - outage ref. S ODF = 0.5
t2 - forced outage due to DC-E ends
t3 - forced outage due to TL ends

AOD due to TL = t3 - t0
ODF due to TL = 1.0
EOD due to TL = 1.0 (t3 - t0) - outage ref. R is counted in the total number of events attributable to TL.
Outage due to DC-E does not increase ODF and so the EOD = 0. Since EOD is zero, outage ref. S is not counted in the total number of events attributable to DC-E.

Case 2 Second outage extends duration.

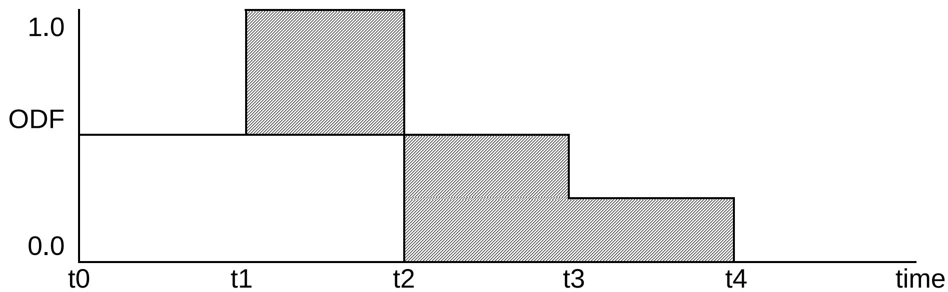


t0 - forced outage due to AC-E starts - outage ref. G ODF = 0.5
t1 - forced outage due to another event AC-E starts - outage ref. H ODF = 0.25
t2 - forced outage - ref. G ends
t3 - forced outage - ref. H ends

AOD due to AC-E ref. G = t2 - t0
ODF for outage ref. G = 0.5
EOD due to AC-E ref. G = 0.5 (t2 - t0)
AOD due to AC-E ref. H = t3 - t1, but period t1 to t2 already accounted for so effectively it is taken as
= t3 - t2.
ODF due to outage ref. H = 0.25
EOD due to AC-E ref. H = 0.25 (t3 - t2)

Since both outages are category AC-E and both EOD are non-zero, 2 is added to the total number of AC-E events by these two outages.

Case 3 Second outage with variable ODF.



t0 - forced outage due to V starts ODF = 0.5
t1 - forced outage due to AC-E starts ODF = 0.5
t2 - forced outage due to V ends
t3 - forced outage due to AC-E changes ODF ODF = 0.25
t4 - forced outage due to AC-E ends

This type of outage diagram occurs when the second outage takes out of service equipment not affected by the first outage.

EOD due to V = 0.5 (t2 - t0)
EOD due to AC-E = 0.5 (t3 - t1) + 0.25 (t4 - t3)

APPENDIX B

FAULT CLASSIFICATION CODES	CATEGORY SUBCATEGORY
A.C. and Auxiliary Equipment	AC-E.
AC Filter and Shunt Bank	AC-E.F
AC Control and Protection	AC-E.CP
Convertor Transformer	AC-E.TX
Synchronous Compensator	AC-E.SC
Auxiliary Equipment & Auxiliary Power	AC-E.AX
Other AC Switchyard Equipment	AC-E.SW
Valves	V.
Valve Electrical	V.E
Valve, Valve Cooling (integral to valve)	V.VC
HVDC Control and Protection Equipment	C-P.
Local HVDC Control & Protection	C-P.L
Master HVDC Control & Protection	C-P.M
Telecommunication Interface/Coding Equipment	C-P.T
Primary D.C. Equipment	DC-E.
DC Filters	DC-E.F
DC Smoothing Reactor	DC-E.SR
DC Switching Equipment	DC-E.SW
DC Ground Electrode	DC-E.GE
DC Ground Electrode Line	DC-E.EL
Other DC Yard and Valve Hall Equipment	DC-E.O
Other	O
DC Transmission Line	TL
External AC System	EXT

TABLE 1

DC SYSTEM PERFORMANCE FOR BACK-TO-BACK SYSTEMS
AND FOR TWO-TERMINAL SYSTEMS REPORTING JOINTLY

System: ____________________________

Year: ____________________________

1. ENERGY TRANSMITTED GWh										
1.1 From ______________ To ______________										
1.2 From ______________ To ______________										
1.3 Total										
2. ENERGY UTILIZATION % Pm = MW U										
3. ENERGY AVAILABILITY % EA										
4. ENERGY UNAVAILABILITY % due to:										
4.1 Scheduled Outages SEU										
4.2 Forced Outages FEU										
4.21 Substations FEUSS										
4.22 DC Transmission Line* FEUTL										
5. FORCED OUTAGES due to:									Number of Events	Equiv Outage Hours
5.1 Substations SS										
5.11 A.C. and Auxiliary Equipment AC-E										
5.12 Valves V										
5.13 Control and Protection Equipment C-P										
5.14 Primary D.C. Equipment DC-E										
5.15 Other O										
5.2 DC Transmission Line * TL										
5.3 External AC System ** EXT										
6. COMMUTATION FAILURE STARTS CFS(A)/RECORDABLE AC FAULTS										
7. FORCED OUTAGE SEVERITY	Capacity Reduction		Convertor		Pole		Bipole		Total	
	Number Of Events	Forced Energy Unavail.	Number Of Events	Forced Energy Unavail.	Number Of Events	Forced Energy Unavail.	Number Of Events	Forced Energy Unavail.	Number Of Events	Forced Energy Unavail.

* Not applicable for back-to-back systems

** Not included in unavailability

TABLE 1 M/S

DC SYSTEM PERFORMANCE FOR MULTITERMINAL SYSTEMS
AND FOR STATIONS REPORTING SEPARATELY
AS PART OF TWO-TERMINAL SYSTEMS

System: ____________________

Station: ____________________

Year: ____________________

1. ENERGY TRANSMITTED GWh			
1.1 As Rectifier			
1.2 As Inverter			
1.3 Total			
2. ENERGY UTILIZATION %	Pm = MW U		
3. ENERGY AVAILABILITY %	EA		
4. ENERGY UNAVAILABILITY % due to:			
4.1 Scheduled Outages	SEU		
4.2 Forced Outages	FEU		
4.21 Substations	FEUSS		
4.22 DC Transmission Line*	FEUTL		
5. FORCED OUTAGES due to:		Number of Events	Equiv Outage Hours
5.1 Substations	SS		
5.11 A.C. and Auxiliary Equipment	AC-E		
5.12 Valves	V		
5.13 Control and Protection Equipment	C-P		
5.14 Primary D.C. Equipment	DC-E		
5.15 Other	O		
5.2 DC Transmission Line *	TL		
5.3 External AC System **	EXT		
6. COMMUTATION FAILURE STARTS CFS(A)/RECORDABLE AC FAULTS			

7. FORCED OUTAGE SEVERITY	Capacity Reduction		Convertor		Pole		Bipole		Total	
	Number Of Events	Forced Energy Unavail.	Number Of Events	Forced Energy Unavail.	Number Of Events	Forced Energy Unavail.	Number Of Events	Forced Energy Unavail.	Number Of Events	Forced Energy Unavail.

* Not applicable for back-to-back systems

** Not included in unavailability

TABLE 2 SS

SCHEDULED OUTAGES SUBSTATION

System: ___________________

Station: ___________________

Year: ___________________

Scheduled Outages due to: *	Outage Code: *	Severity Code:	
A.C. and Auxiliary Equipment	AC-E.X	Bipolar	BP
Valves	V.X	Monopolar	P
Control & Protection	C-P.X	Convertor	C
Primary D.C. Equipment	DC-E.X	Capacity Reduction	RP
Other	O.X		
Planned Maintenance	PM		

Outage Code	Event or Equipment Failure Description	Severity Code	Repaired(R) Replaced by Spare (S) or Manually Restarted (M)	Actual Outage Duration AOD h	Reduction of Capacity %

* See Section 4 or Appendix B of the Protocol for outage code subclassification for deferred outages.

TABLE 2 FS

FORCED OUTAGES SUBSTATION

System: ____________________

Station: ____________________

Year: ____________________

Forced Outages due to:	Outage Code: *	Severity Code:	
A.C. and Auxiliary Equipment	AC-E.X	Bipolar	BP
Valves	V.X	Monopolar	P
Control & Protection	C-P.X	Convertor	C
Primary D.C. Equipment	DC-E.X	Capacity Reduction	RP
Other	O.X		

Outage Code	Event or Equipment Failure Description (Outage Type)	Severity Code	Repaired(R) Replaced by Spare (S) or Manually Restarted (M)	Actual Outage Duration AOD h	Reduction of Capacity %

* See Section 4 or Appendix B of the Protocol for outage code subclassification.

Outage Type:

- DD - delayed deblock
- RB - ramped down and blocked
- RE - reduction in MW
- SR - stopped rampTR - automatic trip

TABLE 3

HVDC OVERHEAD LINE PROTECTION OPERATIONS

System: ______________________________

Year: ______________________________

Event No.	Date	Time of Day	Pole Voltage & Polarity	Number of Attempted Restarts	Final Restart Successful/ Unsuccessful	Actual Outage Duration If Unsucc.	Notes, e.g. say if restart is at reduced voltage, which line section is affected or if automatic sectionalizing occurs

TABLE 4

AC SYSTEM FAULTS & COMMUTATION FAILURE
STARTS BACK-TO-BACK, TWO TERMINAL OR
MULTITERMINAL SYSTEMS

System: ____________________

Year: ____________________

	Number of a.c Recordable System Faults at Inverter	Number of CFS(A)	Number of CFS(B)
1.1 Substation A:			
1.2 Substation B:			
1.3 Substation C:			
1.4 Substation D:			
1.5 Substation E:			
2. Complete HVDC System			

CFS(A) - Commutation failure starts by ac system faults
CFS(B) - Commutation failure starts initiated by control problems, switching events or other causes.

TABLE 5

CONVERTOR UNIT HOURS & THYRISTORS FAILED

System: ______________________

Year: ______________________

Convertor Unit Reference *	6 or 12 Pulse	Hours Energized	Number of Thyristors Failed **
	Totals:		

* Convertor unit reference refers to station, pole or convertor designator per clause 5.6.

** See Clause 5.6, Step 4.

TABLE 6

System: ____________________
Station: ____________________
Year: ____________________

FORCED OUTAGE SUMMARY

FORCED OUTAGES due to:	Outage Code	Capacity Reduction			Convertor			Pole			Bipole			Total	
		Number of Events	Actual Outage Hours	Equiv. Outage Hours	Number of Events	Actual Outage Hours	Equiv. Outage Hours	Number of Events	Actual Outage Hours	Equiv. Outage Hours	Number of Events	Actual Outage Hours	Equiv. Outage Hours	Number of Events	Equiv. Outage Hours
AC Filter and Shunt Bank	AC-E.F														
AC Switchyard Equipment	AC-E.SW														
AC Control and Protection	AC-E.CP														
Convertor Transformer	AC-E.TX														
Synchronous Compensator	AC-E.SC														
Auxiliary Equipment	AC-E.AX														
Total AC and Aux. Equipment	AC-E														
Valve Electrical	V.E														
Valve Cooling (integral with valve)	V.VC														
Total Valves	V														
Local HVDC C&P	C-P.L														
Master HVDC C&P	C-P.M														
Telecommunication	C-P.T														
Total HVDC C&P	C-P														
DC Filters	DC-E.F														
DC Smoothing Reactor	DC-E.SR														
DC Switching Equipment	DC-E.SW														
DC Ground Electrode	DC-E.GE														
DC Ground Electrode Line	DC-E.EL														
Other DC Yard and Valve Hall Equip.	DC-E.O														
Total DC Equipment	DC-E														
Other	O														
TOTAL SUBSTATIONS	SS														
DC Transmission Line *	TL														
External AC System **	EXT														

* Not applicable for back-to-back systems ** Not included in unavailability