MANITOBA HYDRO

TRANSMISSION SYSTEM
INTERCONNECTION REQUIREMENTS

July 2016
Version 4

Manitoba Hydro

This page intentionally blank

LEGISLATIVE AUTHORITY

Section 15.0.3(1) of *The Manitoba Hydro Act (C.C.S.M. c. H190)* authorizes Manitoba Hydro to: (a) make rules, set terms and conditions, or issue directions respecting (i) the interconnection of the works of others with the corporation's works, and(ii) the operation of the works of others that are interconnected with the corporation's works; and (b) carry out studies to evaluate the effects of a proposed interconnection .In addition, pursuant to Section 10 of *Regulation 186/90 – Electric Power Terms and Conditions and Supply*, Manitoba Hydro is authorized to determine the voltage, frequency, phasing and other characteristics of power, the determination of which is final and binding on the user. Pursuant to this legislative authority, Manitoba Hydro has established the following Transmission System interconnection requirements for the facilities of third parties interconnected to the MH TRANSMISSION SYSTEM.

PLANNING CRITERIA AND RELIABILITY STANDARDS

This document also contains the planning criteria that Manitoba Hydro generally uses as guidelines to ensure that the Manitoba Hydro transmission system is adequate to: reliably deliver power to systems connected with and customers dependent upon Manitoba Hydro's transmission system; provide support to distribution systems interconnected with Manitoba Hydro's system; and deliver energy from existing and new generation facilities connected to the Manitoba Hydro transmission system.

Compliance by third parties with the technical requirements described in this document will ensure that facilities interconnected to the MH TRANSMISSION SYSTEM will comply with the planning criteria of MH. The owner of certain interconnected facilities must also comply with the reliability requirements in effect under Sections 5.0.1 and 15.0.2 of The Manitoba Hydro Act. Facility Owners/operators are responsible to ensure that they are compliant with NERC and other applicable reliability standards.

This page intentionally blank

MANITOBA HYDRO

TRANSMISSION SYSTEM INTERCONNECTION REQUIREMENTS

TABLE OF CONTENTS

1.0 INTRODUCTION 9

1.1 DEFINITIONS 9
1.2 SCOPE AND REVISIONS 15
1.3 APPLICABILITY 15
1.4 ADDITIONAL REQUIREMENTS 15
1.5 OBJECTIVES 16
1.6 INSPECTION AND REVIEW 16
1.7 FAILURE TO COMPLY 16
1.8 DISCLAIMER 17

2.0 MH TRANSMISSION SYSTEM - SYSTEM INFORMATION AND DESIGN PRACTICE 19

2.1 RELIABILITY STANDARDS 19
2.2 NOMINAL VOLTAGE, STEADY STATE VOLTAGE VARIATIONS AND EQUIPMENT VOLTAGE RATINGS 19
2.3 POST-CONTINGENCY VOLTAGE VARIATIONS 20
2.4 TRANSIENT VOLTAGE VARIATIONS 20
2.5 FREQUENCY AND FREQUENCY VARIATIONS 21
2.6 TRANSIENT FREQUENCY VARIATIONS 21
2.7 BLACK START RESOURCE 22
2.8 POWER QUALITY 22
2.9 SYSTEM PROTECTION AND CONTROL 22
2.9.1 Protection System Implementation 22
2.9.2 Normal Fault Clearing Times 22
2.9.3 System Damping 23
2.9.4 Transmission Line Protection Systems 24
2.9.5 Bus Protection 25
2.9.6 REMEDIAL ACTION SCHEME 25
2.10 UNDERFREQUENCY LOAD SHED (UFLS) 26
2.11 UNDERVOLTAGE LOAD SHED (UVLS) 26
2.12 SYSTEM GROUNDING 26
2.13 INSULATION LEVELS 26
2.14 SHORT CIRCUIT LEVELS 27
2.15 COMMUNICATION SYSTEMS 28
2.16 AUTOMATIC GENERATION CONTROL 28
2.17 TRANSFORMER WINDING CONFIGURATIONS 29
2.18 STATION BATTERY 29
2.19 SYSTEM STUDIES 30
2.19.1 OPEN ACCESS INTERCONNECTION AND OPEN ACCESS TRANSMISSION TARIFF STUDIES 30
2.19.2 Transmission System Planning Performance Requirements Studies 30
2.19.3 CUSTOMER LOAD Studies 30
2.19.4 OPERATING STUDIES 30
2.20 REACTIVE POWER MARGINS 31
2.21 OUT-OF-STEP RELAY MARGINS 31
2.22 MODELLING DATA 32
2.23 EQUIPMENT RATINGS 32

2.24 STATION RING RATINGS 33
2.25 MONITORING FACILITIES 33
2.25.1 Disturbance Monitoring 33
2.25.2 Phasor Measurement Units 34
2.25.3 Geomagnetically Induced Current (GIC) Monitoring 34
2.26 SYSTEM UNDER VOLTAGE CONTROLLER 34
2.27 HVDC MINIMUM RATING 34
2.28 DOMESTIC LOAD 34
2.28.1 Interconnection Location and Voltage Level 34
2.28.2 Voltage Regulation and Power Factor Requirements 35
2.28.3 Protection 35
2.28.4 Telemetering and Metering, Supervisory Control and Data Acquisition (SCADA) 35
2.28.5 Verification of Load Demand Characteristic Modelling 35
2.28.6 Transformer Spare 35

3.0 GENERATOR INTERCONNECTION REQUIREMENTS 36

3.1 INTERCONNECTION LOCATION AND VOLTAGE LEVEL 36
3.2 SEALING OF TECHNICAL REPORTS, DRAWINGS, MEMOS, ETC 36
3.3 REACTIVE POWER REQUIREMENTS 36
3.4 DYNAMIC POWER REQUIREMENTS 37
3.5 VOLTAGE RIDE THROUGH 38
3.6 FREQUENCY VARIATIONS 39
3.7 INERTIA CONSTANT (H) 39
3.8 SYNCHRONOUS GENERATOR CONTROLS 40
3.8.1 Speed Governor 40
3.8.2 Excitation System 41
3.8.3 Automatic Voltage Regulator (AVR) 42
3.8.4 Joint Var Control 42
3.8.5 Joint Load Control 42
3.8.6 Power Ramp Rates 42
3.8.7 Maximum Power Limit 43
3.8.8 Power System Stabilizer (PSS) 43
3.8.9 Automatic Generation Control (AGC) 43
3.9 SYNCHRONIZING FACILITIES 44
3.10 REMEDIAL ACTION SCHEMES (RAS) 44
3.11 BLACK START CAPABILITY 44
3.12 POWER QUALITY 44
3.12.1 Power Quality 44
3.12.2 Resonance and Self-Excitation 45
3.13 PROTECTION REQUIREMENTS 46
3.13 PROTECTION REQUIREMENTS 47
3.14 COMMUNICATIONS 49
3.15 REVENUE METERING 49
3.15.1 General 49
3.15.2 Accuracy 50
3.15.3 Metering Configuration 50
3.15.4 Energy Losses 50
3.15.5 Meter Reading 51
3.15.6 Check Metering 51
3.15.7 Meter Seals 51
3.15.8 Meter Tests 51
3.15.9 Security 51
3.16 TELEMETERING, METERING, AND SUPERVISORY CONTROL AND DATA ACQUISITION(SCADA) 52
3.17 DISTURBANCE MONITORING EQUIPMENT 53

3.18 INSULATION LEVELS 54
3.19 SHORT CIRCUIT LEVELS 54
3.20 GROUNDING 54
3.21 LIGHTNING (SURGE) PROTECTION 54
3.22 SAFETY AND DESIGN STANDARDS 54
3.23 ENVIRONMENTAL CONDITIONS 55
3.24 CLEARANCES AND ACCESS 55
3.25 ISOLATION 55
3.26 TRANSFORMER CONNECTION 55
3.27 MODELLING DATA AND SPECIAL TESTS 56
3.28 COMMISSIONING TESTS 56
3.29 TESTING AND MAINTENANCE COORDINATION 56
3.30 COORDINATED JOINT STUDIES 57
3.31 GENERATION FORECASTING 57

4.0 WIND GENERATOR INTERCONNECTION REQUIREMENTS 58

4.1 VOLTAGE TOLERANCE 58
4.2 FREQUENCY TOLERANCE 58
4.3 POWER CONTROL 58
4.4 REACTIVE POWER CAPABILITY/CONTROL 58
4.5 ASYNCHRONOUS WIND GENERATOR CONTROLS 59
4.5.1 Voltage Regulation 59
4.5.2 Frequency Response 59
4.5.3 Power Ramp Rates 60
4.5.4 Other Controls 60
4.6 VOLTAGE RIDE-THROUGH 60
4.7 POST DISTURBANCE RECOVERY 61
4.8 SYNCHRONIZING FACILITIES 61
4.9 MODELLING DATA 61
4.10 MODELLING DATA VERIFICATION 61
4.11 SPECIAL COMMISSIONING TESTS 62
4.12 POWER QUALITY 62
4.13 OPERATIONAL MONITORING AND WIND DATA 63
4.14 ADDITIONAL PROTECTION REQUIREMENTS 65
4.16 UNDERGROUND CABLES 65
4.17 GENERATOR TAPPING 65

5.0 CUSTOMER LOAD INTERCONNECTION REQUIREMENTS 66

5.1 INTERCONNECTION LOCATION AND VOLTAGE LEVEL 66
5.2 SEALING OF TECHNICAL REPORTS, DRAWINGS, MEMOS, ETC. 66
5.3 LOAD TAPPING 67
5.4 OPERATING PROCEDURES 67
5.5 VOLTAGE REGULATION AND POWER FACTOR REQUIREMENTS 67
5.6 VOLTAGE AND FREQUENCY AT POINT(S) OF DELIVERY 68
5.7 POWER QUALITY 68
5.7.1 Power Quality 68
5.7.2 Resonance and self-excitation 68
5.8 PROTECTION REQUIREMENTS 68
5.9 UNDERFREQUENCY LOAD SHED (UFLS) 71
5.10 UNDERVOLTAGE LOAD SHED (UVLS) 72
5.11 LOAD RESTORATION 72
5.12 LINE AUTO-RECLOSING 72
5.13 REVENUE METERING 72
5.13.1 General 72

5.13.2 Accuracy ... 73
5.13.3 Metering Configuration ... 73
5.13.4 Energy Losses ... 74
5.13.5 Meter Reading ... 74
5.13.6 Check Metering ... 74
5.13.7 Meter Seals ... 74
5.13.8 Meter Tests ... 74
5.13.9 Security ... 74
5.14 TELEMETERING AND METERING, SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) ... 75
5.15 DISTURBANCE MONITORING ... 75
5.16 COMMUNICATIONS ... 76
5.17 INSULATION LEVELS ... 76
5.18 SHORT CIRCUIT LEVELS ... 76
5.19 LIGHTNING (SURGE) PROTECTION ... 76
5.20 SAFETY AND DESIGN STANDARDS ... 76
5.21 ENVIRONMENTAL CONDITIONS ... 77
5.22 CLEARANCES AND ACCESS ... 77
5.23 ISOLATION ... 77
5.24 TRANSFORMER CONNECTION ... 77
5.25 VERIFICATION OF LOAD DEMAND CHARACTERISTIC MODELLING ... 78
5.26 TESTING AND MAINTENANCE COORDINATION ... 78
5.27 INSPECTION REQUIREMENTS ... 78
5.28 COORDINATED JOINT STUDIES ... 78
5.29 NOTIFICATION OF NEW OR MODIFIED FACILITIES ... 78

6.0 TRANSMISSION LINE OWNER INTERCONNECTION REQUIREMENTS ... 80

6.1 INTERCONNECTION LOCATION AND VOLTAGE LEVEL ... 80
6.2 SEALING OF TECHNICAL REPORTS, DRAWINGS, MEMOS, ETC. ... 80
6.3 OPERATING PROCEDURES ... 80
6.4 REACTIVE POWER REQUIREMENTS ... 80
6.5 VOLTAGE AND FREQUENCY AT POINT(S) OF DELIVERY ... 80
6.6 TRANSMISSION LINE DESIGN CRITERIA ... 81
6.6.1 Structural Design Criteria ... 81
6.6.2 Electrical Loading Design Criteria ... 81
6.6.3 External Electrical Effects ... 81
6.6.4 Shield Wires ... 81
6.7 POWER QUALITY ... 82
6.7.1 Power Quality ... 82
6.7.2 Resonance and self-excitation ... 82
6.8 PROTECTION SYSTEMS ... 83
6.9 RECLOSING ... 84
6.10 SYNCHRONIZING ... 85
6.11 REMEDIAL ACTION SCHEMES (RAS) ... 85
6.12 REVENUE METERING ... 85
6.12.1 General ... 85
6.12.2 Accuracy ... 86
6.12.3 Metering Configuration ... 86
6.12.4 Energy Losses ... 86
6.12.5 Meter Reading ... 86
6.12.6 Check Metering ... 87
6.12.7 Meter Seals ... 87
6.12.8 Meter Tests ... 87
6.12.9 Security Audit ... 87
6.13 TELEMETERING, METERING, SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) ... 87

6.14 DISTURBANCE MONITORING 88
6.15 COMMUNICATIONS 88
6.16 INSULATION LEVELS 88
6.17 SHORT CIRCUIT LEVELS 89
6.18 SAFETY 89
6.19 ENVIRONMENTAL CONDITIONS 89
6.20 CLEARANCES AND ACCESS 89
6.21 ISOLATION 89
6.22 TESTING AND MAINTENANCE COORDINATION 89
6.23 PROTECTION SYSTEM MAINTENANCE AND TESTING 89
6.24 INSPECTION REQUIREMENTS 90

7.0 TECHNICAL DATA TO BE PROVIDED BY THE FACILITY OWNER 92

7.1 GENERATOR FACILITY TECHNICAL DATA 93
7.1.1 Thermal Turbine-Generator Mechanical Data (70 MVA or larger unit) *95*
7.1.2 Synchronous Generator Data *96*
7.1.3 Induction Generator Data *97*
7.1.4 Non-Standard Generator with Power Electronic Interface Data *98*
7.2 CUSTOMER LOAD FACILITY TECHNICAL DATA 99
7.3 TRANSMISSION LINE OWNER INTERCONNECTION FACILITY TECHNICAL DATA 101

8.0 FIGURES. 104

9.0 REFERENCES 112

10.0 DOCUMENT CHANGE HISTORY 114

This page intentionally blank

MANITOBA HYDRO

TRANSMISSION SYSTEM INTERCONNECTION REQUIREMENTS

1.0 INTRODUCTION

These Transmission System interconnection requirements identify the technical requirements for interconnection of FACILITY(IES) to the MH TRANSMISSION SYSTEM and operation of FACILITY(IES) connected to the MH TRANSMISSION SYSTEM.

1.1 Definitions

This section defines the capitalized terms used in this document. The definitions used herein may be different from definitions of similar terms used in other documents *and are exclusive to this document. The definitions used herein are not intended to be used in any fashion to interpret, modify or explain in any way a definition of a similar term in any other document.*

1.1.1 BLACK START CAPABILITY: The ability of a generating unit or station to go from a shutdown condition to an operating condition and start delivering power without assistance from the electric system.

1.1.2 BULK ELECTRIC SYSTEM (BES): As defined in the *"Glossary of Terms Used in NERC Reliability Standards"*. http://www.nerc.com/files/glossary_of_terms.pdf

1.1.3 CUSTOMER LOAD: A person or entity proposing to interconnect its CUSTOMER LOAD FACILITY(IES) to the MH TRANSMISSION SYSTEM or to make a SUBSTANTIAL MODIFICATION to an existing CUSTOMER LOAD FACILITY(IES) connected to the MH TRANSMISSION SYSTEM.

1.1.4 CUSTOMER LOAD FACILITY(IES): A facility with electrical load that normally receives power from the MH TRANSMISSION SYSTEM. The CUSTOMER LOAD FACILITY(IES) may include its own generation, reactive power compensation, transformation and plant distribution.

1.1.5 CUSTOMER LOAD INTERCONNECTION FACILITY(IES): All facilities and equipment owned and/or controlled, operated and maintained by the CUSTOMER LOAD, including any modifications, additions, or upgrades made to such facilities and equipment, that are necessary to physically and electrically interconnect the CUSTOMER LOAD FACILITY(IES) to the POINT(S) OF INTERCONNECTION.

1.1.6 EMERGENCY CONDITION(S): Any condition or situation that is likely to endanger life or property, violate any environmental law; or is likely to cause a material adverse effect on the security of, or damage to the FACILITY, the INTERCONNECTION FACILITY(IES), the MH TRANSMISSION SYSTEM or the transmission system of other electric utilities. Any condition or situation that results from lack of sufficient generating capacity to meet load requirements or that result from economic conditions shall not constitute an EMERGENCY CONDITION, unless one of the enumerated conditions or situations identified in this definition also exists.

1.1.7 EMERGENCY OPERATING GUIDES: OPERATING PROCEDURES that are developed by MH due to unforeseen real time system conditions or problems observed in the next day study and are effective only during the EMERGENCY CONDITION. These guides may not include formal documentation during the EMERGENCY CONDITIONS if time does not permit.

1.1.8 FACILITY(IES): CUSTOMER LOAD FACILITY(IES) or GENERATOR FACILITY(IES) or TRANSMISSION LINE OWNER FACILITY(IES), as applicable.

1.1.9 FACILITY OWNER(S): A GENERATOR, CUSTOMER LOAD or TRANSMISSION LINE OWNER(S) interconnecting or interconnected to the MH system.

1.1.10 GENERATOR: A person or entity proposing to interconnect its GENERATOR FACILITY(IES) to the MH TRANSMISSION SYSTEM or to make a SUBSTANTIAL MODIFICATION to its existing GENERATOR FACILITY(IES) connected to the MH TRANSMISSION SYSTEM.

1.1.11 GENERATOR FACILITY(IES): A facility that generates electrical power and delivers capacity and energy to the MH TRANSMISSION SYSTEM.

1.1.12 GENERATOR INTERCONNECTION FACILITY(IES): As defined in the MH Open Access Interconnection Tariff.

1.1.13 GOOD UTILITY PRACTICE: As defined in the MH Open Access Interconnection Tariff.

1.1.14 INTERCONNECTION FACILITY(IES): the facilities and equipment required to physically and electrically connect the FACILITY(IES) to the MH System and includes CUSTOMER LOAD INTERCONNECTION FACILITY(IES), GENERATOR INTERCONNECTION FACILITY(IES), TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) and MH INTERCONNECTION FACILITY(IES). INTERCONNECTION FACILITY(IES) do not include INTERCONNECTION SYSTEM UPGRADES.

1.1.15 INTERCONNECTION STUDIES: studies performed by MH to determine the effects that the FACILITY(IES) have on the MH TRANSMISSION SYSTEM and to identify any INTERCONNECTION FACILITY(IES) required to accommodate the interconnection of the FACILITY(IES) to the MH system, including any INTERCONNECTION SYSTEM UPGRADES, as needed to comply with the technical requirements of this document and GOOD UTILITY PRACTICE. INTERCONNECTION STUDIES may include an INTERCONNECTION EVALUATION STUDY and an INTERCONNECTION FACILITIES STUDY.

1.1.16 INTERCONNECTION EVALUATION STUDY: As defined in the MH Open Access Interconnection Tariff.

1.1.17 INTERCONNECTION FACILITIES STUDY: As defined in the MH Open Access Interconnection Tariff.

1.1.18 INTERCONNECTION SYSTEM UPGRADES: As defined in the MH Open Access Interconnection Tariff.

1.1.19 INTERCONNECTION AND OPERATING AGREEMENT (IOA): As defined in the MH Open Access Interconnection Tariff.

1.1.20 MH: Manitoba Hydro.

1.1.21 MH DISTRIBUTION SYSTEM: Transmission facilities, below 100 kV, owned and operated by MH used to serve NATIVE LOAD.

1.1.22 MH HVdc TRANSMISSION SYSTEM: The MH direct current transmission lines including all converter stations, and associated equipment.

1.1.23 MH INTERCONNECTION FACILITY(IES): All facilities and equipment owned and/or controlled, operated and maintained by MH, including any modifications, additions, or upgrades made to such facilities and equipment, that are necessary to physically and electrically interconnect the MH TRANSMISSION SYSTEM to the POINT(S) OF INTERCONNECTION. MH INTERCONNECTION FACILITY(IES) do not include INTERCONNECTION SYSTEM UPGRADES.

1.1.24 MH SYSTEM CONTROL CENTRE: Control Centre located in Winnipeg, Manitoba from which Manitoba Hydro controls its transmission system, including interconnections with other TRANSMISSION LINE OWNERS.

1.1.25 MH SYSTEM OPERATOR: A person authorized to operate or supervise operation of the MH TRANSMISSION SYSTEM.

1.1.26 MH TRANSMISSION SYSTEM: Transmission facilities, 100 kV and above, owned and operated by MH; excluding the NORTHERN COLLECTOR SYSTEM and the MH HVdc TRANSMISSION SYSTEM.

1.1.27 MISO: Midcontinent Independent System Operator, Inc.

1.1.28 MRO: Midwest Reliability Organization.

1.1.29 NATIVE LOAD CUSTOMER: As defined in the MH Open Access Transmission Tariff.

1.1.30 NERC: North American Electric Reliability Corporation, Inc.

1.1.31 NORTH AMERICAN GRID: Interconnected transmission network of transmission owners in the United States and Canada consisting of three interconnections: Eastern

Interconnection, Western Interconnection and ERCOT Interconnection. The MH TRANSMISSION SYSTEM is interconnected with the transmission networks of other transmission owners within the Eastern Interconnection.

1.1.32 NORTHERN COLLECTOR SYSTEM: Isolated 138 kV and 230 kV transmission systems in Northern Manitoba owned by MH that interconnect the Nelson River Kettle, Long Spruce and Limestone GENERATOR FACILITY(IES)to the MH HVdc TRANSMISSION SYSTEM.

1.1.33 NETWORK INTEGRATION TRANSMISSION SERVICE: As defined in the MH Open Access Transmission Tariff.

1.1.34 NETWORK RESOURCE: As defined in the MH Open Access Transmission Tariff.

1.1.35 OPERATING PROCEDURES: A set of operating instructions carried out by the MH SYSTEM OPERATOR when certain events occur on the transmission system that may compromise security and reliability if no action is taken. OPERATING PROCEDURES are developed as one of the following types: TEMPORARY OPERATING GUIDES, STANDING OPERATING GUIDES and EMERGENCY OPERATING GUIDES.

1.1.36 POINT(S) OF DELIVERY: Shall mean the point on the INTERCONNECTION FACILITIES where the CUSTOMER LOAD INTERCONNECTION FACILITIES or the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) interconnect with the MH INTERCONNECTION FACILITIES as determined by MH.

1.1.37 POINT(S) OF INTERCONNECTION: As defined in the MH Open Access Interconnection Tariff.

1.1.38 REMEDIAL ACTION SCHEME (RAS): As defined in the *"Glossary of Terms Used in NERC Reliability Standards"*. http://www.nerc.com/files/glossary_of_terms.pdf

1.1.39 STANDING OPERATING GUIDES: OPERATING PROCEDURES that are developed by MH for those FACILITY(IES) that are known problems under a variety of system conditions. These guides may be developed as seasonal guides and are effective for any time of the season. The STANDING OPERATING GUIDES specify the limitation on the FACILITY(IES) under normal and single critical element outage conditions. These guides also provide default operating limits for multiple critical outages, which usually triggers the request for TEMPORARY OPERATING GUIDES.

1.1.40 SUBSTANTIAL MODIFICATION:
(a) A modification to a GENERATOR FACILITY(IES) that, as determined by MH, results in a change in:
- Real power output greater than 1.0 MW, or
- Reactive power output greater than 1.0 Mvar, or

- The steady state, transient and sub-transient reactance of the Generator or the Generator Interconnection Facilities by more than 10% of the as-built values, or
- The inertia of the Generator by more than 10% of the as-built values, or
- The protection system of the GENERATOR FACILITY(IES) or GENERATOR INTERCONNECTION FACILITY(IES), or
- The generator voltage, frequency, rotor angle and field current dynamic response by more than 10% of the as-build values following a step change in frequency set-point or voltage set-point.
- A modification to a GENERATOR FACILITY(IES) resulting from the addition of facilities or the interconnection of a third party GENERATOR FACILITY(IES) to the GENERATOR OWNER'S existing GENERATOR FACILITY(IES) or GENERATOR INTERCONNECTION FACILITY(IES).

(c) A modification to a CUSTOMER LOAD FACILITY(IES) that, as determined by MH, results in a change in:

- Demand that exceeds 1.0 MVA, (e.g. the addition of a motor load in excess of 200 hp),or
- Demand that exceeds the maximum contractual demand, or
- The reactive power facilities (e.g. reactors, capacitors, synchronous condensers),or
- The protection system of the CUSTOMER LOAD FACILITY(IES) or CUSTOMER LOAD INTERCONNECTION FACILITY(IES), or
- Load composition (e.g. the addition of a variable frequency drive), or
- Load characteristics (e.g. modification to large motor starting logic, harmonics).

(d) A modification to a TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) that, as determined by MH, results in:

- The addition or deletion of terminating stations, including tapping of a transmission line, or
- Modification to the protection system(s) including RAS, or
- The addition or retirement of reactive power facilities, or
- The change in a FACILITY rating of more than 1 MVA.

1.1.41 TEMPORARY OPERATING GUIDES: OPERATING PROCEDURES that are developed by MH as a result of outage coordination and are required for a scheduled outage to be approved. The TEMPORARY OPERATING GUIDES specify the operating limits and mitigation actions and are effective only for the duration of the planned outage. TEMPORARY OPERATING GUIDES are also developed from EMERGENCY OPERATING GUIDES as a result of system EMERGENCY CONDITIONS that are anticipated to continue into the future.

1.1.42 TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES): All facilities and equipment owned and/or controlled, operated and maintained in Manitoba by the TRANSMISSION LINE OWNER, including any modifications, additions, or upgrades made to such facilities and equipment, that are necessary to physically and electrically interconnect the TRANSMISSION LINE OWNER FACILITY(IES) to the POINT(S) OF DELIVERY.

1.1.43 TRANSMISSION LINE OWNER: shall mean a transmission owner of a transmission system proposing to interconnect its TRANSMISSION LINE OWNER FACILITY(IES) to the MH TRANSMISSION SYSTEM or to make a SUBSTANTIAL MODIFICATION to its existing TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) connected to the MH TRANSMISSION SYSTEM.

1.1.44 TRANSMISSION LINE OWNER FACILITY(IES): A facility with electrical load and generation that may receive power from or interchange power with the MH TRANSMISSION SYSTEM. The TRANSMISSION LINE OWNER FACILITY(IES) may include its own generation, load, reactive power compensation, transformation, transmission and distribution.

1.1.45 WIND DATA shall mean the raw time and date stamped measurements averaged and recorded at a minimum of ten (10) minute intervals, as obtained from the meteorological tower data-loggers within the wind GENERATOR FACILITY(IES). The data includes accurate measurements of wind speed, wind direction, temperature and barometric pressure. The wind data shall include wind speed and wind direction measured at a minimum of two heights: (i) ten (10) meters, and (ii) as close to intended turbine hub elevation as practical and shall be measured using accepted calibrated wind industry monitoring equipment including meteorological tower data-loggers, which equipment shall be maintained and operated in accordance with good wind industry monitoring practice.

1.2 Scope and Revisions

This document defines technical requirements for FACILITY(IES) and establishes responsibilities of FACILITY OWNERS seeking to interconnect to the MH TRANSMISSION SYSTEM or with FACILITY(IES) already interconnected to the MH TRANSMISSION SYSTEM, subject to Section 1.4.

The requirements of this document are subject to revision at any time as may be required to ensure the reliability and security of the MH TRANSMISSION SYSTEM or to comply with changes to planning standards or criteria established by MH or outside bodies such as the MRO or its successor organization, and the NERC or its successor organization. The entity wishing to interconnect with the MH TRANSMISSION SYSTEM, or undertake a Substantial Modification to its interconnected FACILITY(IES) or its portion of the INTERCONNECTION FACILITY(IES), must comply with the revision of this document in effect on the date when the INTERCONNECTION AND OPERATING AGREEMENT or amendment thereto or similar agreement is executed between the FACILITY OWNER and MH.

1.3 Applicability

This document specifies the technical requirements for interconnecting GENERATOR FACILITY(IES) or CUSTOMER LOAD FACILITY(IES) or TRANSMISSION LINE OWNER FACILITY(IES) to the MH TRANSMISSION SYSTEM and is applicable to:

- interconnection of new FACILITY(IES);
- a SUBSTANTIAL MODIFICATION to an existing FACILITY(IES) or GENERATOR, CUSTOMER LOAD or TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES), interconnected to the MH TRANSMISSION SYSTEM;
- FACILITY(IES) interconnected to the MH TRANSMISSION SYSTEM,
- GENERATOR FACILITY(IES) interconnected to the MH system at 66 kV with Transmission Service under the MH Open Access Transmission Tariff,
- 66 kV FACILITY(IES) that are part of the BES.

1.4 Additional Requirements

Additional technical requirements not specified in this document may apply for interconnecting new High Voltage direct current transmission or Flexible AC Transmission System (FACTS) devices to the MH TRANSMISSION SYSTEM. Such additional technical requirements will be defined by MH on a case by case basis.

Additional technical requirements for interconnection to the Dorsey HVdc Converter Station, the Northern Collector System or future converter stations are not specified in this document and will be defined by MH on a case by case basis.

1.5 Objectives

This document lays out a common set of practices and design criteria that must be met by all applicable FACILITY(IES) OWNERS seeking to interconnect or whose Facilities are already interconnected to the MH TRANSMISSION SYSTEM, as identified in Section 1.3. This document may assist Facility Owners wishing to interconnect with the MH Transmission System with the planning and design of their Facility.

Minimum technical requirements are defined with the objective of ensuring that the MH TRANSMISSION SYSTEM will operate reliably and safely under normal operating conditions, when the FACILITY(IES) are interconnected to it.

Some of the technical requirements cannot be precisely defined until the location and some basic information on the proposed new FACILITY(IES) are provided to MH. The final technical requirements will be determined by INTERCONNECTION STUDIES carried out by MH. The FACILITY OWNER will provide information, as described in Section 7.0, to MH for carrying out such studies.

1.6 Inspection and Review

All information submitted by the FACILITY OWNER is subject to review by MH. MH reserves the right to require additional information and investigations as deemed necessary to ensure that the requirements outlined in this document are fulfilled.

In accordance with Sections 15.0.4(2) through 15.0.4(4) of *The Manitoba Hydro Act*,: (a) new FACILITY(IES) or modified FACILITY(IES) are subject to inspection by MH prior to initial energization; and (b) all interconnected FACILITY(IES) are subject to periodic review and inspection by MH to ensure that compliance with this document is being maintained. MH will provide reasonable notification as to the time and date of the inspection.

1.7 Failure to Comply

MH reserves the right to take enforcement actions in accordance with Section 15.0.5 of *The Manitoba Hydro Act* to ensure that the FACILITY OWNER complies with the requirements of this document. Where the FACILITY OWNER fails to comply with the requirements of this document or if Manitoba Hydro determines that the interconnection of a Facility could negatively impact power quality or the security or reliability of the supply of power, the following consequences may occur:

1. The FACILITY OWNER may be directed to perform remedial work to make the FACILITY(IES) compliant;
2. MH may disconnect or refuse to connect the Facility;
3. MH may refuse to supply or limit the supply, of electricity to the Facility Owner;
4. The FACILITY OWNER *may be liable for any damages occurring to the MH System.*

1.8 Disclaimer

This document is not intended as an instruction manual for the FACILITY OWNER(S) connecting to the MH Transmission System. The FACILITY OWNER(S) must recognize that they are, at all times, solely responsible for their FACILITY(IES) design, construction and operation.

This page intentionally blank

2.0 MH Transmission System - System Information and Design Practice

This section provides system information, operating limits and performance criteria applicable to the MH Transmission System. It also provides information on some aspects of MH's normal design practice and planning criteria related to equipment connected to or used on the MH Transmission System.

The information in this Section is provided to assist the Facility Owner in the planning and design of the Facility only and is subject to revision as noted in Section 1.2. The Facility Owner must contact MH to obtain data for the specific Point(s) of Interconnection or Point(s) of Delivery.

<table>
<tr><th>No.</th><th>Item</th><th colspan="4">Information and Requirements</th></tr>
<tr><td>2.1</td><td>Reliability Standards</td><td colspan="4">The MH Transmission System is planned, designed and constructed to satisfy the requirements in the Reliability Standards Regulation enacted pursuant to The Manitoba Hydro Act [1].</td></tr>
<tr><td rowspan="9">2.2</td><td rowspan="9">Nominal Voltage, Steady State Voltage Variations and Equipment Voltage Ratings</td><td colspan="4">Equipment connected to the MH Transmission System shall be capable of withstanding steady state voltages variations and meet the specified maximum voltage rating.
The system nominal voltage ratings, steady-state minimum/maximum voltage variations and minimum voltage rating of equipment are as follows:</td></tr>
<tr><td rowspan="2">System Nominal Voltage (kV)</td><td colspan="2">Steady-state operating limits (+/- 5% of nominal)</td><td rowspan="2">Minimum Voltage for rating of equipment (kV)</td></tr>
<tr><td>Minimum Voltage (kV)</td><td>Maximum Voltage (kV)</td></tr>
<tr><td>66</td><td>63</td><td>69</td><td>72.6</td></tr>
<tr><td>115</td><td>109</td><td>121</td><td>127</td></tr>
<tr><td>138</td><td>131</td><td>145</td><td>152</td></tr>
<tr><td>230</td><td>219</td><td>242</td><td>253</td></tr>
<tr><td>500</td><td>475</td><td>525</td><td>550</td></tr>
<tr><td colspan="4">Mitigation or system upgrades may be required if bus voltages violate steady-state voltage criteria.

Please contact MH for list of buses that deviate from the above table.</td></tr>
</table>

No.	Item	Information and Requirements
2.3	Post-contingency Voltage Variations	Equipment connected to the MH Transmission System shall be capable of withstanding post-contingency voltages variations. Post-contingency is the period beginning approximately 120 cycles after a disturbance has occurred and after the MH Transmission System has reached new steady state conditions. The MH Design and Transmission Planning post-contingency voltage variation criteria is: *±10% of nominal system voltage for up to 30 minutes.* Mitigation and/or system upgrades are required if bus voltages violate post-contingency voltage criteria. Please contact MH for list of buses that deviate from this criterion.
2.4	Transient Voltage Variations	Equipment interconnected to the MH Transmission System shall be capable of withstanding transient voltage variations. Transient voltage variations include both transient (short duration surges such as switching surges) and dynamic variations (ie longer duration but temporary swings). The transient voltage period is the period immediately after a disturbance has occurred (but not including the fault duration) up to approximately 120 cycles after the disturbance has occurred (up to the time all transient voltage variations have reached a new steady state). The MH Design and Transmission Planning transient voltage variation criteria are summarized as an "envelope function." The voltage "envelope" is applied immediately after the disturbance has occurred or immediately after a fault clears. The envelope function is made up of a high voltage curve and a low voltage curve and defines the MH transient voltage performance criteria that must be satisfied in Interconnection Studies for the Contingencies and events listed in the *Reliability Standards Regulation*. Dynamic bus voltages are required to remain inside the voltage envelope function. **Mitigation and/or system upgrades are required if bus voltages violate this transient voltage performance criteria**.

High Voltage Curve			
Bus Voltage (P.U.)	Duration	Time After Event	
		Start	End
Undefined Switching Surge	2 cycles	0 cycles	2 cycles
1.3	12 cycles	0 cycles	12 cycles
1.3 to 1.1	120 cycles	12 cycles	120 cycles
≤ 1.10	30 minutes	120 cycles	1920 cycles

<table>
<tr><th>No.</th><th>Item</th><th>Information and Requirements</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><th colspan="4">Low Voltage Curve</th></tr>
<tr><th rowspan="2">Bus Voltage (P.U.)</th><th rowspan="2">Duration</th><th colspan="2">Time After Event</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td>0.7</td><td>30 cycles</td><td>0 cycles</td><td>30 cycles</td></tr>
<tr><td>0.7 to 0.9</td><td>120 cycles</td><td>0 cycles</td><td>120 cycles</td></tr>
<tr><td>≥ 0.9</td><td>30 minutes</td><td>120 cycles</td><td>1920 cycles</td></tr>
</table>
MH Transmission System transient voltage performance criteria are illustrated in Figure 1 of Section 8.
Please contact MH for list of buses that deviate from the above table.
</td></tr>
<tr><td>2.5</td><td>Frequency and Frequency Variations</td><td>

The nominal system frequency is 60 Hz.
The normal variation is within ±0.02 Hz of 60 Hz, and the maximum variation is within ±0.5 Hz of 60 Hz when the MH Transmission System remains interconnected with the North American Grid.
The frequency may drop to 57.5 Hz or rise to 63.5 Hz for up to 10 seconds immediately following a major disturbance that results in MH Transmission System separation from the North American Grid. Following the initial 10 seconds after separation, the frequency variations could be up to ±0.1 Hz for 10 to 15 minutes.
During extreme events such as a large generation loss in Manitoba that may cause isolation from the North American Grid, the frequency may drop below 57.5 Hz with an initial frequency decay rate of 1 Hz/s to 10 Hz/s.

Equipment interconnected to the MH Transmission System shall be capable of withstanding the following dynamic frequency performance criteria listed below and illustrated in Figure 2 of Section 8:
<table>
<tr><th>Criteria</th><th>Bus Frequency F_{bus} (Hz)</th><th>Duration (seconds)</th></tr>
<tr><td>Low Frequency</td><td>57.5</td><td>10.0</td></tr>
<tr><td>Low Frequency</td><td>57.5 to 59.5</td><td>30.0</td></tr>
<tr><td>Nominal Frequency</td><td>59.5 to 60.5</td><td>Continuous</td></tr>
<tr><td>High Frequency</td><td>63.5 to 60.5</td><td>30.0</td></tr>
<tr><td>High Frequency</td><td>63.5</td><td>10.0</td></tr>
</table>
</td></tr>
<tr><td>2.6</td><td>Transient Frequency Variations</td><td>The MH Transmission System is planned to ensure underfrequency load shed relays do not operate following a single contingency event. The bus frequency is not permitted to drop below 59.6 Hz for more than 83 msec. (setting of the first block of load shed as defined in Section 2.10) following single contingency events (as defined in the Reliability Standards Regulation) .
Mitigation and/or system upgrades are required if bus frequency violates the dynamic frequency performance criteria.</td></tr>
</table>

No.	Item	Information and Requirements		
2.7	Black Start Resource	As required by the *Reliability Standards Regulation,* the MH Transmission System is designed and operated such that it can be restored to normal operation following a disturbance in which one or more areas of the Bulk Electric System (BES) shuts down. To do this MH has identified Generator Facilities that are required to act as Black Start Resources. For system restoration the MH Transmission System is divided into generation islands each containing at least one Black Start Resource. Black Start Resources must be able to start completely independent of the BES, using only those resources that are immediately available and that are capable of delivering power hours after the event. These generating units must capable of energizing transmission lines and restoring system loads. Units selected for the Black Start role are normally main generating units.		
2.8	Power Quality	The MH Transmission System is designed and operated such that its power quality levels are within the limits specified in PQS2000 [2][2], *"Power Quality Specification For Interconnection to Manitoba Hydro's Electrical System."*		
2.9	System Protection and Control	2.9.1 Protection System Implementation	Protection systems on the MH Transmission System are to be implemented so as to ensure fast, reliable clearing of system faults and fast enough to ensure stability of the System.	
		2.9.2 Normal Fault Clearing Times	MH designs all new facilities to ensure that fault clearing times do not exceed the following limits::	
			66 kV*	8 cycles
			115/138 kV	5 cycles
			230 kV	5 cycles
			500 kV	3 cycles
			* 66 kV system defined in Section 1.3. Fault clearing time is the total time from fault inception to last breaker interruption.	

<table>
<tr><th>No.</th><th>Item</th><th colspan="2">Information and Requirements</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td></td><td>Manitoba Hydro designs all new facilities to have the following delayed fault clearing times (assuming 3 cycle breakers):
<table>
<tr><td>Breaker Failure</td><td>18 cycles</td></tr>
<tr><td>Backup Protection
(Primary protection system failure)</td><td>30 cycles</td></tr>
</table>
End to end communications may be required to achieve these times. Other fault clearing times may be considered on a case by case basis as identified in INTERCONNECTION STUDIES

Existing stations may not meet these specifications and will be upgraded as the need is identified or as the opportunity arises.MH must be contacted to obtain maximum clearing times and the conditions under which the maximum clearing times apply for a specific POINT(S) OF INTERCONNECTION or POINT(S) OF DELIVERY.

Actual or designed clearing time plus one cycle margin (to account for modelling error) shall be used in INTERCONNECTION STUDIES.</td></tr>
<tr><td>2.9.3 System Damping</td><td>Power system stabilizers or equivalent transmission control devices are designed to have a positive damping effect on local generator oscillations as well as inter-plant and inter-area oscillations.

For inter-area oscillations the power oscillation damping ratio “r” threshold shall be the least restrictive criterion of all regions participating in the oscillations. The inter-area damping criterion will be defined during INTERCONNECTION STUDIES if required.

For disturbances within Manitoba, the power oscillation damping ratio “r” threshold is:
<table>
<tr><td>r => 0.04</td><td>acceptable</td></tr>
<tr><td>r <0.04</td><td>requires mitigation</td></tr>
</table></td></tr>
</table>

No.	Item	Information and Requirements	
		2.9.4 Transmission Line Protection Systems	Manitoba Hydro designs all new transmission line facilities to provide detection and isolation of faults over the length of the line, plus backup clearing of faults for all adjacent elements and lines and consist of: ***100 kV and above systems:*** Dual digital relay packages are utilized to provide fully redundant protection systems. At least one package includes fault location capability, and each package includes reasonable waveform and events recording (e.g. digital packages). Both systems include communications aided tripping, generally employing separate routes, so as to provide high speed clearing of faults over the full line length, even if one system is out-of-service or fails to operate. Where practical redundant protections utilize separate PT and CT cores. Breaker failure protection is provided for all 230kV and above breakers and 115kV and 138kV network breakers. Breakers for 115kV and 138kV load taps off transmission lines do not require breaker fail protection however this may be provided at the facility owner's discretion and expense. Loss of one communication system must not result in backup clearing of other (non-faulted) system elements unless one of the two communication systems is out-of-service for scheduled maintenance. Redundant protection systems are required for 100kV and above system additions. Redundancy requires that the protection system should have no credible single point of failure that would result in both protection systems failing to clear a fault within the specified normal clearing time. Different dual protection packages are chosen so as to avoid the possibility of simultaneous failures to both systems due to manufacturer's defects, component failures, misunderstanding or misapplication of settings or functions. Also, dual packages allow taking a package out of service for maintenance while keeping the line in-service. This can often be achieved through use of different manufacturer's equipment or devices working on different principles.

No.	Item	Information and Requirements	
			Protection command signals such as transfer trips or permissive trips for systems 100kV and above require redundant, independent route communication systems. Circuit breakers are provided with dual trip coils for independent connection to one system of redundant protection relays. Auxiliary power to relay systems including their communications is required as per Section 2.15. MH is required to develop documentation of the protection system maintenance and testing program in compliance with the requirements of the The Manitoba Hydro Act Reliability Standards Regulation Existing Transmission lines may not meet these specifications and will be upgraded as the need is identified or as the opportunity arises.
		2.9.5 Bus Protection	***100 kV and above systems:*** Dual relay packages are utilized to provide fully redundant protection systems. Each package includes reasonable waveform and events recording (e.g. digital packages). Where practical redundant protections utilize separate PT and CT cores. Breaker failure protection is provided for all breakers.
		2.9.6 REMEDIAL ACTION SCHEME (RAS)	MH designs REMEDIAL ACTION SCHEME with the following considerations: • The RAS should not be too complex, • The amount of generation cross-tripped (or runback) should not exceed the amount of firm generation added or firm transmission service requested, • The cost of calling on emergency reserves, as well as lost opportunity sales, • The value of transmission losses, • The RAS should typically resolve reliability issues for at most a prior outage followed by a single contingency. Design, operation, and maintenance of the RAS is subject to standards in the *Reliability Standards Regulation* and Manitoba Hydro Station Standard 1-01000-WO-65000-0003.

<table>
<tr><th>No.</th><th>Item</th><th>Information and Requirements</th></tr>
<tr><td>2.10</td><td>Underfrequency Load Shed (UFLS)</td><td>As required by the Reliability Standards Regulation, MH takes part in an Underfrequency Load Shed (UFLS) program to help ensure integrity of the MH TRANSMISSION SYSTEM during extreme power system events resulting in the loss of a large amount of generation. It is organized into blocks of load to be shed at fixed frequency set points as determined by MH.

The load shed blocks are set to trip at one of the following fixed frequency set points:
<table>
<tr><th>Shedding Block Number</th><th>Frequency Set Point (Hz)</th><th>Relay Time (cycles)</th></tr>
<tr><td>1</td><td>59.6</td><td>7.0</td></tr>
<tr><td>2</td><td>59.3</td><td>6.0</td></tr>
<tr><td>3</td><td>59.0</td><td>6.0</td></tr>
<tr><td>4</td><td>58.7</td><td>6.0</td></tr>
<tr><td>5</td><td>58.4</td><td>6.0</td></tr>
<tr><td>6</td><td>58.0</td><td>6.0</td></tr>
</table>
These load shed blocks are subject to change based on changes to the MH TRANSMISSION SYSTEM.</td></tr>
<tr><td>2.11</td><td>Undervoltage Load Shed (UVLS)</td><td>There are no Undervoltage Load Shed (UVLS) schemes at present on the MH TRANSMISSION SYSTEM. MH reserves the right to require the Facility Owner(s) to take part in an UVLS scheme. MH will determine the need for UVLS based on the results of the INTERCONNECTION STUDIES.</td></tr>
<tr><td>2.12</td><td>System Grounding</td><td>The MH TRANSMISSION SYSTEM is operated as effectively (solidly) grounded at nominal voltage levels above 200 kV.
The 115 and 138 kV are often operated with ungrounded-wye transformers.</td></tr>
<tr><td>2.13</td><td>Insulation Levels</td><td>Insulation Levels used on the MH TRANSMISSION SYSTEM are:
<table>
<tr><th>Nominal Voltage (kV)</th><th>Lightning Impulse Level (LIL) (kV)</th></tr>
<tr><td>66</td><td>350</td></tr>
<tr><td>115</td><td>550</td></tr>
<tr><td>138</td><td>650</td></tr>
<tr><td>230</td><td>900 everywhere
1050 (special cases as determined by MH)</td></tr>
<tr><td>500</td><td>1550 for transformers and
1800 for all other equipment</td></tr>
</table></td></tr>
</table>

No.	Item	Information and Requirements
		Lightning (Surge) protection against direct lightning strokes shall be provided for protecting outdoor equipment including transformers. MH requires Lightning (Surge) protection to protect 230 kV and above station equipment at • both end of cables at cable terminations, • both ends of transmission lines at station entrance, • at station equipment terminals (such as transformers) as per GOOD UTILITY PRACTICE. Lightning protection shall be designed for a zero rate of failure (that is, all voltage stresses are at least three standard deviations less than the critical flashover voltage) taking into account the regional lightning stroke density (estimated from either the Canadian Lightning Detection Network (CLDN) data or the local keraunic map if CLDN data is not available) and tower footing resistances as applicable.
2.14	Short Circuit Levels	Equipment is designed for operation at short circuit levels that take into account future development and expansion of the MH TRANSMISSION SYSTEM. The short circuit levels at any POINT(S) OF INTERCONNECTION or POINT(S) OF DELIVERY depend on the voltage level and location and are available on request from MH. Circuit breakers require replacement once the short circuit level exceeds 95% of the breaker rating.

No.	Item	Information and Requirements
2.15	Communication Systems	Communication Systems are generally designed to have the following characteristics: • For each required communication function, dual, independent, communications systems are used to interface between FACILITY(IES) and the designated MH site(s), such that "no foreseeable single event or single component failure shall cause a major loss of communications functionality". The two communication systems avoid common intermediate sites. FACILITY(IES) are able to operate with either system out of service. MH prefers to avoid using leased circuits, however a leased circuit is occasionally used as one of the two individual communication systems. • Each individual communication system has a high functional dependability and low probability of being out of service for a long period of time. The probability of both communication systems being simultaneously out of service is extremely low. The requirement is for a functional unavailability not to exceed 10 seconds per year. • Communications systems that are required to transmit or receive protection signals are designed to operate through power system faults or outages. • Sufficient communications capacity is provided to meet all the MH TRANSMISSION SYSTEM needs. • Communications systems meet MH design practices and are adequate to ensure that the MH TRANSMISSION SYSTEM performance meets power system reliability requirements. The relevant MH design practices are available on request from MH. • Communication channels are of high quality, suitable for analog and digital traffic at the required speeds. • Communications delays are minimised to allow for fast power system protection operation (no more than 2 milliseconds traffic delay). • Standby power is required for all telecommunications as per Section 2.18. • All communication systems are maintainable without jeopardising the MH TRANSMISSION SYSTEM or unreasonably affecting its operation.
2.16	Automatic Generation Control	Manitoba Hydro is a control area and uses Automatic Generation Control to maintain system frequency and scheduled interchange levels. Automatic Generation Control is operated and monitored according to the *Reliability Standards Regulation*.

<table>
<tr><th>No.</th><th>Item</th><th colspan="2">Information and Requirements</th></tr>
<tr><td rowspan="10">2.17</td><td rowspan="10">Transformer Winding Configurations</td><td colspan="2">Typical transformer winding arrangements include:</td></tr>
<tr><td>500 kV-230 kV-46 kV</td><td>Grounded-Wye, Grounded-Wye, Delta (auto transformer)</td></tr>
<tr><td>230 kV-115 kV-13.8 kV</td><td>Grounded-Wye, Grounded-Wye, Delta (auto transformer)</td></tr>
<tr><td>230 kV-138 kV-13.8 kV</td><td>Grounded-Wye, Grounded-Wye, Delta (auto transformer)</td></tr>
<tr><td>115 kV-13.8 kV or
230 kV-13.8 kV</td><td>Grounded-Wye, Delta (generator transformer)</td></tr>
<tr><td>230 kV-66 kV</td><td>Grounded-Wye, Delta</td></tr>
<tr><td>230 kV-25 kV</td><td>Grounded-Wye, Grounded-Wye, with buried Delta</td></tr>
<tr><td>115 kV-66 kV</td><td>Grounded-Wye, Delta</td></tr>
<tr><td>115 kV-25 kV</td><td>Ungrounded-Wye, Grounded-Wye, with buried Delta</td></tr>
<tr><td colspan="2">In general transformers are equipped with de-energized taps in five steps of 2.5% in the range of 2.5% buck to 7.5% boost. Auto transformers do not have de-energized taps.
The 230-138 kV auto transformers are suitable for both step-up and step-down operation, with the Load Tap Changer (LTC) on the 230 kV and a +/-10% variation.
The 230-115 kV auto transformers are almost all step-down, with the LTC on the 115 kV and mostly variations of +/-10% or +/-15%.
The 500-230 kV auto transformers are suitable for both step-up and step-down operation, with the LTC on the 500 kV in +/-7.5% variation.</td></tr>
<tr><td>2.18</td><td>Station Battery</td><td colspan="2">Station battery for stations with a system restoration plan must be able to with stand a 12 hour outage to the battery chargers and must:
• be able to serve all normal dc loads,
• survive the largest credible station event at the beginning of the 12-hour period,
• survive one open-close-open operation on each station device during the 12-hour period with some margin.
Stations without a restoration plan may be required to have a 16 hour battery capability.</td></tr>
</table>

No.	Item	Information and Requirements	
2.19	System Studies	Several types of System Studies are performed to ensure the MH Transmission System is designed to meet the standards in the *Reliability Standards Regulation*. Interconnection Studies may include Open Access Interconnection Studies, Open Access Transmission Tariff Studies or Customer Load Studies.	
		2.19.1 Open Access Interconnection and Open Access Transmission Tariff Studies	MH studies conducted under the terms of the Open Access Interconnection and Open Access Transmission Tariff
		2.19.2 Transmission System Planning Performance Requirements Studies	MH studies to identify any system upgrades than may be required to meet the standards in the *Reliability Standards Regulation*.
		2.19.3 Customer Load Studies	MH studies to determine the effect and requirements for the interconnection of Customer Load Facilities to the MH Transmission System.
		2.19.4 Operating Studies	MH studies to identify system intact and prior outage conditions that may limit the operation of any Facility(ies) connected to the MH System. These studies are used to develop Operating Procedures. Operating Studies are conducted seasonally and as needed.

<table>
<tr><th>No.</th><th>Item</th><th>Information and Requirements</th></tr>
<tr><td>2.20</td><td>Reactive Power Margins</td><td>The MH TRANSMISSION SYSTEM is designed such that it maintains the following pre-contingency steady state MVAR margins:
Static var compensators at Ponton and Birchtree are operated at 0 MVAr precontingency. All other MH generator units are monitored to ensure they are not operating at capacitive output limits.
<table>
<tr><th>Station</th><th>Capacitive Reserve</th><th>Other Conditions</th><th>Modelled</th></tr>
<tr><td>Dorsey</td><td>460 MVAR</td><td>not applicable</td><td>one 160 MVA Synchronous Condenser out-of-service with a 300 MVAR reserve</td></tr>
<tr><td>Grand Rapids</td><td>125 MVAR</td><td>system intact</td><td></td></tr>
<tr><td>Seven Sisters</td><td>8 MVAR</td><td>system intact</td><td></td></tr>
</table></td></tr>
<tr><td>2.21</td><td>Out-of-Step Relay Margins</td><td>The MH TRANSMISSION SYSTEM is designed such that it maintains the following Out-of-Step (OOS) Relay Margins on the Canadian to USA tie-lines:
<table>
<tr><th rowspan="2">Line</th><th colspan="2">Steady State</th><th rowspan="2">Dynamic</th></tr>
<tr><th>Pre-Contingency</th><th>Post-Contingency</th></tr>
<tr><td>B10T at Tioga</td><td>110%</td><td>50%</td><td>25%</td></tr>
<tr><td>G82P at Peace Garden</td><td>110%</td><td>50%</td><td>25%</td></tr>
<tr><td>L20D at Drayton</td><td>110%</td><td>50%</td><td>25%</td></tr>
<tr><td>M602F at both the Riel and Forbes ends</td><td>110%</td><td>50%</td><td>50% (MHEX = South Flow)
25% (MHEX = North Flow)</td></tr>
<tr><td>R50M at Moranville</td><td>110%</td><td>50%</td><td>25%</td></tr>
<tr><td>F3M at International Falls</td><td>110%</td><td>50%</td><td>25%</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>No.</th><th>Item</th><th>Information and Requirements</th></tr>
<tr><td>2.22</td><td>Modelling Data</td><td>Models representing the MH system conform to the standards in the Reliability Standards Regulation.
MH uses models for the following purposes:
• To determine compliance with interconnection criteria and performance standards.
This includes but is not limited to the following analysis:
• Steady state or contingency analysis to identify loading and voltage issues.
• Voltage stability analysis to identify voltage collapse.
• Time domain simulation in a full network power system model, typically for simulation studies up to 10 seconds and not normally more than 30 seconds to identify performance under steady state and disturbance conditions including remote faults and faults at or close to the POINT(S) OF INTERCONNECTION or POINT(S) OF DELIVERY.
• Linear system analysis (eigenvalue analysis) to identify angle damping.
Different models may be required for each type of analysis. The model shall be suitable for transient and other dynamic stability analysis and is compatible with the following software tool,
• PSS®E (Siemens Power Technologies Inc.).
• MH reserves the right to request data for any other software tool as required by study needs.</td></tr>
<tr><td>2.23</td><td>Equipment Ratings</td><td>The MH TRANSMISSION SYSTEM including the NORTHERN COLLECTOR SYSTEM and MH HVdc TRANSMISSION SYSTEM is planned, designed and constructed to satisfy the ratings detailed in “Facility Ratings Methodology for Manitoba Hydro’s Bulk Electric System” [3] as required by the Reliability Standards Regulation.

Facility ratings for the MH TRANSMISSION SYSTEM is documented on the internal website: http://esdapps.hydro.mb.ca/ta/EquipmentRatings. The facility ratings for specific equipment is available upon request.

Following a contingency, if a short-term overload rating is applied, it is necessary to be able to reduce the loading to the steady state thermal rating within 30 minutes of the overload occurrence.

For INTERCONNECTION STUDIES a FACILITY OWNER(S) is responsible to upgrade existing FACILITY(IES) which are thermally overloaded and for which the Distribution Factor (DF) for pre-contingency conditions, the “Power Transfer Distribution Factor (PTDF)” is greater than or equal to 3% or the DF for post-contingency conditions, the “Outage Transfer Distribution Factor (OTDF)” is greater than or equal to 5%.

The PTDF and OTDF are calculated by the pre and post Facility line flows:

$$DF = \frac{MW_{PostFacility} - MW_{PreFacility}}{MVA_{Facility}}$$</td></tr>
</table>

<table>
<tr><th>No.</th><th>Item</th><th colspan="2">Information and Requirements</th></tr>
<tr><td>2.24</td><td>Station Ring Ratings</td><td colspan="2">MH designs and constructs all new facilities with a ring bus including all low, intermediate and high bus sections, connectors, disconnect switches, circuit breakers, current transformers to be rated at:
<table>
<tr><th>Nominal
Bus Voltage
(kV)</th><th>Station
Rating (Amps)</th></tr>
<tr><td>230</td><td>2790</td></tr>
<tr><td>138</td><td>2000</td></tr>
<tr><td>115</td><td>2790*/2000</td></tr>
<tr><td>66</td><td>2000</td></tr>
</table>
* for 230 kV to 115kV Stations.

High bus line terminations shall be rated in accordance with the maximum expected, current capacities of associated transmission lines.
All equipment ratings (circuit breakers, disconnect switches, etc.) shall match the appropriate bus ratings.
Higher ratings than the above are determined on a case by case basis by MH during System Studies (Section 2.19).
</td></tr>
<tr><td rowspan="2">2.25</td><td rowspan="2">Monitoring Facilities</td><td colspan="2">MH uses recording and monitoring facilities to analyze protection operations, system faults and system disturbances on the MH TRANSMISSION SYSTEM. Equipment used may include a combination of digital relays and meters with internal recording of events and waveforms, sequential events recording, transient fault recording, fault locating or disturbance recording equipment.

Information gathered typically includes trip initiations (from relays or other protective sensors), system current and voltage waveforms, and breaker status. Where protection systems involve multiple sites (e.g. line protections), monitoring includes time tagging in sufficient detail and resolution to determine initiating conditions and sequence of operations. Where the system elements have the potential to affect BES system stability, longer term disturbance recording functions are used.

All information is generally in a format such that data can be quickly and easily exchanged with other entities as required by the Reliability Standards Regulation.</td></tr>
<tr><td>2.25.1 Disturbance Monitoring</td><td>MH requires the installation of Disturbance Monitoring Equipment (DME) at critical sites. Sites which meet or exceed the requirements in [4] must install DME equipment that meet or exceed the functional requirements in [5]</td></tr>
</table>

No.	Item	Information and Requirements	
		2.25.2 Phasor Measurement Units	MH requires the installation of Phasor Measurement Units (PMUs). The site locations are determined by MH during System Studies (Section 2.19). The PMU function must meet the requirements in [5].
		2.25.3 Geomagnetically Induced Current (GIC) Monitoring	Geomagnetically Induced Current (GIC) monitoring is required on all grounded Wye transformers that satisfy the following conditions: 1) are 75 MVA or greater and 2) are 100 kV or greater. And must include real time measurements of: • Transformer Neutral Current (AC and DC quantities), • High and Low side phase currents, • High and Low side phase voltages, • Transformer health quantities such as temperature (optional), • Sample rate appropriate for harmonic calculations up to and including the 7th harmonic. • Measurement technology must work reliably during large DC current flows defined by MH at each location.
2.26	System Under Voltage Controller	Manitoba Hydro plans and designs its system such that single contingency events do not trigger operation of the Dorsey/Riel System Under Voltage Controller (SUVC). System upgrades will be required to ensure this criterion is not violated. SUVC operation is permitted for double or other multiple contingency events with slow clearing.	
2.27	HVDC Minimum Rating	The MH High Voltage Direct Current (HVDC) System is planned, designed and constructed such that the minimum total HVDC Facility rating is equal to the total amount of Network Integration Transmission Service from all Generator Facility(ies) connected to the Northern Collector System plus 500 MW (largest HVDC valve group rating).	
2.28	Domestic Load	MH serves its domestic load (Native Load Customers) off of the MH Distribution System which is connected to the MH Transmission System. The connection between the two systems is typically at 230/66 kV, 138/66 kV or 115/66 kV. For 66 kV connections, MH defines the Point(s) of Delivery (POD) between the two systems as being at the low voltage terminal of the step down transformer(s), the POD for all other connections is at the high side of the step down transformer. MH plans and designs all new POD's such that the following criteria are satisfied (Existing stations may not meet these specifications and will be upgraded as the need is identified or as the opportunity arises):	
		2.28.1 Interconnection Location and Voltage Level	The voltage level and the geographic location of the POD on the MH Transmission System is determined by the MH Transmission Business Unit (TBU) in consultation with the MH Customer Service & Distribution Business Unit (CS&D). MH will follow the line tapping standards specified in Section 5.3 when selecting the location for a POD.

<table>
<tr><th>No.</th><th>Item</th><th colspan="2">Information and Requirements</th></tr>
<tr><td></td><td></td><td>2.28.2 Voltage Regulation and Power Factor Requirements</td><td>MH will maintain the voltage at the POD within the range specified in Sections 2.2, 2.3, and 2.4. CS&D provides any additional voltage regulation required by the domestic load.
The MH DISTRIBUTION SYSTEM is planned to minimize the reactive power exchange at the POD.</td></tr>
<tr><td></td><td></td><td>2.28.3 Protection</td><td>In addition to Section 2.9, a POD may be required to take part in Underfrequency Load Shed (Section 2.10) and Undervoltage Load Shed (Section 2.11) schemes as determined by INTERCONNECTION STUDIES.</td></tr>
<tr><td></td><td></td><td>2.28.4
Telemetering and Metering, Supervisory Control and Data Acquisition (SCADA)</td><td>All POD's inside a station are equipped with a Supervisory Control and Data Acquisition (SCADA) Remote Terminal Unit (RTU) and are connected via appropriate, dedicated communication channels to the Manitoba Hydro System Control Centre (SCC). The RTU provides the following information and control capabilities:
• Status: The RTU shall provide position indication of all transmission voltage circuit breakers and motor operated disconnect devices,
• Alarms: The RTU shall provide equipment alarm information for each protective device and associated protective relaying in the transmission path,
• The RTU will provide Power (MW), Reactive Power (Mvar), current (A), and voltage (V) quantities at the POD.
All Telemetering and Metering, Supervisory Control and Data Acquisition shall be at the POD.</td></tr>
<tr><td></td><td></td><td>2.28.5
Verification of Load Demand Characteristic Modelling</td><td>In addition to the requirements of Section 2.22, the representation of the load demand characteristics for POD's with heavy loading (greater than 10 MVA) requires periodic review by MH to ensure accuracy of the demand modelling. CS&D annually provides updated demand data and carries out any field tests required to verify load characteristics.
The CS&D provides MW/Mvar forecast of load requirements (see Section 7.2) for analysis as follows:
• Annual forecast of load (gross and net) for next 10 years,
• Load composition (see Section 7.2 for details),
• Load reactive characteristics.</td></tr>
<tr><td></td><td></td><td>2.28.6 Transformer Spare</td><td>MH plans, designs and constructs all 66 kV stations such that following the loss of the largest transformer bank, there is sufficient transformation to serve peak load. Brief interruptions to facilitate switching within the station to allow load transfers to adjacent stations are permitted.</td></tr>
</table>

3.0 GENERATOR INTERCONNECTION REQUIREMENTS

This section defines the technical requirements that are applicable for new GENERATOR(S) applying to interconnect to the 115 kV, 138 kV, 230 kV, 500 kV and applicable 66 kV nominal voltage levels on the MH TRANSMISSION SYSTEM or existing GENERATOR(S)applying to make a SUBSTANTIAL MODIFICATION to their GENERATOR FACILITY(IES).

No.	Item	Requirement
3.1	Interconnection Location and Voltage Level	The GENERATOR may apply to interconnect to the MH TRANSMISSION SYSTEM at the nominal voltage levels above 60 kV as defined in Section 2.2. Each GENERATOR shall have a unique POINT(S) OF INTERCONNECTION and may not share a POINT(S) OF INTERCONNECTION with another GENERATOR. The voltage level and the geographic location of the POINT(S) OF INTERCONNECTION to the MH TRANSMISSION SYSTEM are to be determined by MH in consultation with the GENERATOR. MH shall be the final authority in determining voltage level and the geographic location of the POINT(S) OF INTERCONNECTION.
3.2	Sealing of Technical Reports, Drawings, Memos, etc.	All reports, memos, drawings, equipment specifications, and modelling data of technical nature (excluding manufacturing drawings) shall be sealed by a Professional Engineer certified to practice in the Province of Manitoba in accordance with *The Engineering and Geoscientific Professions Act of Manitoba*.
3.3	Reactive Power Requirements	The GENERATOR FACILITY(IES) shall be designed to provide reactive power supply and absorption capability acceptable to MH. The adequacy of such capability shall be determined by the INTERCONNECTION STUDIES. INTERCONNECTION STUDIES and/or studies associated with a request for transmission service may require power factor capability in excess of the minimum requirements specified below.
		All GENERATOR FACILITY(IES) larger than 10 MW interconnected to the MH TRANSMISSION SYSTEM shall be able to control the voltage level at the POINT(S) OF INTERCONNECTION as determined by the MH SYSTEM OPERATOR by adjusting the generator's power factor. For GENERATOR FACILITY(IES) larger than 10 MW, the GENERATOR shall design the GENERATOR FACILITY(IES) to maintain power delivery at continuous rated power output measured at the generator terminals at a power factor within the range of 0.90 overexcited (leading) to 0.95 underexcited (lagging) [6], [7] & [8]. INTERCONNECTION STUDIES will determine if a range different from this may be permitted.

No.	Item	Requirement
		For GENERATOR FACILITY(IES) smaller than 10 MW, the GENERATOR shall design the GENERATOR FACILITY(IES), at minimum, to maintain power delivery at continuous rated power output measured at the POINT(S) OF INTERCONNECTION at unity power factor. The reactive supply shall be available over the full range of operating conditions Refer to Figure 5 in Section 8. The GENERATOR shall be responsible for providing any necessary reactive power facilities as determined by INTERCONNECTION STUDIES.
3.4	Dynamic Power Requirements	INTERCONNECTION STUDIES will determine the need for additional dynamic reactive power support to ensure voltages remain within the voltage ranges specified in Sections 2.2, 2.3 and 2.4. The dynamic reactive support may be required at the Point of Interconnection or at other points in the MH TRANSMISSION SYSTEM.

<table>
<tr><th>No.</th><th>Item</th><th>Requirement</th></tr>
<tr><td>3.5</td><td>Voltage Ride Through</td><td>
The GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES), interconnected to the MH TRANSMISSION SYSTEM shall meet the following voltage ride-through characterises:
<table>
<tr><th colspan="2">Low Voltage Ride Through</th></tr>
<tr><td>Bus Voltage at P.O.I. (pu)</td><td>Duration (Cycles)</td></tr>
<tr><td>0.00</td><td>9.0</td></tr>
<tr><td>≤ 0.50</td><td>18.0</td></tr>
<tr><td>≤ 0.65</td><td>120.0</td></tr>
<tr><td>≤ 0.75</td><td>180.0</td></tr>
<tr><td>≤ 0.85</td><td>300.0</td></tr>
<tr><td>≥ 0.90</td><td>continuous</td></tr>
</table>
<table>
<tr><th colspan="2">High Voltage Ride Through</th></tr>
<tr><td>Bus Voltage at P.O.I. (pu)</td><td>Duration (Cycles)</td></tr>
<tr><td>≥ 1.350</td><td>12.0</td></tr>
<tr><td>≥ 1.300</td><td>30.0</td></tr>
<tr><td>≥ 1.275</td><td>120.0</td></tr>
<tr><td>≥ 1.220</td><td>180.0</td></tr>
<tr><td>≥ 1.150</td><td>300.0</td></tr>
<tr><td>≤ 1.100</td><td>continuous</td></tr>
</table>
The GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES), interconnected to the MH TRANSMISSION SYSTEM at the applicable system nominal voltage, shall:

Be capable of operating continuously within the minimum and maximum voltage limits as defined in Sections 2.2, 2.3 and 2.4 as applicable based on POINT(S) OF INTERCONNECTION. MH reserves the right to require the GENERATOR's equipment to be capable of operation outside the normal minimum and maximum values defined in Sections 2.2, 2.3 and 2.4 at specific locations on the MH TRANSMISSION SYSTEM.
Have equipment rated at the voltage levels for rating of equipment as defined in Section 2.2 as applicable at the POINT(S) OF INTERCONNECTION.
Be capable of remaining in operation during transient under voltage events following system disturbances to the under voltage levels and durations defined in Section 2.4.

</td></tr>
</table>

<table>
<tr><th>No.</th><th>Item</th><th>Requirement</th></tr>
<tr><td></td><td></td><td>

Be capable of withstanding, switching (or transient) and temporary (or dynamic) over voltage events and remaining in service up to the voltage levels and durations defined in the Section 2.4.
Be capable of remaining in operation during under-voltages caused by nearby faults not on the Interconnection Facilities. The minimum voltage at the Point(s) of Interconnection is 0% for the fault duration and less than 50% for 18 cycles.

</td></tr>
<tr><td>3.6</td><td>Frequency Variations</td><td>
The design criteria for frequency variation used on the MH Transmission System is given in Section 2.5 and 2.6. The Generator Facility(ies) and Generator Interconnection Facility(ies) are required to be designed to operate reliably for the following fundamental frequency range when interconnected to the MH Transmission System:
<table>
<tr><td>Under frequency Limit</td><td>Over frequency Limit</td><td>Minimum Time</td></tr>
<tr><td>60.0-59.0 Hz</td><td>60.0-61.5 Hz</td><td>N/A continuous</td></tr>
<tr><td>59.0-58.7 Hz</td><td>61.5-62.0Hz</td><td>10 minutes</td></tr>
<tr><td>58.7-57.5 Hz</td><td>62.0-63.5 Hz</td><td>30 seconds</td></tr>
</table>
These ranges are set to coordinate with the MH UFLS program defined in Section 2.10.
Generator tripping is permitted if required to prevent damage to Generator Facility(ies) for frequency conditions outside the operating limits defined above.
A Generator Facility(ies) that does not meet the above under frequency requirements shall arrange to automatically trip load (in addition to automatic/manual load already shed by the MH UFLS program) to match the anticipated generation loss, at comparable frequency levels. The Generator shall coordinate frequency relay settings with MH.
Interconnection Studies will determine if modifications to the over frequency limits are permitted or required based on the Point(s) of Interconnection.
Generator Facility(ies) must be able to ride through a frequency rate of change of 4.0 Hz/second.
Refer to Figure 2 in Section 8 for the frequency tolerance curve for the Generator Facility(ies).
</td></tr>
<tr><td>3.7</td><td>Inertia Constant (H)</td><td>
The impact on stability performance of the inertia of the generator unit will be reviewed during the Interconnection Studies. The Interconnection Studies shall demonstrate the ability of the generator unit to maintain synchronism for typical fault clearing times (see Section 2.9.2) at or near the Point(s) of Interconnection.
Mitigating measures to correct any performance issues will be determined during the Interconnection Studies.
</td></tr>
</table>

No.	Item	Requirement	
3.8	Synchronous Generator Controls	3.8.1 Speed Governor	Synchronous generator units shall have a functioning speed governor to ensure satisfactory frequency response. The speed governor shall have the following characteristics: • 5% speed droop (defined as the % change in speed to get 100% governor action), • Fully responsive to frequency deviations exceeding ±0.036 Hz, • Capable of providing immediate and sustained response to abnormal frequency excursions, • Control generator speed stably during interconnected and also during islanded operation, • Control generator speed following full load rejection so as to prevent a trip on overspeed. The performance requirements of the governor system shall be in accordance with IEEE Standard 125 [9][9] for hydraulic turbines and with IEEE Standard 122 [10][10] for steam turbines. Similar performance requirements shall apply to all types of prime movers. The GENERATOR shall be responsible for demonstrating stable performance with adequate damping under all operating conditions.

<table>
<tr><th>No.</th><th>Item</th><th colspan="2">Requirement</th></tr>
<tr><td></td><td></td><td>3.8.2
Excitation System</td><td>New synchronous generator units and/or SUBSTANTIAL MODIFICATIONS to an existing GENERATOR FACILITY(IES) may require the addition of a high initial response type of exciter if INTERCONNECTION STUDIES demonstrate all or part of the following:
• The high initial response excitation system is required to meet minimum transient voltage criteria;
• The high initial response excitation system is required to enhance the ability of the Generation Facility to damp electromechanical modes of oscillation and meet minimum damping criteria.
• The generator unit size exceeds 70 MVA.
The excitation system shall be designed in accordance with the guidelines of IEEE Standard 421.4 [11][11].
A static excitation system voltage response time will depend on results from INTERCONNECTION STUDIES, but shall not be greater than 100 milliseconds.
For rotating exciters, the excitation system nominal response (historically referred to as the excitation system response ratio), at rated speed, shall be at least 2.0.
The INTERCONNECTION STUDIES shall determine the required positive and negative ceiling voltage of the excitation system. The exciter ceiling voltage shall not be less than 2.0 times rated field voltage.
The excitation system voltage response time, ceiling voltage and nominal response are defined in IEEE 421.1 [12].
INTERCONNECTION STUDIES shall determine the need for excitation system limiters. Limiters shall be coordinated with generator protection so that limiter action will occur rather than protection action for system events resulting in voltage and frequency excursions within the ranges specified in Sections 2.4 and 2.5.</td></tr>
</table>

No.	Item	Requirement	
		3.8.3 Automatic Voltage Regulator (AVR)	A continuously acting Automatic Voltage Regulator (AVR) equipped with a line drop compensator, or equivalent, providing a minimum of 60% line drop compensation shall be required for each Generator Facility(ies) rated larger than 10 MW. The AVR shall have the capability to maintain the steady-state voltage within ±0.5% of the set point at the Point(s) of Interconnection or other control point as determined by the MH System Operator. AVR/exciter operation shall be stable Transient Gain Reduction (TGR) and lower gain settings may only be used as back-up settings to preserve control system stability in the cases where the Power System Stabilizer (PSS) is taken or forced out of service. Generator Facility(ies) interconnected to the MH Transmission System that is not equipped with an AVR, may be required to install an AVR if Substantial Modifications, are undertaken. MH will determine the need for an AVR based on the results of the Interconnection Studies. The MH System Operator will determine the AVR voltage control set point.
		3.8.4 Joint Var Control	For an interconnection of a generating plant consisting of several units, joint Var control capability shall be provided with the capability to control a remote bus. The joint Var control requirements are to be determined in consultation with MH.
		3.8.5 Joint Load Control	For an interconnection of a generating plant consisting of several units, joint load control (JLC) capability shall be provided such that the units can effectively share load at a common bus. This will allow the MH System Operator to remotely load/unload the units as an aggregate plant. The JLC requirements are to be determined in Interconnection Studies.
		3.8.6 Power Ramp Rates	The real power output of the Generator Facility(ies) is required to be adjustable. MH will review if the power ramp rate is adequate to follow load if MH requires the generators to be on Automatic Generation Control (AGC) or any other load control scheme. Typical power ramp rates are 2 MW/second.

No.	Item	Requirement	
		3.8.7 Maximum Power Limit	GENERATOR FACILITY(IES) shall not exceed the maximum output value specified in the IOA.
		3.8.8 Power System Stabilizer (PSS)	All generator units 70 MVA or larger shall be provided with a PSS and a high initial response static exciter. INTERCONNECTION STUDIES will determine the required voltage response time If INTERCONNECTION STUDIES determine that the PSS does not provide significant damping to electromechanical modes of oscillation then the static excitation system shall have the capability of accepting a stabilizing signal input as a minimum requirement. Synchronous generator units with a lower rating than 70 MVA may also need a PSS to enhance damping. The need to provide a PSS on smaller units and the required characteristics of the PSS will be determined by MH during INTERCONNECTION STUDIES. Power system stabilizers, if they exist, need to be blocked when the generator is operated in an islanded mode.
		3.8.9 Automatic Generation Control (AGC)	MH reserves the right to require that generator units be capable of AGC operation. MH will determine the need for AGC operation during the INTERCONNECTION STUDIES. Typical AGC requirements are provided in Section 2.16 and shall meet the requirements specified in the *Reliability Standards Regulation*. The MH SYSTEM OPERATOR shall determine AGC operating protocol and operating set points.

<table>
<tr><th>No.</th><th>Item</th><th colspan="2">Requirement</th></tr>
<tr><td>3.9</td><td>Synchronizing Facilities</td><td colspan="2">The GENERATOR shall provide synchronizing facilities including a facility for backup manual synchronizing.
Synchronizing shall be accomplished through the closing of a circuit breaker under the control of an automatic synchronizer with automatic voltage and speed matching for the incoming generator so as to achieve a “bumpless” connection with minimum disturbance to the MH TRANSMISSION SYSTEM.
The GENERATOR shall be responsible for determining the synchronizer settings. The Synchronizing Facilities shall meet IEEE Standard C37.118 [35]. The GENERATOR shall resolve any adverse effects caused by generator synchronization. Typical maximum synchronizer settings are:
• Frequency difference: 0.10 Hz,
• Voltage difference: 3%,
• Phase angle difference: 20 degrees.
The GENERATOR FACILITY(IES) operator is responsible for synchronization of the GENERATOR FACILITY(IES) to the MH TRANSMISSION SYSTEM subject to authorization from the MH SYSTEM OPERATOR.</td></tr>
<tr><td>3.10</td><td>REMEDIAL ACTION SCHEMES (RAS)</td><td colspan="2">The generator units shall be designed with capability of being either direct tripped or automatically run back to reduce power output. INTERCONNECTION STUDIES may require implementation of other REMEDIAL ACTION SCHEMES (RAS). Such requirements may be imposed at any time as dictated by the requirements of the MH TRANSMISSION SYSTEM. Design of RAS schemes will be subject to the requirements specified in Section 2.9.6 and the Reliability Standards Regulation.</td></tr>
<tr><td>3.11</td><td>BLACK START CAPABILITY</td><td colspan="2">As identified in Section 2.7, MH may require the GENERATOR to provide BLACK START CAPABILITY of the GENERATOR FACILITY(IES) if deemed necessary based on the location of the POINT(S) OF INTERCONNECTION and type of generator. INTERCONNECTION STUDIES will determine specific black start requirements according to the Manitoba Hydro Generator Interconnection Operating Requirements.</td></tr>
<tr><td>3.12</td><td>Power Quality</td><td>3.12.1
Power Quality</td><td>The GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) shall be designed and operated such that its power quality levels are within the limits specified in PQS2000, “Power Quality Specification For Interconnection to Manitoba Hydro’s Electrical System” [2][2].</td></tr>
</table>

No.	Item	Requirement	
		3.12.2 Resonance and Self-Excitation	The GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) shall be designed to avoid introducing detrimental resonances into the MH TRANSMISSION SYSTEM. The GENERATOR shall assess the risk of self-excitation of machines and implement appropriate design measures to protect the GENERATOR FACILITY(IES) as required. The GENERATOR shall work in consultation with MH to determine an appropriate solution. MH will provide the GENERATOR with harmonic impedance characteristics at the POINT(S) OF INTERCONNECTION on request. The GENERATOR shall ensure that any issues related to resonance and self-excitation are addressed in the GENERATOR FACILITY(IES) design.

<table>
<tr><th>No.</th><th>Item</th><th>Requirement</th></tr>
<tr><td>3.13</td><td>Protection Requirements</td><td>
Information on the MH TRANSMISSION SYSTEM protection and control practices is provided in Section 2.9.
The GENERATOR shall be responsible for the following:

To ensure that the GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) are protected for all operating conditions and for all faults on the MH TRANSMISSION SYSTEM.
To install protective relaying equipment and systems that will sense and properly react to failure and malfunction of the GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITIES. The design of protective relaying installations will be in accordance with accepted industry standards and shall satisfy criteria in the Reliability Standards Regulation. The protection shall fully protect the safety of the public and of MH personnel interfacing with the GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITIES.
To install high side breaker failure protection at the generating station and on all generator unit breakers [13]. Existing generating stations shall have breaker failure protection installed on an opportunity basis, as determined during INTERCONNECTION STUDIES, as part of a SUBSTANTIAL MODIFICATION.
Determining the settings for relays that protect the generator units and other plant equipment. The GENERATOR shall coordinate the protection and associated protection settings for installed equipment in the GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) with the settings of the MH TRANSMISSION SYSTEM protection schemes in the area. MH will provide details of the MH system protection to the GENERATOR to facilitate this coordination.

The GENERATOR shall produce and provide to MH the following engineering documents for review 60 days prior to energization.:

A protection Single Line Diagram (SLD) for the entire GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) showing protection relay make and model, AC connections, tripping and other critical protection inputs and outputs.
Complete protection settings and logic for all relays including the electronic setting files.
A protection relay coordination report which demonstrates how the settings were determined.

MH shall be the final authority on establishing control and protection settings that impact the performance and operation of the MH TRANSMISSION SYSTEM.

</td></tr>
</table>

No.	Item	Requirement
3.13	Protection Requirements	Information on the MH TRANSMISSION SYSTEM protection and control practices is provided in Section 2.9. The GENERATOR shall be responsible for the following: • To ensure that the GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) are protected for all operating conditions and for all faults on the MH TRANSMISSION SYSTEM. • To install protective relaying equipment and systems that will sense and properly react to failure and malfunction of the GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITIES. The design of protective relaying installations will be in accordance with accepted industry standards and shall satisfy criteria in the *Reliability Standards Regulation.* The protection shall fully protect the safety of the public and of MH personnel interfacing with the GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITIES. • To install high side breaker failure protection at the generating station and on all generator unit breakers [13]. Existing generating stations shall have breaker failure protection installed on an opportunity basis, as determined during INTERCONNECTION STUDIES, as part of a SUBSTANTIAL MODIFICATION. • Determining the settings for relays that protect the generator units and other plant equipment. The GENERATOR shall coordinate the protection and associated protection settings for installed equipment in the GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) with the settings of the MH TRANSMISSION SYSTEM protection schemes in the area. MH will provide details of the MH system protection to the GENERATOR to facilitate this coordination. • • The GENERATOR shall produce and provide to MH the following engineering documents for review 60 days prior to energization.: 4. A protection Single Line Diagram (SLD) for the entire GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) showing protection relay make and model, AC connections, tripping and other critical protection inputs and outputs. 5. Complete protection settings and logic for all relays including the electronic setting files. 6. A protection relay coordination report which demonstrates how the settings were determined. • MH shall be the final authority on establishing control and protection settings that impact the performance and operation of the MH TRANSMISSION SYSTEM.

No.	Item	Requirement
		MH does not provide primary protection and cannot guarantee remote backup protection for any GENERATOR FACILITY(IES). Fault interrupting devices shall have adequate fault interrupting and momentary withstand ratings to satisfy the short circuit level requirements (see Section 3.19) and shall meet normal clearing times established by the INTERCONNECTION STUDIES. Normal clearing times are given in Section 2.9.2. In cases where INTERCONNECTION STUDIES indicate the reliability of the MH TRANSMISSION SYSTEM may be jeopardized, MH may require the GENERATOR to install additional protection. MH will provide information as to the type of additional protections and the required clearing times of these protections. These protections can include but are not limited to the following: • Bus differential, • Overvoltage, • Undervoltage, • Breaker failure, • Out of step, • Loss of field, • Reverse power, • Islanding, • Voltage balance, • Directional overcurrent, and • Transfer trip. *Selection of equipment:* MH reserves the right to specify equipment hardware requirements for all MH-GENERATOR protection system interfaces. Typically this impacts transmission line protection systems including relay make and model, protection communication interfaces, and relay maintenance devices such as test switches. Provisioning of all equipment including spare relays are the GENERATOR's responsibility Data on these protection and control systems including settings, as requested in Section 7.1, shall be provided to MH.

<table>
<tr><th>No.</th><th>Item</th><th colspan="2">Requirement</th></tr>
<tr><td>3.14</td><td>Communications</td><td colspan="2">Communications facilities are required between the GENERATOR FACILITY(IES) and the MH TRANSMISSION SYSTEM. The GENERATOR shall provide and maintain the required communications from the GENERATOR FACILITY(IES) to the site(s) designated by MH. The communications type and performance shall be adequate for its intended use and shall satisfy the requirements further specified herein. MH will specify the interface at its sites.

Communications may be required but are not limited to:
• System protection,
• REMEDIAL ACTION SCHEMES (RAS),
• Supervisory control (including associated data acquisition and alarms),
• Telemetering,
• Operational voice communication, from a standalone dedicated voice line that is capable of functioning for up to 12 hours in a system or site shutdown condition or complete loss of station service supply,
• Facsimile and e-mail communication.

GENERATOR FACILITY(IES) larger than 2 MW may be required to be dispatchable as determined by MH. There could be exception for smaller GENERATOR FACILITY(IES) depending on the POINT(S) OF INTERCONNECTION. Refer to telemetering block diagram in Section 8, for an overview of the communication requirements for non-dispatchable (Figure 3) and for dispatchable generation (Figure 4).

The exact requirement for communications, and functional characteristics, will be dependent on the function served and where appropriate by the reliability and/or redundancy defined during INTERCONNECTION STUDIES.

Information on MH practice with regard to communications is available in Section 2.15 and illustrated in Figures 3 and 4 in Section 8

All communications maintenance and planned outages shall be coordinated through MH.</td></tr>
<tr><td>3.15</td><td>Revenue Metering</td><td>3.15.1 General</td><td>Metering shall conform to the Transmission Owners Customer Metering Standards [14][14].

The specific types of metering equipment, timing devices, locations of meters, the details of the metering arrangement and the records to be kept shall be compatible with MH practice and shall be determined by MH in consultation with the GENERATOR.

If the GENERATOR is a seller of electricity, they are required by Measurement Canada to hold a Certificate of Registration and be in conformance with the Electricity and Gas Inspection Act and Regulations.</td></tr>
</table>

No.	Item	Requirement	
		3.15.2 Accuracy	Revenue quality metering equipment shall consist of meters approved for revenue metering by Industry Canada. Metering equipment shall be installed, calibrated, repaired, replaced, maintained and tested in accordance with Measurement Canada and Manitoba Hydro specifications [15][15]. MH requires 3 element metering accuracy for wye circuits and 2 element metering accuracy for delta circuits. Potential and current transformers for revenue metering shall conform to the Standard CAN/CSA-C60044-1:07 [16][16] and CAN/CSA-C60044-2:07 [17] for 0.3 metering accuracy class. Independent current transformers are required. Additional secondary windings on voltage transformers may be used for other purposes such as protective relaying as long as the burden is not excessive.
		3.15.3 Metering Configuration	The following signals are to be provided: • Active and reactive power, • Hourly integrated real and reactive power, where required. • Demand power, where required. Instrument Transformers and such other devices or equipment as shall be necessary to give the instantaneous values of megawatts and megavars, and an automatic record of kilowatt-hours and megavar-hours for each clock hour. Metering shall be able to provide monthly accumulated active and reactive power quantities. When there is a possibility of flows of electricity in either direction, dual register metering equipment shall be installed to record metering data for each direction of flow. With a CT of sufficient accuracy only one meter on the high side of the transformer is adequate to measure both input and output power. Two revenue meters shall be installed if MH supplies the station load directly.
		3.15.4 Energy Losses	Metering shall be installed at the POINT(S) OF INTERCONNECTION. Where metering is installed at a different location, the metering shall be compensated for losses to the POINT(S) OF INTERCONNECTION. A disconnect device shall not be installed between the power transformer and the point of metering to ensure that no-load losses are correctly registered.

No.	Item	Requirement	
		3.15.5 Meter Reading	Revenue meters may be read locally once per month by MH or may be remotely accessed by MH via telephone. Telemetering facilities to transmit monthly and hourly real and reactive power revenue metering data to MH's SYSTEM CONTROL CENTRE or other facility as directed by MH, shall be provided by the GENERATOR. Telemetered data shall be in a format compatible with MV90 data collection software or other format as specified by MH.
		3.15.6 Check Metering	The GENERATOR shall provide backup metering or check metering if MH determines that it is required. Check metering shall not be connected to the instrument transformers used for revenue metering in the GENERATOR FACILITY(IES).
		3.15.7 Meter Seals	Meters shall be sealed and the seals may be broken only by an inspector or accredited meter verifier appointed under the *Electricity and Gas Inspection Act*, R.S.C. 1985, c.E-4 [18][18] and then only for the purposes of inspection, verification, testing, re-verification or adjustment in accordance with provisions of the *Electricity and Gas Inspection Act*.
		3.15.8 Meter Tests	Periodically MH shall specify tests [19][19] to confirm the accuracy of meters including but not limited to: • Instrument transformers, • Meters/data Loggers, • Alarms and Monitoring Facilities, • Communications Test, • General Quality, • Site Documentation, • Error Correction Factors, • Loss Adjustments.
		3.15.9 Security	The GENERATOR shall provide provision for MH to lock all measuring devices. In accordance with the IOA, MH shall have the right to audit the site security of the metering installation [19]. This shall include, but not be limited to: • Instrument transformers, • Meters/data Loggers.

No.	Item	Requirement
3.16	Telemetering, Metering, and Supervisory Control and Data Acquisition(SCADA)	The GENERATOR shall provide a Remote Terminal Unit (RTU) or Data Link to a MH RTU capable of exchanging SCADA information with the MH SYSTEM CONTROL CENTRE. The protocol for data exchange via the RTU shall be compatible with that used for communications by the MH SYSTEM CONTROL CENTRE. MH will provide the GENERATOR with the protocol for data exchange. As a minimum, the GENERATOR is required to provide the following data needed by the Supervisory Control and Data Acquisition (SCADA) system: • Hourly integrated billing MWh (see 3.15), • Hourly integrated MVARh (see 3.15), • Individual generator(s) MW and MVAR, where identified, • Generator(s) breaker and Motor Operated Disconnect (MOD) status and control (if applicable), • Individual generator on/off status, if no generator breaker exists, • Total station instantaneous MW and MVAR, • Station service instantaneous MW, MVAR, hourly MWh and MVARh, • Generator transformer(s) high voltage side breaker(s) and isolator(s) status, • Bus voltage at high voltage bus, • Bus frequency, • Forebay elevation, if applicable, • Tailrace elevation, if applicable, • Unit discharge hourly, if applicable, • Total plant discharge hourly, if applicable, • PSS status, if applicable, • AVR status, if applicable, • AVR voltage setpoint, if requested, • Total plant MW setpoint, if requested, • Instantaneous ambient temperature, if requested, • Generator step-up transformer tap setting, if requested. • Spillway gate – height indication and control of each gate, if applicable • Indication of house unit status, if applicable SCADA readings shall be taken in four (4) second intervals.

No.	Item	Requirement
		If an AVR is required subject to section 3.8.3, the GENERATOR shall either provide full supervisory control facilities for each generator unit or a total plant Mvar control point adjustable from the MH SYSTEM CONTROL CENTRE, or provide 24 hour telephone access to a continuously staffed or remotely controlled GENERATOR FACILITY(IES) control centre via a dedicated phone line. Within an agreed time (typically 10 minutes), the GENERATOR FACILITY(IES) shall be able to adjust the voltage set point as directed by the MH SYSTEM OPERATOR. All measuring devices and metering equipment required for this purpose shall be supplied, installed and maintained by the GENERATOR. If the GENERATOR FACILITY(IES) is dispatched by the MH SYSTEM OPERATOR, the GENERATOR shall either provide full supervisory control facilities for each generator unit or a total plant MW control point adjustable from the MH SYSTEM CONTROL CENTRE, or provide 24 hour telephone access to a continuously staffed or remotely controlled GENERATOR FACILITY control centre via a dedicated phone line. Within a time specified by MH, the GENERATOR FACILITY(IES) shall be able to: • Start-up, synchronize and fully load the available generators and, • Change the output of any of the on-line generators within the limits of the generator design and subject to Section 3.8.5. The GENERATOR FACILITY(IES) may need to be connected to the MH Automatic Generation Control system as determined by MH. If MH requires the generator unit to be connected to the AGC system, the GENERATOR shall provide the appropriate telemetering and control equipment for the AGC signals.
3.17	Disturbance Monitoring Equipment	If directed by MH, the GENERATOR shall provide Disturbance Monitoring Equipment for disturbance monitoring in accordance with MH specifications. MH will determine the need for disturbance monitoring during INTERCONNECTION STUDIES. Dynamic Swing Recording data and/or transient fault recording data shall be provided to MH on request to allow post fault analysis of any disturbances that adversely impact the MH TRANSMISSION SYSTEM in order to determine the possible fault cause and remedial action necessary. Information on monitoring facilities typically used by MH is available in Section 2.25.

No.	Item	Requirement
3.18	Insulation Levels	The GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) shall comply with CAN/CSA C22.3 C71 "Insulation Coordination (Part 1: Definitions, Principles and Rules, Part 2: Application Guide)"[20]. Equipment interconnected to the MH TRANSMISSION SYSTEM on the high voltage side of generator transformer(s) shall be insulated to at least the Lightning Impulse Levels (LIL) applicable to the system nominal voltage defined in Section 2.13, subject to insulation coordination studies. The GENERATOR shall be responsible for conducting insulation coordination studies.
3.19	Short Circuit Levels	The GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) shall be designed for operation at short circuit (fault) levels that take into account future development of the MH TRANSMISSION SYSTEM. The short circuit levels to be used in the design depend on the POINT(S) OF INTERCONNECTION and future planned development and are available on request from MH. If the GENERATOR FACILITY(IES) causes fault current limits of existing equipment interconnected to the MH TRANSMISSION SYSTEM to be exceeded, the GENERATOR is responsible for mitigation. Affected equipment will be identified and mitigation costs determined in INTERCONNECTION STUDIES. Circuit breakers are replaced as per Section 2.14.
3.20	Grounding	Each generating unit forming part of the GENERATOR FACILITY(IES) shall be grounded in accordance with GOOD UTILITY PRACTICE [21][21]. The overall grounding for the GENERATOR FACILITY(IES) shall be designed in accordance with the guidelines of IEEE Standard 80 [22]. The INTERCONNECTION STUDIES shall determine if modifications to the ground grids of existing substations are necessary to keep grid voltage rises within safe levels.
3.21	Lightning (Surge) Protection	Lightning (Surge) Protection against direct lightning strokes shall be provided for protecting outdoor equipment including transformers forming part of the GENERATOR FACILITY(IES) and the GENERATOR INTERCONNECTION FACILITY(IES). Lightning protection shall be designed for a zero rate of failure (that is, all voltage stresses are at least three standard deviations less than the critical flashover voltage) taking into account the regional lightning stroke density (estimated from either the Canadian Lightning Detection Network (CLDN) data or from a local keraunic level map if the CLDN data is not available) and tower footing or grounding grid resistances as applicable to the GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) .
3.22	Safety and Design Standards	The GENERATOR FACILITY(IES) and GENERATOR INTERCONNECTION FACILITY(IES) shall comply with safety requirements in the Canadian Electrical Code [20].

No.	Item	Requirement
3.23	Environmental Conditions	Any equipment that can impact the MH TRANSMISSION SYSTEM shall be designed to function safely and reliably under the environmental conditions prevalent at the selected site. In particular, such equipment located outdoors at the POINT(S) OF INTERCONNECTION necessary for isolating the GENERATOR INTERCONNECTION FACILITY(IES) from the MH TRANSMISSION SYSTEM shall function reliably in extreme cold weather conditions with minimum temperatures as low as –50°C.
3.24	Clearances and Access	Energized parts shall be maintained at safe vertical and horizontal clearances that are compliant with the Canadian Electrical Code Part 3 [20].
3.25	Isolation	The GENERATOR shall provide fault interrupting devices and isolating devices at a location(s) defined by MH at or near the POINT(S) OF INTERCONNECTION. Isolating devices shall be manually operable or motor operated isolation switches that provide visual electrical isolation. The isolation switch shall simultaneously operate all phases (i.e. gang-operated open/close). In some instances, MH may require motor operated isolation switches to allow rapid remote or automatic isolation from the MH TRANSMISSION SYSTEM. The requirement to provide motor operated isolation devices will be determined by MH on a case by case basis during INTERCONNECTION STUDIES. Provision shall also be made for MH to padlock these isolation switches securely in the open position as per the MH Corporate Safety and Occupational Health Rules [23]. If the POINT(S) OF INTERCONNECTION is remote from the interconnecting MH substation, then the isolating device(s) shall also have a safety ground switch(es) installed on the MH side of the isolating device(s). The need for the safety ground switches will be determined during INTERCONNECTION STUDIES.
3.26	Transformer Connection	Transformer reactance and tap settings shall be coordinated with MH to optimize the leading and lagging reactive power capability that can be provided to the network. The transformer shall be designed in accordance with IEEE Standard C57.116 [24][24]. The transformer connection is normally required to be delta on the generator side and grounded star on the MH TRANSMISSION SYSTEM side so as to block transmission of triplen harmonic currents and isolate generator and transmission side grounding networks. If this is not practical, an alternative arrangement acceptable to MH is to be determined in consultation with MH. Typical MH transformer configurations are provided in Section 2.17. Tap changers shall be supplied with adequate tap changer range to allow operation over the range of operating voltage, at the POINT(S) OF INTERCONNECTION, specified in Section 2.2.

No.	Item	Requirement
3.27	Modelling Data and Special Tests	The GENERATOR shall provide preliminary modelling data for the generator and associated equipment for INTERCONNECTION STUDIES and final as-built modelling data following commissioning of the GENERATOR FACILITY. The model shall include generator, governor, exciter, stabilizer, compensators, excitation limiters, load controllers, and all internal protection systems. The GENERATOR shall determine and document actual generator unit capability, reactive power limits, control settings and response times of generation equipment by field verification and testing to validate generator models and data provided to MH. The GENERATOR shall provide detailed models for INTERCONNECTION STUDIES. If the models are proprietary, MH will sign a non-disclosure agreement. The GENERATOR shall provide non-proprietary models in standard IEEE format. These models may be released to external regional organizations such as the MRO, MISO, etc. for joint regional studies. All models shall be in a format which can be used by PSS®E and shall be maintained by the GENERATOR. The GENERATOR shall be responsible to re-validate all modelling data from time to time as requested by MH or as required by the *Reliability Standards Regulation*.
3.28	Commissioning Tests	The GENERATOR shall provide commissioning/verifications tests to demonstrate that the FACILITY(IES) conforms to all of the interconnection requirements set forth by MH. In particular the field tests shall demonstrate: 1. Verification of real power capability, 2. Verification of reactive power capability, 3. Verification of generator excitation system and voltage controls including exciter step response, 4. Verification of generator unit frequency response including governor step response, 5. Coordination of generator voltage regulator controls with unit capabilities and protection, 6. Generator performance during frequency and voltage excursions either by field tests or manufacturer type tests. The complete set of commissioning/verification tests will be determined in consultation with MH. Manitoba Hydro will be the final authority on commissioning/verification tests.
3.29	Testing and Maintenance Coordination	As per the IOA the GENERATOR shall provide planned testing and maintenance work schedules for equipment within the GENERATOR FACILITY(IES). MH shall be given advance notification of planned outages for scheduled test and maintenance work. The GENERATOR shall have a generation protection system maintenance and testing program in place as required in the *Reliability Standards Regulation*. Documentation of the protection system maintenance and testing program for the GENERATOR FACILITY(IES) shall be provided to MH upon request.

No.	Item	Requirement
3.30	Coordinated Joint Studies	THE GENERATOR shall cooperate with MH and participate in any coordinated joint studies or investigations required to verify or confirm compliance with the *Reliability Standards Regulation* or the requirements in this document. Procedures are defined in the MH Open Access Interconnection Tariff [25], Section 3.5 [25] Coordination with Adjacent Systems.
3.31	Generation Forecasting	MH requires the output forecast of the FACILITY(IES) to enable the operation of the MH TRANSMISSION SYSTEM in accordance with Good Utility Practice [19]. Prior to energization and thereafter the GENERATOR shall provide the following data at a frequency determined by the MH SYSTEM OPERATOR: • Availability of generation in MW for any prime mover fuel limitations. • Generation unit data including unit identification, date/time/ power and status. • A weekly generation plan seven days prior to the date of dispatch. • Site limitations that may reduce the accuracy of the forecast (e.g. ice, water license restrictions, temperature limits).

4.0 WIND GENERATOR INTERCONNECTION REQUIREMENTS

This section covers interconnection requirements specific to GENERATOR FACILITY(IES) utilizing wind turbine generators. The interconnection requirements from Section 3 still apply unless otherwise indicated in this section. The minimum requirements specified here do not make any distinction as to types of wind generation turbine technology.

No.	Item	Requirement
4.1	Voltage Tolerance	All individual wind turbine generators shall satisfy the voltage criteria at the POINT(S) OF INTERCONNECTION as specified in Section 2.2, 2.3 and 2.4. All individual wind turbine generators shall operate continuously if the voltage at the POINT(S) OF INTERCONNECTION is between 0.9 p.u. and 1.10 p.u.
4.2	Frequency Tolerance	All individual wind turbine generators shall satisfy the frequency criteria at the POINT(S) OF INTERCONNECTION as specified in Section 2.5 and 2.6. They shall operate continuously and remain connected if the frequency is between 59 Hz and 61.5 Hz. INTERCONNECTION STUDIES will determine if modifications to the over frequency limits are permitted or required based on the POINT(S) OF INTERCONNECTION.
4.3	Power Control	The MH SYSTEM OPERATOR shall be able to at all times contact the wind generating facility operator to issue a directive to reduce or curtail the output of the FACILITY(IES) in the event of an emergency condition on the transmission system (Section 3.14). Reduction amounts, curtailments and ramp rates are specified by the MH SYSTEM OPERATOR. In general the wind FACILITY(IES) shall be able to curtail within 5 minutes and have a minimum power ramp rate of 20 MW/minute and the ability to reduce to 0 MW in 5 minutes.. GENERATOR FACILITY(IES)shall not exceed the maximum output value specified in the IOA.
4.4	Reactive Power Capability/Control	Wind FACILITY(IES) shall be able to operate between +0.95 and -0.95 power factor when it is generating its rated name plate capacity measured at the POINT(S) OF INTERCONNECTION. The reactive power capability shall be sufficient to ensure both steady state and transient stability during and after a disturbance. INTERCONNECTION STUDIES will determine the appropriate amount of dynamic reactive power on a site by site basis. The reactive supply shall be available over the full range of operating conditions Refer to Figure 5 in Section 8. The use of mechanically-switched reactors or capacitors, static Var compensators or similar devices may be acceptable alternatives for providing all or part of the reactive supply as shown in Figure 5 in Section 8, if verified by the INTERCONNECTION STUDIES.

No.	Item	Requirement	
4.5	Asynchronous Wind Generator Controls	4.5.1 Voltage Regulation	A continuously acting voltage regulator equipped with a line drop compensator or equivalent providing a minimum of 60% line drop compensation shall be required for each wind FACILITY(IES) rated larger than 10 MW. The voltage regulator shall have the capability to maintain the steady-state voltage within ±0.5% of the set point at the POINT(S) OF INTERCONNECTION or other control point as determined by the MH SYSTEM OPERATOR. Voltage regulator operation shall be stable and transient gain reduction shall not be used to preserve control system stability. The voltage response time will depend on results from INTERCONNECTION STUDIES, but shall not be greater than 100 milliseconds. Wind FACILITY(IES) interconnected to the MH TRANSMISSION SYSTEM that is not equipped with a voltage regulator, may be required to install a voltage regulator if SUBSTANTIAL MODIFICATIONS, as defined in Section 1.3, are undertaken. MH will determine the need for a voltage regulator based on the results of the INTERCONNECTION STUDIES. Wind FACILITY(IES) relying on mechanically-switched shunt capacitors for steady-state voltage regulation shall have the capacitor banks equipped with "rapid discharge" circuits capable of rendering the capacitors available for re-insertion within 5 seconds of de-energization. Additional switched shunt capacitors could be added as an alternative to "rapid discharge" such that the full rating is available for re-insertion. The voltage response time of mechanically-switched capacitor banks shall be adjustable and shall not be greater than 15 seconds. INTERCONNECTION STUDIES will determine if this type of voltage regulation is permissible. The MH SYSTEM OPERATOR will determine the voltage control set point.
		4.5.2 Frequency Response	At present, wind FACILITY(IES) do not have to respond to dynamic changes in system frequency as required by synchronous generators in Section 3.8.1. INTERCONNECTION STUDIES will monitor the impact of wind generating facilities to ensure the MH Underfrequency Load Shed Program is not affected. MH reserves the right to require some form of frequency response be included with future wind generating FACILITY(IES). A 5% droop setting during over frequency conditions may be required and will be identified through INTERCONNECTION STUDIES. In other words, an increase in frequency of 5% (63 Hz) may require a 100% reduction in wind power output.

<table>
<tr><th>No.</th><th>Item</th><th colspan="2">Requirement</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td>4.5.3 Power Ramp Rates</td><td>The real power output of the wind FACILITY(IES) is required to be adjustable during start-up. MH will review the power ramp rate to determine if there are impacts on the MH TRANSMISSION SYSTEM. The MH SYSTEM OPERATOR will determine the power ramp rate. The minute-to-minute variation in the wind FACILITY(IES) output cannot exceed the MH real time regulating reserve of +/- 40 MW normal or +/- 80 MW occasional. The need for additional regulating reserve shall be determined during INTERCONNECTION STUDIES.</td></tr>
<tr><td>4.5.4 Other Controls</td><td>An asynchronous type generator, such as may be connected to wind turbines, is not required to be provided with a Power System Stabilizer or be capable of automatic generation control. Two wind FACILITYIES connected in a radial configuration, as shown in Fig. 7 (Section 8), may require joint var control. The Generator shall design the necessary controls to ensure proper voltage control coordination between the wind generating facilities and provide details to MH to review. Dynamic reactive power devices may be required to be provided with a power system stabilizer to damp mechanical oscillations. The Generator shall design the necessary controls and provide the details to MH for review. MH reserves the right to review other induction generator controls during INTERCONNECTION STUDIES for compliance with MH planning standards.</td></tr>
<tr><td>4.6</td><td>Voltage Ride-through</td><td colspan="2">All individual wind turbine generators shall remain in-service and not trip during a normally cleared single, multi-phase or three-phase fault that occurs on the MH TRANSMISSION SYSTEM. This clearing time is dependent upon the interconnection voltage level and is based on the worst clearing time plus one cycle. Where available, MH uses the actual clearing time plus one cycle margin. See Section 2.9.2 for typical clearing timings.

Figure 1 in Section 8 illustrates low voltage ride through characteristics, measured at the POINT(S) OF INTERCONNECTION. Individual wind turbine tripping is NOT permitted inside the ‘green and orange’ regions. Individual wind turbines shall not trip within the ‘orange’ region however reduced power output is permissible. Once the voltage recovers from the ‘orange’ region to the ‘green’ region, the wind turbine power output shall return to its original value within the power gradient limits determined in Section 4.5.3. Individual wind turbine tripping is permitted inside the ‘white’ region.

The low voltage ride through curve applies for all faults including unbalanced faults, thus the turbine is expected to ride through significantly unbalanced voltages with high negative phase sequence currents of short periods of time.

For prolonged disturbances, where voltage does not recover according to Figure 1, individual wind turbine generators’ may be tripped by under-voltage protection. Any shunt capacitors shall also be tripped to prevent over-voltage.</td></tr>
</table>

No.	Item	Requirement
4.7	Post Disturbance Recovery	INTERCONNECTION STUDIES will determine if following a disturbance, the power recovery characteristics of the wind generating facilities are adequate to maintain performance with the *Reliability Standards Regulation*. The MVAR output of the GENERATOR FACILITY(IES) shall respond in a controlled fashion to help system voltage recovery following a disturbance..
4.8	Synchronizing Facilities	Large asynchronous generators (above 1 MW) shall use a mechanical speed matching relay for synchronizing set to accept mechanical speed within +/- 5% of 60 Hz, with an error of less than +/- 2% being preferred. Speed matching is required to ensure that voltage regulation and voltage flicker at the POINT(S) OF INTERCONNECTION are within limits. Magnetizing inrush current may cause voltage drop at the POINT(S) OF INTERCONNECTION even when speed matching is used. The GENERATOR shall be responsible for mitigating excessive voltage drop at the POINT(S) OF INTERCONNECTION caused by induction generator synchronization. The Synchronizing Facilities shall meet IEEE Standard C37.118 [35].
4.9	Modelling Data	In addition to Section 3.27 the GENERATOR shall provide as-built PSS®E models of the wind generator, wind electrical, wind mechanical, pitch controllers, aerodynamic, gust, auxiliary wind controls, and all internal protection systems. Depending on the POINT(S) OF INTERCONNECTION, detailed (three-phase) modelling data may be requested to address subsynchronous resonance, machine self-excitation and other control interactions.
4.10	Modelling Data Verification	As required by the *Reliability Standards Regulation*, the GENERATOR shall demonstrate by physical performance tests of at least 10% of the wind turbine generators for every type used in the wind FACILITY(IES)that the wind turbine generator performs in agreement with the models provided. Differences between the models and the actual equipment may require additional INTERCONNECTION STUDIES to verify the effects on system performance.

No.	Item	Requirement
4.11	Special Commissioning Tests	Commissioning/Verifications tests and studies shall be performed to demonstrate that the FACILITY(IES) conforms to all of the interconnection requirements set forth by MH. These test results shall be provided within 30 days following appropriate wind speed conditions to conduct the tests. In particular unless otherwise specified below the field tests shall demonstrate; a) The low voltage ride-through capability for each type of turbine controls either by field tests or manufacturer type tests. b) Voltage regulation and reactive power response by demonstrating the ability to control collector and transmission system voltage in a stable manner. The voltage set-point capability may be demonstrated by adjusting the voltage set-point of the voltage regulation system. c) Reactive power control and the ability to provide continuous reactive power: • Power factor control (if provided). • Availability of continuous reactive power over the range of voltage and frequency. d) That measured harmonics are within acceptable levels. e) That measured voltage flicker is within acceptable levels. f) The coordination between the wind FACILITY(IES) protection equipment and system. This may be done by simulation. g) Power ramping and power curtailment. Any type tests or special tests performed by the GENERATOR shall be sealed by a professional engineer. Interconnection will be refused to any wind FACILITY(IES) if any of the above commissioning tests fail to conform to the interconnection requirements identified in the INTERCONNECTION STUDIES and IOA.
4.12	Power Quality	In addition to Section 3.12, voltage flicker shall be assessed during INTERCONNECTION STUDIES as per procedures given in IEC 61400-21 [26] and MH PQS2000 [2]. The GENERATOR shall provide the necessary data which includes but is not limited to flicker coefficients, flicker step factor, and voltage change factor.

No.	Item	Requirement
4.13	Operational Monitoring and WIND DATA	Sufficient representative wind speed measurement shall be collected from the FACILITY(IES) in order to reasonably estimate wind speeds across the site. A minimum of one full year of measurement collection is needed to quantify energy from a site with sufficient certainty. These data shall be collected from one or more locations that are well-exposed and are expected to be reasonably representative of the winds experienced by the proposed turbines. The acceptable method for assessment of winds across a large project (greater that 20MW) is to install at least one long-term meteorological tower and at the GENERATOR'S discretion use several shorter-term towers to more fully characterize the wind speeds across the project site. Use of SODAR or other techniques without reliable long-term measurements from an on-site meteorological tower is not acceptable. Use of measurements from on-site equipment located on wind turbine towers is not acceptable, except as a means for accounting for brief temporary gaps in long-term meteorological tower data. Whenever possible, wind speeds shall be measured at ±2.5% of the hub height of the turbine expected to be used. For towers on a hill, it is necessary to measure wind speeds at more than one height to estimate wind shear on the site. The sensors shall be located at least 15 meters vertically apart and be generally equally unobstructed. Meteorological data shall be sampled every one or two seconds and averaged over not more than a ten-minute period. All measuring equipment (anemometers, wind vanes, air temperature sensors and air pressure sensors) mounted on meteorological masts (met towers) shall meet the technical requirements specified in CAN/CSA-C61400-12-1-07 [27]. Sufficient anemometry shall be in place to identify periods of tower shading and to identify drifting calibration If a dense canopy of trees is present at the site, the lowest usable sensor shall be located 10 meters above the canopy. At a minimum, at least one vane shall be located on each tower, and temperature measurements shall be available from at least one tower. The temperature sensor shall be a shielded type that is mounted at least one tower diameter away from the tower face to minimize tower heating effects, and oriented on the tower for maximum exposure to the prevailing wind direction to ensure adequate ventilation. Barometric pressure data shall be available, preferably measured on site from at least one tower.

No.	Item	Requirement
		In addition to Section 3.16, MH requires the following WIND DATA to be delivered to a MH computer in the format specified by MH and a periodicity specified by MH: a) Date and time, b) Met tower identification, c) Average wind speed, d) Instantaneous wind velocity kph at turbine elevation, e) Wind speed variation, f) Wind direction average, g) Wind direction variance, h) Temperature, i) Pressure, j) Relative Humidity. Typically data interval is every 10 minutes. The GENERATOR shall provide the following information in accordance with the IOA: 1. Provide maps showing the locations of all meteorological data collection locations (e.g., met towers), proposed turbine locations, and the site topography. 2. Provide the period of record of data collection for each met tower. 3. Provide, for each met tower, the following information: a) Sensor heights, b) Sensor types (manufacturer and model), c) Sensor directions, d) Data averaging interval. (10 minute or lower required), e) Whether sensors were calibrated and what calibrations were applied to data, f) Anemometer slopes and offsets used for the data reduction and documentation of wind speed, g) Height and direction of any nearby obstacles (houses, vegetation, etc.). 4. Identify the companies or organizations responsible for data collection. 5. Describe the sensor mounting arrangements and meteorological tower maintenance program.

No.	Item	Requirement
		6. Describe any variations from the sensor placement and data collection methodologies described above and note any problems that may increase uncertainties in measurements. The following electrical data shall be delivered to a MH computer in the format specified by MH and a periodicity specified by MH: a) Mega-watt and Mega-var output, b) Turbine status or number of operational turbines, c) Status of circuit breakers on the transformer and shunt compensation devices, d) The tap position of transformer (voltage regulator set-point and status), e) Bus Voltage, f) Status and settings including amount(s) and ramp down rate of curtailment schemes. All electrical quantities are to be measured at the point of interconnection
4.14	Additional Protection Requirements	In addition to Section 3.13 additional protection to avoid isolation of the wind FACILITY(IES) onto local load or neighbouring TRANSMISSION SYSTEMS may be required and will be identified during INTERCONNECTION STUDIES.
4.16	Underground Cables	Underground cables shall be installed in accordance with CSA C22.3 No.7 [20]. MH recommends that the depth of burial should be increased to a minimum of 1.40 meters when cables are placed on agricultural land or in ditches. MH requires that there be no splice located within 3.00 meters of crossing any other utility. MH recommends that all splices be protected with mechanical protection and their location be noted. MH also recommends that all splice locations be marked with electronic buried markers or by GPS coordinates. Refer to CD 205-14 [28][28].
4.17	Generator Tapping	The default method of tapping an existing transmission line is via a 3-breaker ring, as shown in Figure 6 in Section 8. INTERCONNECTION STUDIES will determine, on a case by case basis, whether a 2-breaker tap may be permitted. Tapping a transmission line with circuit switches will be permitted only for radial lines. Up to two wind FACILITY(IES) will be permitted to interconnect to the same radial line provided that there is no customer load on the line. Due to reliability reasons, CUSTOMER LOAD will not be permitted to tap onto a radial line with a wind generating plant. Refer to Figure 7 in Section 8.

5.0 CUSTOMER LOAD INTERCONNECTION REQUIREMENTS

This section defines the requirements that are applicable for CUSTOMER LOADS applying to interconnect to the 115 kV, 138 kV, 230 kV and 500 kV nominal voltage levels on the MH TRANSMISSION SYSTEM or existing CUSTOMER LOADS applying to undertake a SUBSTANTIAL MODIFICATION to their The CUSTOMER LOAD FACILITY(IES). CUSTOMER LOAD FACILITY(IES) may contain generation resources for supplying its own loads. If the CUSTOMER LOAD FACILITY(IES) includes such generation resources, then these generation resources are required to satisfy the interconnection requirements for GENERATOR FACILITY(IES)in Section 3 and Section 4 if applicable.

No.	Item	Requirement
5.1	Interconnection Location and Voltage Level	The CUSTOMER LOAD may apply to interconnect to the MH TRANSMISSION SYSTEM at the nominal voltage levels above 100 kV defined in Section 2.2 The voltage level and the geographic location of the POINT(S) OF DELIVERY on the MH TRANSMISSION SYSTEM shall be determined by MH in consultation with the CUSTOMER LOAD. MH will be the final authority in determining the geographic location of the POINT(S) OF DELIVERY.
5.2	Sealing of Technical Reports, Drawings, Memos, etc.	All reports, memos, drawings, equipment specifications, and modelling data of technical nature (excluding manufacturing drawings) shall be sealed by a Professional Engineer certified to practice in the Province of Manitoba in accordance with *The Engineering and Geoscientific Professions Act of Manitoba*.

No.	Item	Requirement
5.3	Load Tapping .	CUSTOMER LOADS are normally interconnected to the MH TRANSMISSION SYSTEM at an existing Transmission Station. On a case by case basis MH may consider interconnecting loads to the 230kV transmission system by the tapping of a 230kV line. The maximum number of taps allowed for a 230kV transmission line is one per transmission line. Interconnection studies will determine the feasibility of tapping. The line tapping standard for CUSTOMER LOADS that are greater than or equal to 100 MVA, is a Manitoba Hydro owned three breaker ring configuration plus a CUSTOMER LOAD owned disconnect switch and a breaker as shown in Figure 8 in Section 7. The line tapping standard for CUSTOMER LOADS that are between 30 MVA to 99 MVA, is three Manitoba Hydro owned disconnect switches (manually operated) in a “T-tap” configuration plus a CUSTOMER LOAD owned disconnect switch and a breaker as shown in Figure 9 in Section 7. Three-terminal line protection shall be required to prevent line tripping for faults beyond the customer owned breaker: • Transfer Trip: A transfer trip scheme shall be provided to activate upstream interrupting devices for a customer owned breaker failure situation. Breaker fail protection is required on the customer owned breaker. • Dual communication is required for protection and transfer trip functions For CUSTOMER LOADS that are less than 30MVA, tapping of transmission lines 230 kV and greater to interconnect loads will not be permitted. The connection of CUSTOMER LOADS on 115 kV and 138 kV transmission lines will be determined on a case by case basis during INTERCONNECTION STUDIES. At a minimum CUSTOMER LOADS taps on 115 kV and 138 kV shall provide a disconnect switch and a breaker (CUSTOMER LOAD owned) at the POD.
5.4	OPERATING PROCEDURES	The CUSTOMER LOAD shall abide by any OPERATING PROCEDURES, which include one of the following types: ABNORMAL, EMERGENCY OR NORMAL OPERATING GUIDES, imposed by the MH SYSTEM OPERATOR.
5.5	Voltage Regulation and Power Factor Requirements	MH reserves the right to operate the MH TRANSMISSION SYSTEM with voltage anywhere within the normal steady-state minimum and maximum voltage operating limits specified in Section 2.2, 2.3 and 2.4. The CUSTOMER LOAD shall provide any additional voltage regulation required by the CUSTOMER LOAD FACILITY(IES). Operation of the CUSTOMER LOAD FACILITY(IES) at or near unity power factor (as measured at the POD) is recommended to reduce load-factor demand billing or adversely affecting the MH TRANSMISSION SYSTEM.

No.	Item	Requirement	
5.6	Voltage and Frequency at POINT(S) OF DELIVERY	CUSTOMER LOAD FACILITY(IES) shall be capable of operation over the range of voltage and frequency variation that may occur at the POINT(S) OF DELIVERY, as defined under Sections 2.3, 2.4 and 2.5. Voltage for rating of equipment to be interconnected to the MH TRANSMISSION SYSTEM is also defined in Section 2.2. MH reserves the right to require the CUSTOMER LOAD's equipment to be capable of operation outside these normal minimum and maximum values defined in Section 2.2, 2.3 and 2.4 at specific locations on the MH TRANSMISSION SYSTEM.	
5.7	Power Quality	5.7.1 Power Quality	The CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES) shall be designed and operated such that its power quality levels are within the limits specified in PQS2000 [2][2], "Power Quality Specification For Interconnection to Manitoba Hydro's Electrical System."
		5.7.2 Resonance and self-excitation	The CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES) shall be designed to avoid introducing detrimental resonance into the MH TRANSMISSION SYSTEM. The CUSTOMER LOAD shall assess the risk of self-excitation of any internal GENERATOR FACILITY(IES) or motor load and take appropriate design measures to protect the CUSTOMER LOAD FACILITY(IES) as required. MH will provide the CUSTOMER LOAD with harmonic impedance characteristics of the MH system at the POINT(S) OF DELIVERY on request. The CUSTOMER LOAD shall provide MH with plans for remedial measures, and the associated studies to demonstrate that potential resonances can be avoided or mitigated.
5.8	Protection Requirements	MH is not responsible for protecting the CUSTOMER LOAD FACILITY(IES) from faults on the CUSTOMER LOAD FACILITY(IES). MH cannot guarantee that line protection will operate for faults on the CUSTOMER LOAD FACILITY(IES) following a failure of fault clearing by CUSTOMER owned equipment. The CUSTOMER LOAD is responsible for the following: • Ensuring that the CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES) are protected for all operating conditions and for all faults on the MH TRANSMISSION SYSTEM.	

No.	Item	Requirement
		• Providing protective relaying equipment and systems that shall sense and properly react to failure and malfunction of the CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES) equipment. The design of protective relaying installations shall be in accordance with accepted standards. MH may require redundant protection if INTERCONNECTION STUDIES demonstrate that a failure of a single protection system component jeopardizes the reliability of the MH TRANSMISSION SYSTEM. The protection shall fully protect the safety of the public and of MH personnel interfacing with the CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES). • Determining the settings for relays that protect the plant equipment within the CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES). The protection and associated protection settings for installed equipment shall be coordinated by the CUSTOMER LOAD with the settings of the MH TRANSMISSION SYSTEM protection schemes in the area. MH will provide details of the MH system protection to the CUSTOMER LOAD to facilitate this coordination. • Producing and providing to MH the following engineering documents for review 60 days prior to energization: 1. A protection Single Line Diagram (SLD) for the entire customer owned facility showing protection relay make and model, AC connections, tripping and other critical protection inputs and outputs. 2. Complete protection settings and logic for all relays including the electronic setting files. 3. A protection relay coordination report which demonstrates how the settings were determined. • MH shall be the final authority on establishing control and protection settings that impact the performance and operation of the MH TRANSMISSION SYSTEM. **MH does not provide primary protection and cannot guarantee remote backup protection for any CUSTOMER LOAD FACILITY(IES).** Fault interrupting devices shall have adequate fault interrupting and momentary withstand ratings to satisfy the short circuit level requirements (see Section 5.18) and shall meet maximum clearing times established by the INTERCONNECTION STUDIES. Typical clearing times are given in Section 2.9.2.

No.	Item	Requirement
		INTERCONNECTION STUDIES may require that the CUSTOMER LOAD install additional protection to ensure the reliability of the MH TRANSMISSION SYSTEM is not jeopardized. These protections can include but are not limited to the following: • Overvoltage, • Bus Protection, • Breaker failure protection, • 3 Terminal current differential protection for load taps on 230kV lines. *Selection of equipment:* MH reserves the right to specify equipment hardware requirements for all MH-CUSTOMER LOAD protection system interfaces. Typically this impacts transmission line protection systems including relay make and model, protection communication interfaces, and relay maintenance devices such as test switches. Provisioning of all equipment including spare relays are the CUSTOMER LOAD's responsibility. *Protection of major apparatus* All faults and conditions in major apparatus such as transformer banks, reactors, capacitor banks, etc. which have the potential to impact the MH TRANSMISSION SYSTEM shall be cleared quickly and without affecting other system elements unnecessarily. If INTERCONNECTION STUDIES demonstrate the reliability of the MH TRANSMISSION SYSTEM is jeopardized, redundancy may be required. Similarly, if communication equipment is required to provide primary protection for the apparatus protection (e.g. transfer tripping), this shall utilize redundant systems over separate routes. If apparatus is co-terminated with other critical transmission system elements, automatic isolation after a fault shall be considered so as to allow immediate restoration of healthy elements. *Reverse power protection* Reverse power protection may be required to prevent undesirable inadvertent power flow into the MH TRANSMISSION SYSTEM if the CUSTOMER LOAD FACILITY(IES) has its own generation interconnected or is interconnected to other systems. INTERCONNECTION STUDIES will determine if such protection is necessary, and the required functionality of the protection system. *Reverse fault protection* Reverse fault protection will be required to prevent undesirable backfeed (current or voltage) into faults on the MH TRANSMISSION SYSTEM if the CUSTOMER LOAD FACILITY(IES) has its own generation interconnected or is interconnected to other systems. INTERCONNECTION STUDIES will determine if such protection is necessary, and the required functionality of the protection system.

No.	Item	Requirement
		Protection for other installed CUSTOMER LOAD FACILITY equipment. Although this area is solely the responsibility of the CUSTOMER LOAD, the protection provided shall be coordinated with the MH TRANSMISSION SYSTEM protection schemes in the area; shall not affect the reliability and security of the MH TRANSMISSION SYSTEM and shall fully protect the safety of the public and of MH personnel. *Auto Isolation* MH reserves the right to automatically isolate CUSTOMER LOAD INTERCONNECTION FACILITY(IES) that includes a GENERATOR FACILITY(IES) to avoid isolation of the GENERATOR FACILITY(IES) on other CUSTOMER LOAD FACILITY(IES) following loss of the high voltage supply connection. Data on the protection and control systems including settings shall be provided to MH as described in Section 7.2.
5.9	Underfrequency Load Shed (UFLS)	MH reserves the right to require all CUSTOMER LOAD FACILITY(IES) to participate in the UFLS program described in Section 2.10. The customer will be required to install UFLS equipment inside the customer station. To facilitate future implementation of the UFLS, the customer shall ensure that the protective relaying installed at the customer site shall incorporate time delayed Underfrequency elements (ANSI device 81). UFLS may or may not be enabled initially, but future System Studies (Section 2.19) may identify a requirement to enable/disable UFLS protection, or to modify settings. MH will specify the particular frequency setting required. It is the responsibility of the CUSTOMER LOAD to provide to MH evidence that appropriate UFLS relay settings have been applied and to routinely maintain and test customer-owned UFLS relays. Testing of the relays does not require live tripping of equipment. A test schedule, test results and maintenance records shall be provided to MH by the customer upon request. MH reserves the right to witness UFLS relay testing. MH also reserves the right to inspect UFLS equipment within the CUSTOMER LOAD FACILITY(IES) to verify settings, proper maintenance and operability. The requirement for load shedding is defined in terms of a percentage of total load and, within reason; the CUSTOMER LOAD will determine which of the loads they want to be included in the load shed plan so long as the total load shed meets the required target. MH shall supply and maintain UFLS relays located within the CUSTOMER LOAD FACILITY(IES). CUSTOMER LOAD shall install the UFLS provided by MH. MH will provide the settings for the UFLS relays. Due to the potentially rapid decay in system frequency, the tripping shall not be intentionally delayed. Any significant delays in tripping would defeat the coordination between load shedding set points or the entire program. Operating time to disconnect an individual load point shall not exceed 14 cycles (233 ms) based on a 6 cycle relay time and 8 cycle circuit breaker operating time.

No.	Item	Requirement	
5.10	Undervoltage Load Shed (UVLS)	MH reserves the right to require the CUSTOMER LOAD FACILITY(IES) to participate in an UVLS program. The UVLS scheme shall be subject to the requirements determined by MH during INTERCONNECTION STUDIES. MH shall supply and maintain UVLS relays located within the CUSTOMER LOAD FACILITY(IES). CUSTOMER LOAD shall install the UVLS provided by MH. MH will provide the settings for the UVLS relays.	
5.11	Load Restoration	In most cases, the loads will be restored following UVLS and UFLS through supervisory control, or after being authorized by the MH SYSTEM OPERATOR. Automatic restoration may be permitted once system frequency has stabilized for a fixed length of time (e.g. 60 ±0.2 Hz for 5 minutes) in locations with no remote supervisory control and no local operators. The operator of the CUSTOMER LOAD FACILITY(IES) shall get confirmation from the MH SYSTEM OPERATOR before restoring loads, as placing large loads back on the system before adequate generation is restored could result in further system degradation. The MH SYSTEM OPERATOR will be the authority regarding permission to install automatic load restoration devices.	
5.12	Line Auto-Reclosing	Line auto-reclosing is not employed on most of the MH TRANSMISSION SYSTEM above 100 kV. Limited auto-reclosing may be utilized on radial lines, particularly where supervisory control is not available. If required, auto-reclosing may be permitted by MH subject to mitigation of all negative impacts as determined during INTERCONNECTION STUDIES. Subsequent operating experience may lead to the imposition of restrictions on auto-reclosing or further mitigation of negative impacts.	
5.13	Revenue Metering	5.13.1 General	All measuring devices and metering equipment required for revenue metering shall be owned, supplied, installed and maintained by MH except as provided under MH Corporate Policy [15]. The specific types of metering equipment, timing devices, locations of meters, the details of the metering arrangement and the records to be kept shall be compatible with normal MH practice [14] and MH Corporate Policy [15] and shall be determined by MH in consultation with the CUSTOMER LOAD.

No.	Item	Requirement	
		5.13.2 Accuracy	Revenue quality metering equipment shall consist of meters approved for revenue metering by Industry Canada. Metering equipment shall be installed, calibrated, repaired, replaced, maintained and tested in accordance with the provisions of *The Electricity and Gas Inspection Act*, *Electricity and Gas Inspection Regulations*, Measurement Canada [18] and Manitoba Hydro specifications. MH requires 3 element metering accuracy for wye circuits and 2 element metering accuracy for delta circuits. Potential and current transformers for revenue metering shall conform to the Standard CAN/CSA-C60044-1:07 [16][16] and CAN/CSA-C60044-2:07 [17] for 0.3 metering accuracy class and be owned by MH. Independent current transformers are required. If the instrument transformers are owned by the CUSTOMER LOAD, the additional secondary windings on voltage transformers or current transformers may be used for other purposes such as protective relaying as long as the burden is not excessive. MH owned instrument transformers may not be used for protection of the CUSTOMER LOAD INTERCONNECTION FACILITY(IES).
		5.13.3 Metering Configuration	The following signals are to be provided: • Active and reactive power, • Hourly integrated real and reactive power, where required. • Demand power, where required. Instrument Transformers and such other devices or equipment as shall be necessary to give the instantaneous values of kilowatts and kilovars, and an automatic record of kilowatt-hours and kilovar-hours for each clock hour. Metering shall be able to provide monthly accumulated active and reactive power quantities. When there is a possibility of flows of electricity in either direction (i.e. cogeneration installed), dual register metering equipment shall be installed to record metering data for each direction of flow. Two revenue meters may be installed by MH depending on whether separate rates apply to the purchase of electricity from the CUSTOMER LOAD and to the supply of electricity to the CUSTOMER LOAD or depending on the POINT(S) OF INTERCONNECTION of the generation within the CUSTOMER LOAD FACILITY(IES).

No.	Item	Requirement	
		5.13.4 Energy Losses	Metering shall be installed at the POINT(S) OF DELIVERY. Where metering is installed at a different location, MH shall determine a loss compensation factor to the POINT(S) OF DELIVERY [15].
		5.13.5 Meter Reading	Revenue meters may be read locally once per month by MH or may be remotely accessed by MH via telephone. Telemetering facilities to transmit monthly and hourly real and reactive power revenue metering data to MH's SYSTEM CONTROL CENTRE or other facility as directed by MH, shall be provided by the CUSTOMER LOAD except as provided under MH Corporate Policy. Telemetered data shall be in a format compatible with MV90 data collection software or other format as specified by MH.
		5.13.6 Check Metering	MH will provide backup metering or check metering if MH determines it necessary. Check metering shall not be connected to the instrument transformers used for revenue metering in the CUSTOMER LOAD FACILITY(IES).
		5.13.7 Meter Seals	Meters shall be sealed and the seals may be broken only by an inspector or accredited meter verifier appointed under the *Electricity and Gas Inspection Act*, R.S.C. 1985, c.E-4 [18] and then only for the purposes of inspection, verification, testing, re-verification or adjustment in accordance with provisions of the *Electricity and Gas Inspection Act*.
		5.13.8 Meter Tests	Periodically MH shall specify tests to confirm the accuracy of meters including but not limited to: • Instrument transformers, • Meters/data Loggers, • Alarms and Monitoring Facilities, • Communications Test, • General Quality, • Site Documentation, • Error Correction Factors, • Loss Adjustments.
		5.13.9 Security	The CUSTOMER LOAD shall provide provision for MH to lock all measuring devices. MH shall have the right, upon 48 hours written notice, to audit the site security of the metering installation. This shall include, but not be limited to: • Instrument transformers, • Meters/data Loggers.

No.	Item	Requirement
5.14	Telemetering and Metering, Supervisory Control and Data Acquisition (SCADA)	CUSTOMER LOAD FACILITY(IES) shall be equipped with a Supervisory Control and Data Acquisition (SCADA) Remote Terminal Unit (RTU) and shall be connected via appropriate, dedicated communication channels to the Manitoba Hydro System Control Centre (SCC). Manitoba Hydro normally supplies this RTU. The RTU shall provide Manitoba Hydro the following information and control capabilities: • Status: The RTU shall provide Manitoba Hydro position indication of all transmission voltage circuit breakers and motor operated disconnect devices, • Alarms: The RTU shall provide Manitoba Hydro equipment alarm information for each protective device and associated protective relaying in the transmission path, • Analogues: Customer metering is required that also provides functionality similar to Transmission Station metering. The RTU shall provide Manitoba Hydro with Power (MW), Reactive Power (Mvar), current (A), and voltage (V) quantities on the Transmission side of the interconnection. All Telemetering and Metering, Supervisory Control and Data Acquisition shall be at the POD. For system restoration requirements, the customer breaker shall be opened for loss of potential, and to be closed only after Manitoba Hydro operator direction. GENERATOR FACILITY(IES) within any CUSTOMER LOAD FACILITY(IES) may be required to provide the telemetering and metering of quantities as specified in Section 3.16.
5.15	Disturbance Monitoring	If directed by MH, the CUSTOMER LOAD shall provide facilities for disturbance monitoring in accordance with *Reliability Standards Regulation* and MH specifications. MH will determine the need for disturbance monitoring during INTERCONNECTION STUDIES. Dynamic Swing Recording data and/or transient fault recording data shall be provided to MH on request to allow post fault analysis of any disturbances that adversely impact the MH TRANSMISSION SYSTEM in order to determine the possible fault cause and remedial action necessary. Information on monitoring facilities typically used by MH is available in Section 2.25

No.	Item	Requirement
5.16	Communications	Communications facilities are required between the CUSTOMER LOAD FACILITY(IES) and the MH SYSTEM CONTROL CENTRE. The CUSTOMER LOAD shall provide and maintain the required communications from the CUSTOMER LOAD FACILITY(IES) to the site(s) designated by MH. The communications type and performance shall be adequate for its intended use and shall satisfy the requirements further specified herein. Manitoba Hydro will specify the interface at its sites. Communications may be required for but are not limited to: • System protection, • Load curtailment to allow participation in MH curtailable rate programs, • Direct tripping or load shedding by UFLS and/or UVLS schemes, • Supervisory control (including associated data acquisition and alarms), • Telemetering, • Operational voice communication, • Facsimile and e-mail communication. The exact requirement for communications, and functional characteristics, will be dependent on the function served and where appropriate by the reliability and/or redundancy defined during INTERCONNECTION STUDIES. Information on MH practice with regard to communications is available in Section 2.15. All communications maintenance and planned outages shall be coordinated through MH.
5.17	Insulation Levels	The CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES) shall comply with CSA standard CAN/CSA C22.3 C71 “Insulation Coordination (Part 1: Definitions, Principles and Rules, Part 2: Application Guide)” [20]. Equipment interconnected to the MH TRANSMISSION SYSTEM on the high voltage side of load transformer(s) should be insulated to at least the basic insulation levels (BIL) applicable to the system nominal voltage defined in Section 2.13, subject to insulation coordination studies. The CUSTOMER LOAD is responsible for conducting insulation coordination studies.
5.18	Short Circuit Levels	The CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES) shall be designed for operation at short circuit (fault) levels that take into account future development of the MH TRANSMISSION SYSTEM. The short circuit levels to be used in the design depend on the POINT(S) OF DELIVERY and future planned development and are available on request from MH.
5.19	Lightning (Surge) Protection	Lightning (Surge) Protection against direct lightning strokes shall be provided for protecting outdoor equipment including transformers forming part of the CUSTOMER LOAD INTERCONNECTION FACILITY(IES).
5.20	Safety and Design Standards	The CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES) shall comply with safety requirements in the Canadian Electrical Code [20] or other applicable safety standards mandatory within the Province of Manitoba.

No.	Item	Requirement
5.21	Environmental Conditions	Any equipment that can impact the MH TRANSMISSION SYSTEM shall be designed to function safely and reliably under the environmental conditions prevalent at the selected site. In particular, such equipment located outdoors at or near the POINT(S) OF DELIVERY necessary for isolating the CUSTOMER LOAD INTERCONNECTION FACILITY(IES) from the MH TRANSMISSION SYSTEM shall function reliably in extreme cold weather conditions with minimum temperatures as low as –50°C. Where isolating equipment is not designed to operate at minimum temperatures as lows as –50°C, then an alternative means of disconnection shall be available suitable to MH.
5.22	Clearances and Access	Energized parts shall be maintained at safe vertical and horizontal clearances that are compliant with the Canadian Electrical Code [20].
5.23	Isolation	All CUSTOMER LOADS that are interconnected to the MH TRANSMISSION SYSTEM shall supply their own breaker and disconnect switch at the POINT(S) OF DELIVERY. Under normal operating conditions, faults at the customer's facility must be cleared by their circuit breaker first, to avoid an outage of any Manitoba Hydro (MH) transmission line, bus, or transformer. The disconnect switch shall only be operated when the transmission line is de-energized.
		Isolating devices shall be manually operable or motor operated isolation switches that provide visual electrical isolation. The isolation switch shall simultaneously operate all phases (i.e. gang-operated open/close). In some instances, MH may require motor operated isolation switches to allow rapid remote or automatic isolation from the MH TRANSMISSION SYSTEM. The requirement to provide motor operated isolation devices will be determined by MH on a case by case basis. Provision shall also be made for MH to padlock these isolation switches securely in the open position as per the MH Corporate Safety and Occupational Health Rules [23]. MH may install a separate isolation switch outside the customer load facility if 24-hour access to the CUSTOMER LOAD INTERCONNECTION FACILITY(IES) is not available. If the POINT(S) OF DELIVERY is remote from the interconnecting MH substation, then the isolating device(s) shall also have a safety ground switch(ies) installed at MH expense on the MH side of the isolating device(s). The need for the safety ground switch(ies) will be determined during INTERCONNECTION STUDIES.
5.24	Transformer Connection	The main transformer connection shall be designed to block transmission of triplen harmonic currents and isolate load side and transmission side grounding networks. The transformer connection shall follow MH practice, information for which can be obtained from MH. Typical MH transformer configurations are provided in Section 2.17. MH will approve the connection configuration. Provision of tap changers, if necessary, to allow operation of the CUSTOMER LOAD FACILITY(IES) over the normal steady-state voltage range over which the MH TRANSMISSION SYSTEM is operated (see Section 5.6) is the responsibility of the CUSTOMER LOAD.

No.	Item	Requirement
5.25	Verification of Load Demand Characteristic Modelling	In addition to the requirements of Section 2.22, the representation of the load demand characteristics of large (greater than 10 MVA) CUSTOMER LOAD FACILITY(IES) requires periodic review by MH to ensure accuracy of the demand modelling. The CUSTOMER LOAD is required to co-operate with MH annually in providing updated demand data and carrying out any field tests required to verify load characteristics. The CUSTOMER LOAD shall provide MH with MW/Mvar forecast of load requirements (see Section 7.2) for analysis as follows: • Annual forecast of load (gross and net) for next 10 years, • Load composition (see Section 7.2 for details), • Load reactive characteristics. If a GENERATOR FACILITY(IES) exists, detailed unit data shall be provided in accordance with Section 7.1.
5.26	Testing and Maintenance Coordination	The CUSTOMER LOAD shall provide MH planned testing and maintenance work schedules for equipment within the CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITY(IES). MH shall be given advance notification of planned outages for scheduled test and maintenance work where the CUSTOMER LOAD FACILITY(IES) is larger then 20 MVA.
5.27	Inspection Requirements	The CUSTOMER LOAD FACILITY(IES) and CUSTOMER LOAD INTERCONNECTION FACILITIES shall be open to inspection by MH, whenever requested, for verification of compliance with this document. MH shall provide reasonable notice to the CUSTOMER LOAD of the proposed date for any planned inspection visits.
5.28	Coordinated Joint Studies	The CUSTOMER LOAD shall cooperate with MH and participate in any coordinated joint studies or investigations required to verify compliance with Reliability Standards Regulation and the requirements identified in this document.
5.29	Notification of New or Modified Facilities	The CUSTOMER LOAD shall give reasonable notice to MH of any planned new CUSTOMER LOAD FACILITY(IES) or any planned SUBSTANTIAL MODIFICATIONS to existing CUSTOMER LOAD FACILITY(IES). The CUSTOMER LOAD shall obtain MH's approval that the new additions or modifications meet interconnection requirements.

This page intentionally blank

6.0 TRANSMISSION LINE OWNER INTERCONNECTION REQUIREMENTS

This section defines the requirements that are applicable for a TRANSMISSION LINE OWNER applying to interconnect to the 115 kV, 138 kV, 230 kV and 500 kV nominal voltage levels on the MH TRANSMISSION SYSTEM. These Requirements are generally applicable to all transmission line facilities in the Province of Manitoba.

No.	Item	Information and Requirements
6.1	Interconnection Location and Voltage Level	The TRANSMISSION LINE OWNER may apply to connect to the MH TRANSMISSION SYSTEM at the nominal voltage levels above 100 kV defined in Section 2.2. It may also be possible to connect at voltages below 100 kV as determined by MH. The voltage level and the geographic location of the POINT(S) OF DELIVERY to the MH TRANSMISSION SYSTEM are to be determined by MH in consultation with the TRANSMISSION LINE OWNER. MH will be the final authority in determining the POINT(S) OF DELIVERY.
6.2	Sealing of Technical Reports, Drawings, Memos, etc.	All reports, memos, drawings, equipment specifications, and modelling data of technical nature (excluding manufacturing drawings) shall be sealed by a Professional Engineer certified to practice in the Province of Manitoba in accordance with *The Engineering and Geoscientific Professions Act of Manitoba*.
6.3	OPERATING PROCEDURES	The TRANSMISSION LINE OWNER shall abide by any OPERATING PROCEDURES, which include one of the following types: ABNORMAL, EMERGENCY OR NORMAL OPERATING GUIDES, imposed by the MH SYSTEM OPERATOR.
6.4	Reactive Power Requirements	The TRANSMISSION LINE OWNER INTERCONNECTION FACILITY (IES) shall be designed to provide reactive power supply and absorption capability acceptable to MH and satisfy the requirements in the Reliability Standards Regulation enacted pursuant to The Manitoba Hydro Act. The adequacy of such capability shall be demonstrated by the INTERCONNECTION STUDIES. The TRANSMISSION LINE OWNER shall be responsible for providing any necessary reactive power facilities as determined by the above studies.
6.5	Voltage and Frequency at POINT(S) OF DELIVERY	The TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES), when interconnected to the MH TRANSMISSION SYSTEM at the applicable system nominal voltage, shall: • be capable of remaining in operation and withstanding the voltage and frequency variation that may occur at the POINT(S) OF DELIVERY, as defined under Sections 2.2, 2.3, 2.4, 2.5 and 2.6. • Be capable of operating continuously within the minimum and maximum voltage limits as defined in Section 2.2, 2.3, 2.4, 2.5 and 2.6 as applicable based on the POINT(S) OF DELIVERY. MH reserves the right to require the TRANSMISSION OWNER's equipment to be capable of operation outside the normal minimum and maximum values defined in Section 2.2, 2.3, 2.4, 2.5 and 2.6 at specific locations on the MH TRANSMISSION SYSTEM.

No.	Item	Information and Requirements	
6.6	Transmission Line Design Criteria	6.6.1 Structural Design Criteria	Transmission Line Owner Interconnection Facility(ies) up to 240 kV shall be designed to meet the following standards: • Design of Transmission Towers and Foundations, Manitoba Hydro Specification No. TCD-CD-001 [29].This document applies to the design philosophy and criteria that must be satisfied in the design of new transmission line structures and foundations and for modifications to existing transmission line structures and foundations. • CAN/CSA-C22.3 No. 60826 [20], "Design Criteria of Overhead Transmission Lines". • Outages due to conductor galloping shall be negligible. For voltage levels above 240 kV, specific criteria will be developed by the Transmission and Civil Design Department, Manitoba Hydro.
		6.6.2 Electrical Loading Design Criteria	The electrical loading design criteria for Transmission Line Owner Interconnection Facility(ies) shall conform with the MH ratings methodology [3].
		6.6.3 External Electrical Effects	Transmission Line Owner Interconnection Facility(ies) shall be designed to meet the following standards: Audible Noise should be measured as per *IEEE Standard 656-1992*[30]. Transmission Line Owner Interconnection Facility(ies) shall not exceed an A-weighted equivalent sound pressure level of 50 dBA measured at the edge of the right-of-way for a wet-conductor. Electromagnetic Interference (eg radio interference) shall meet Industry Canada's *ICES-004* [31][31], and CSA Standard *CAN3-C108.3.1-M84 R2009* [32]. Transmission Line Owner Interconnection Facility(ies) shall not exceed Electric and Magnetic Fields levels specified in IEEE Standard *C95.6-2002* [33].
		6.6.4 Shield Wires	Transmission Line Owner Interconnection Facility(ies) operating at voltages of 230 kV or greater shall be provided with overhead shielding. Transmission Line Owner Interconnection Facility(ies) operating at voltages of 115 kV or greater shall be provided with overhead shielding when there is a single circuit between substations.

No.	Item	Information and Requirements	
6.7	Power Quality	6.7.1 Power Quality	THE TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) shall be designed and operated such that its power quality levels are within the limits specified in PQS2000 [2][2], "Power Quality Specification For Interconnection to Manitoba Hydro's Electrical System."
		6.7.2 Resonance and self-excitation	The TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) shall be designed to avoid introducing detrimental resonances into the MH TRANSMISSION SYSTEM. The TRANSMISSION LINE OWNER shall assess the risk of self-excitation of any internal generators or motor load and implement appropriate design measures to protect the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) as required. The TRANSMISSION LINE OWNER shall work in consultation with MH to determine an appropriate solution. MH will provide the TRANSMISSION LINE OWNER with harmonic impedance characteristics at the POINT(S) OF DELIVERYon request. The TRANSMISSION LINE OWNER shall ensure that any issues related to resonance and self-excitation are addressed in the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) design.

No.	Item	Information and Requirements
6.8	Protection systems	Information on the MH TRANSMISSION SYSTEM protection and control practices is provided in Section 2.9. The TRANSMISSION LINE OWNER is responsible for the following: • Producing and providing to MH the following engineering documents for review 60 days prior to energization.: 1. A protection Single Line Diagram (SLD) for the entire customer owned facility showing protection relay make and model, AC connections, tripping and other critical protection inputs and outputs. 2. Complete protection settings and logic for all relays including the electronic setting files. 3. A protection relay coordination report which demonstrates how the settings were determined. • MH shall be the final authority on establishing control and protection settings that impact the performance and operation of the MH TRANSMISSION SYSTEM • Ensuring that the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) is protected for all operating conditions and for all faults on the MH system. • Installing protective relaying equipment and systems that will sense and properly react to failure of equipment and to faults on the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES). Typically redundant main and non-redundant backup protective relaying systems are required on TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES). The protection shall fully protect the safety of the public and of MH personnel interfacing with the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES). • Determining the settings for relays that protect the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES). The protection and associated protection settings for installed equipment shall be coordinated by the TRANSMISSION LINE OWNER with settings of the MH TRANSMISSION SYSTEM protection schemes in the area. MH will provide details of the MH system protection to the TRANSMISSION LINE OWNER to facilitate this coordination.

No.	Item	Information and Requirements
		Fault interrupting devices shall have adequate fault interrupting and momentary withstand ratings to satisfy the short circuit level requirements (see Section 6.17) and shall meet maximum clearing times established by the INTERCONNECTION STUDIES. Typical clearing times are given in Section 2.9.2. INTERCONNECTION STUDIES conducted by MH may require that the TRANSMISSION LINE OWNER installs additional protection for the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) so as not to jeopardize the reliability of the MH TRANSMISSION SYSTEM. These protections can include but are not limited to the following: • Fully redundant protection systems, including associated communication facilities, such that no single protection system component failure will prevent required operation, • Overvoltage protections, • System stability protections such as out-of-step or underfrequency. Data on the protection and control systems including settings as defined in Section 6.8 shall be provided to MH.
6.9	Reclosing	Auto-reclosing is not employed on most of the MH TRANSMISSION SYSTEM at 100 kV and above. Limited auto-reclosing may be utilized on radial feeds, particularly where supervisory control is not available. If required, auto-reclosing may be allowed by MH subject to mitigation of all negative impacts as determined by INTERCONNECTION STUDIES. Subsequent negative operating experience may cause MH to re-evaluate the use of auto-reclosing. Single pole trip with auto reclosing is normally applied on 500 kV circuits as determined by INTERCONNECTION STUDIES.

No.	Item	Information and Requirements	
6.10	Synchronizing	Synchro-check functionality is required on all 500 kV and 230 kV circuit breakers. MH will determine if the synchro-check functionality is required on 66 kV, 115 kV and 138 kV circuit breakers during INTERCONNECTION STUDIES. The TRANSMISSION LINE OWNER shall provide synchronizing facilities including a facility for backup manual synchronizing. Manual/remote synchronizing capability shall be provided where required for system switching and restoration. MH will determine the requirements for manual/remote synchronizing during INTERCONNECTION STUDIES. Synchronizing shall normally be accomplished through the closing of a circuit breaker under the control of an automatic synchronizer with automatic voltage and speed matching for the incoming generator so as to achieve a "bumpless" connection with minimum disturbance to the MH TRANSMISSION SYSTEM. The TRANSMISSION LINE OWNER shall be responsible for determining the synchronizer settings. Typical settings used by MH are provided in Section 3.9. The TRANSMISSION LINE OWNER shall resolve any adverse effects caused by generator synchronization. The TRANSMISSION LINE OWNER FACILITY(IES) operator is responsible for synchronization of the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) to the MH TRANSMISSION SYSTEM subject to authorization from the MH SYSTEM OPERATOR.	
6.11	REMEDIAL ACTION SCHEMES (RAS)	The TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES)shall be provided with capability of being direct tripped. INTERCONNECTION STUDIES may require implementation of RAS schemes, which require the tripping of transmission line facilities. Such requirements may be imposed at any time as dictated by the requirements of the MH TRANSMISSION SYSTEM. Design of the tripping schemes shall satisfy requirements in the Reliability Standards Regulation enacted pursuant to The Manitoba Hydro Act. All RAS shall meet the requirements of Section 2.9.6.	
6.12	Revenue Metering	6.12.1 General	Metering shall conform to the MH's Metering Standards [14]. The specific types of metering equipment, timing devices, locations of meters, the details of the metering arrangement and the records to be kept shall be compatible with normal MH practice and shall be determined by MH in consultation with the TRANSMISSION LINE OWNER.

No.	Item	Information and Requirements	
		6.12.2 Accuracy	Revenue quality metering equipment shall consist of meters approved for revenue metering by Industry Canada. Metering equipment shall be installed, calibrated, repaired, replaced, maintained and tested in accordance with the provisions of *The Electricity and Gas Inspection Act* [18][18], *Electricity and Gas Inspection Regulations*, Measurement Canada and Manitoba Hydro specifications. MH requires 3 element metering accuracy for wye circuits and 2 element metering accuracy for delta circuits. Potential and current transformers for revenue metering shall conform to the Standard CAN/CSA-C60044-1:07 [16][16] and CAN/CSA-C60044-2:07 [17][17] for 0.3 metering accuracy class. Independent current transformers are required. Additional secondary windings on voltage transformers may be used for other purposes such as protective relaying as long as the burden is not excessive.
		6.12.3 Metering Configuration	The following signals are to be provided: • Active and reactive power, • Hourly integrated real and reactive power, where required. • Demand power, where required. Instrument Transformers and such other devices or equipment as shall be necessary to give the instantaneous values of megawatts and megavars, and an automatic record of kilowatt-hours and megavar-hours for each clock hour. Metering shall be able to provide monthly accumulated active and reactive power quantities. When there is a possibility of flows of electricity in either direction, dual register metering equipment shall be installed to record metering data for each direction of flow.
		6.12.4 Energy Losses	Metering shall be installed at the POINT(S) OF DELIVERY. Where metering is installed at a different location, MH shall determine a loss compensation factor to the POINT(S) OF DELIVERY.
		6.12.5 Meter Reading	Revenue meters may be read locally once per month by MH or may be remotely accessed by MH via telephone. Telemetering facilities to transmit monthly and hourly real and reactive power revenue metering data to MH's SYSTEM CONTROL CENTRE or other facility as directed by MH, shall be provided by the TRANSMISSION LINE OWNER. Telemetered data shall be in a format compatible with MV90 data collection software or other format as specified by MH.

<table>
<tr><th>No.</th><th>Item</th><th colspan="2">Information and Requirements</th></tr>
<tr><td></td><td></td><td>6.12.6 Check Metering</td><td>MH will provide backup metering or check metering if required, subject to negotiation with the TRANSMISSION LINE OWNER. Check metering shall not be connected to the instrument transformers used for revenue metering in the TRANSMISSION LINE OWNER FACILITY(IES).</td></tr>
<tr><td></td><td></td><td>6.12.7 Meter Seals</td><td>Meters shall be sealed and the seals may be broken only by an inspector or accredited meter verifier appointed under the Electricity and Gas Inspection Act, R.S.C. 1985, c.E-4 [18][18] and then only for the purposes of inspection, verification, testing, re-verification or adjustment in accordance with provisions of the Electricity and Gas Inspection Act.</td></tr>
<tr><td></td><td></td><td>6.12.8 Meter Tests</td><td>Periodically MH shall specify tests to confirm the accuracy of meters including but not limited to:
• Instrument transformers,
• Meters/data Loggers,
• Alarms and Monitoring Facilities,
• Communications Test,
• General Quality,
• Site Documentation,
• Error Correction Factors,
• Loss Adjustments.</td></tr>
<tr><td></td><td></td><td>6.12.9 Security Audit</td><td>MH shall have the right, upon 48 hours written notice, to audit the site security of the metering installation. This shall include, but not be limited to,
• Instrument transformers,
• Meters/data Loggers.</td></tr>
<tr><td>6.13</td><td>Telemetering, Metering, Supervisory Control and Data Acquisition (SCADA)</td><td colspan="2">The TRANSMISSION LINE OWNER shall provide a Remote Terminal Unit capable of exchanging SCADA information with the MH SYSTEM CONTROL CENTRE. The protocol for data exchange via the Remote Terminal Unit shall be compatible with that used for communications by the MH SYSTEM CONTROL CENTRE. MH will provide the TRANSMISSION LINE OWNER with the protocol for data exchange.

As a minimum, the TRANSMISSION LINE OWNER shall provide the following data needed by the Supervisory Control and Data Acquisition (SCADA) system:
• Line MW and Mvar flows including direction at POINT(S) OF DELIVERY,
• Status of circuit breaker(s) and isolator(s),
• Line voltages and current measurements at POINT(S) OF DELIVERY,
• Status of reactive power compensation and power flow control devices.

All measuring devices and metering equipment required for this purpose shall be supplied, installed and maintained by the TRANSMISSION LINE OWNER.</td></tr>
</table>

No.	Item	Information and Requirements
6.14	Disturbance Monitoring	If directed by MH, the TRANSMISSION LINE OWNER shall provide facilities for disturbance monitoring in accordance with MH specifications. MH will determine the need for disturbance monitoring during INTERCONNECTION STUDIES. Dynamic Swing Recording data and/or transient fault recording data shall be provided to MH on request to allow post fault analysis of any disturbances that adversely impact the MH Transmission System in order to determine the possible fault cause and remedial action necessary. Information on monitoring facilities typically used by MH is available in Section 2.25.
6.15	Communications	Communications facilities are required between the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) and the MH SYSTEM CONTROL CENTRE. The TRANSMISSION LINE OWNER shall provide and maintain the required communications from the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) to the site(s) designated by MH. The communications type and performance shall be adequate for its intended use and shall satisfy the requirements further specified herein. MH will specify the interface at its sites. Communications may be required but are not limited to: • System protection, • REMEDIAL ACTION SCHEMES (RAS), • Supervisory control (including associated data acquisition and alarms), • Telemetering, • Operational voice communication, from a stand alone dedicated voice line that is capable of functioning for up to 12 hours in a system or site shutdown condition or complete loss of station service supply, • Facsimile and e-mail communication.
		The exact requirement for communications, and functional characteristics, will be dependent on the function served and where appropriate by the reliability and/or redundancy defined during INTERCONNECTION STUDIES. Information on MH practice with regard to communications for transmission line protection is available in Section 2.9.4 and 2.15. All communications maintenance and planned outages shall be coordinated through MH.
6.16	Insulation Levels	TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) in Manitoba shall comply with CAN3/CSA C22.3 C71 “Insulation Coordination Part 1: Definitions, Principles and Rules, Part 2: Application Guide” [20][20]. The TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) interconnected to the MH TRANSMISSION SYSTEM shall be insulated to at least the lightning impulse levels (LIL) applicable to the system nominal voltage defined in Section 2.13, subject to insulation coordination studies. The TRANSMISSION LINE OWNER shall conduct insulation coordination studies.

No.	Item	Information and Requirements
6.17	Short Circuit Levels	TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) shall be designed for operation at short circuit (fault) levels that take into account future development of the MH TRANSMISSION SYSTEM. The short circuit levels to be used in the design depend on the POINT(S) OF DELIVERYand future planned development and are available on request from MH.
6.18	Safety	The TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) shall comply with safety requirements in the Canadian Electrical Code [20][20] and all applicable safety standards mandatory within the Province of Manitoba.
6.19	Environmental Conditions	Any equipment that can impact the MH TRANSMISSION SYSTEM shall be designed to function safely and reliably under the environmental conditions prevalent at the selected site. In particular, such equipment located outdoors at the POINT(S) OF DELIVERYnecessary for isolating the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) from the MH TRANSMISSION SYSTEM shall function reliably in extreme cold weather conditions with minimum temperatures as low as –50°C.
6.20	Clearances and Access	Energized parts shall be maintained at safe vertical and horizontal clearances as defined in CSA Standard C22.3 No. 1 Overhead Systems [20][20] for TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) in Manitoba.
6.21	Isolation	The TRANSMISSION LINE OWNER shall provide fault interrupting devices and isolating devices at a location(s) defined by MH at or near the POINT(S) OF DELIVERY. Isolating devices shall be manually operable or motor operated isolation switches that provide visual electrical isolation. The isolation switch shall simultaneously operate all phases (i.e. gang-operated open/close). In some instances, MH may require motor operated isolation switches to allow rapid remote or automatic isolation from the MH TRANSMISSION SYSTEM. The requirement to provide motor operated isolation devices will be determined by MH on a case by case basis. Provision shall also be provided for MH to padlock these isolation switches securely in the open position as per the MH Corporate Safety and Occupational Health Rules [23][23]. If the POINT(S) OF DELIVERYis remote from the interconnecting MH substation, then the isolating device(s) shall also have a safety ground switch(es) installed on the MH side of the isolating device(s). The need for the safety ground switch(es) will be determined during INTERCONNECTION STUDIES.
6.22	Testing and Maintenance Coordination	The TRANSMISSION LINE OWNER shall provide planned testing and maintenance work schedules for equipment within the TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES). MH shall be given advance notification of planned outages for scheduled test and maintenance work.
6.23	Protection System Maintenance and Testing	The TRANSMISSION LINE OWNER shall have a protection system maintenance and testing program in place, in accordance with *Reliability Standards Regulation*. The TRANSMISSION LINE OWNER shall provide MH with documentation of the protection system maintenance and testing program.

No.	Item	Information and Requirements
6.24	Inspection Requirements	The TRANSMISSION LINE OWNER INTERCONNECTION FACILITY(IES) in Manitoba shall be open to inspection by MH, whenever requested, for verification of compliance with this document.

This page intentionally blank

7.0 TECHNICAL DATA TO BE PROVIDED BY THE FACILITY OWNER

General technical data, including steady-state and dynamics data, is required by MH to enable evaluation of the FACILITY(IES) being added and to allow realistic simulation of the electric behaviour of the components in the interconnected system. Unit-specific dynamics data shall be provided for generators, excitation systems, voltage regulators, turbine-governor systems, power system stabilizers and other associated generation equipment. Field verification of generator unit data as defined in Section 3.27, 3.29 and 4.10 and load demand characteristics as defined in Section 2.28.5 and 5.25 will be required. Some of this data may not be initially available to the FACILITY OWNER but shall be submitted to MH as it becomes available. Additional data or resubmission of data based on periodic testing as directed by MH shall be provided to MH by the FACILITY OWNER.

7.1 Generator Facility Technical Data

Name and location of generator			
Map showing facility location			
Electrical single line diagram (s) (showing anticipated connection to customer's new or existing system and/or connection to the transmission system)			
Site layout plan			
Total Plant Capacity			
Number of Units and MVA rating (with all temperature dependencies indicated)			
Energy Source (Hydro, Thermal, Gas, etc.), Type of Generator (synchronous, induction, etc.) and Prime Mover Type (steam turbine, reciprocating etc.)			
Scheduled In-Service Dates			
Generating Unit	Active/Reactive Power Capability Curve (Mvar vs. MW)		
	Open Circuit and Full Load Saturation Curves		
	Generator V Curve		
	Grounding Method (and impedance value if applicable)		
	Synchronous Generator Data detailed in 3.27 Induction Generator Data detailed in 4.9 Generator with Power Electronic Interface data detailed in 4.9		
	Excitation System and AVR	Make, model and type of exciter (AC or DC, rotary, brushless or static etc.)	
		Make, model and type of AVR	
		AVR setting range	
		Block diagram including values of all gains, time constants and limits in IEEE Standard 421.5 model format [34].	
	Power System Stabilizer	Block diagram including values of all gains, time constants, limits and inputs in IEEE standard 421.5 model format [34].	
	Prime Mover and Governor	Block diagram including all parameters in IEEE Standard model format.	
Step-up Transformer	Type, make, model		
	MVA rating—Normal		
	MVA rating—Emergency		
	Voltage rating of each winding		
	Connection configuration of each winding		
	Saturation Characteristics		
	Tap changer nominal tap, tap step size and tap range		
	Positive sequence impedance on own base (p.u.) at nominal tap for each winding		
	Zero sequence impedance on own base (p.u.) at nominal tap for each winding		
Circuit Breakers: type, make, model, interrupting capability, continuous current rating, tripping and closing times			
Surge arresters: Type, make, model and rating			
Description of protection and control provided and protection and control block diagrams and schematic drawings			

List of protection and control settings	
Description of interface provided for remote control and monitoring	
Description of facilities for metering and revenue metering	
Description of communication facilities	
Single line diagram and description of station service and auxiliary load	
Scheduled maintenance annual outage requirements	
Forced outage rate—expected design value	
Phase Unbalance (%)	
Individual harmonic or interharmonic voltage distortion (%)	
Total voltage distortion THD (%)	
High frequency harmonic noise maximum balanced IT	
Wind turbine voltage quality data as per IEC 61400-21 [26]	

7.1.1 Thermal Turbine-Generator Mechanical Data (70 MVA or larger unit)

Site Name	
Generator Number or Unique Identifier	
Number of lumped rotating masses on the turbine-generator shaft	
Moment of inertia of each lumped mass	
fraction of the total external mechanical torque applied to each lumped mass	
spring constant of the shaft section between each lumped mass	
speed deviation self-damping coefficient for each lumped mass	
Mutual damping coefficient between pairs of lumped masses	

7.1.2 Synchronous Generator Data

<table>
<tr><td colspan="3">Site Name, Generator number or Unique Identifier</td><td></td></tr>
<tr><td rowspan="4">Rated</td><td colspan="2">MVA</td><td></td></tr>
<tr><td colspan="2">MW</td><td></td></tr>
<tr><td colspan="2">PF</td><td></td></tr>
<tr><td colspan="2">kV</td><td></td></tr>
<tr><td colspan="3">Synchronous Speed (rpm)</td><td></td></tr>
<tr><td colspan="3">Short Circuit Ratio</td><td></td></tr>
<tr><td colspan="3">Inertia Constant H (MW-S./MVA) (generator and turbine combined)</td><td></td></tr>
<tr><td rowspan="20">REACTANCES IN PERCENT ON MACHINE OR STATION MVA BASE (Include both saturated and unsaturated reactances)</td><td colspan="2">Potier Reactance X_p</td><td></td></tr>
<tr><td colspan="2">Stator Leakage Reactance X_l</td><td></td></tr>
<tr><td colspan="2">Negative sequence resistance R_2</td><td></td></tr>
<tr><td colspan="2">Zero sequence resistance R_0</td><td></td></tr>
<tr><td rowspan="8">AT RATED CURRENT</td><td>Direct axis synchronous reactance X_d</td><td></td></tr>
<tr><td>Direct axis transient reactance X'_d</td><td></td></tr>
<tr><td>Direct axis sub-transient reactance X''_d[1]</td><td></td></tr>
<tr><td>Quadrature axis synchronous reactance X_q</td><td></td></tr>
<tr><td>Quadrature axis transient reactance X'_q</td><td></td></tr>
<tr><td>Quadrature axis sub-transient reactance X''_q[1]</td><td></td></tr>
<tr><td>Negative sequence reactance X_2</td><td></td></tr>
<tr><td>Zero sequence reactance X_0</td><td></td></tr>
<tr><td rowspan="8">AT RATED VOLTAGE</td><td>Direct axis synchronous reactance X_d</td><td></td></tr>
<tr><td>Direct axis transient reactance X'_d</td><td></td></tr>
<tr><td>Direct axis sub-transient reactance X''_d[1]</td><td></td></tr>
<tr><td>Quadrature axis synchronous reactance X_q</td><td></td></tr>
<tr><td>Quadrature axis transient reactance X'_q</td><td></td></tr>
<tr><td>Quadrature axis sub-transient reactance X''_q[1]</td><td></td></tr>
<tr><td>Negative sequence reactance X_2</td><td></td></tr>
<tr><td>Zero sequence reactance X_0</td><td></td></tr>
<tr><td colspan="3">Armature dc resistance R_a (ohms at 100°C, per phase)</td><td></td></tr>
<tr><td colspan="3">Field resistance R_f (ohms at 25°C)</td><td></td></tr>
<tr><td colspan="3">Direct axis transient short-circuit time constant T'_d (seconds)</td><td></td></tr>
<tr><td colspan="3">Direct axis sub-transient short-circuit time constant T''_d (seconds)</td><td></td></tr>
<tr><td colspan="3">Quadrature axis transient short-circuit time constant T'_q (seconds)</td><td></td></tr>
<tr><td colspan="3">Quadrature axis sub-transient short-circuit time constant T''_q (seconds)</td><td></td></tr>
<tr><td colspan="3">Direct axis transient open-circuit time constant T'_{do} (seconds)</td><td></td></tr>
<tr><td colspan="3">Direct axis sub-transient open-circuit time content T''_{do} (seconds)</td><td></td></tr>
<tr><td colspan="3">Quadrature axis transient open-circuit time constant T'_{qo} (seconds)</td><td></td></tr>
<tr><td colspan="3">Quadrature axis sub-transient open-circuit time constant T''_{qo} (seconds)</td><td></td></tr>
<tr><td colspan="3">Armature short-circuit time constant T_a (seconds)</td><td></td></tr>
</table>

[1] The ratio X''_d/X''_q is specified as follows: $0.9 < X''_d/X''_q < 1.1$
A ratio near unity helps the machine to provide good damping and ensures that following a sudden three-phase short-circuit on the armature terminals of the generator, the second harmonic components of the armature current are reduced.

Loss of full load, Speed rise (transient Delta t)	

7.1.3 Induction Generator Data

Site Name			
Generator Number or Unique Identifier			
Rated	MVA		
	MW		
	PF		
	kV		
Torque at Synchronous Speed (pu)			
Mechanical Power Used at Synchronous Speed (MW)			
Inertia Constant H (MW-SEC./MVA) (generator and turbine combined)			
REACTANCES IN PERCENT ON MACHINE OR STATION MVA BASE (Include both saturated and unsaturated reactances)	Stator Leakage Reactance X_l		
	Negative sequence resistance R_2		
	Zero sequence resistance R_0		
	AT RATED CURRENT	Synchronous reactance X	
		Transient reactance X'	
		Sub-transient reactance X"	
		Positive sequence reactance X_1	
		Negative sequence reactance X_2	
		Zero sequence reactance X_0	
	AT RATED VOLTAGE	Synchronous reactance X	
		Transient reactance X'	
		Sub-transient reactance X"	
		Positive sequence reactance X_1	
		Negative sequence reactance X_2	
		Zero sequence reactance X_0	
Transient short-circuit time constant T' (seconds)			
Sub-transient short-circuit time constant T" (seconds)			
Transient open-circuit time constant T'_o (seconds)			
Sub-transient open-circuit time content T''_o (seconds)			

7.1.4 Non-Standard Generator with Power Electronic Interface Data

Site Name		
Generator Number or Unique Identifier		
Rated	MVA	
	MW	
	PF	
	kV	
Contact MH for specific data submission requirements for this type of generator.		

7.2 Customer Load Facility Technical Data

<table>
<tr><td colspan="3">Name and location of customer load facility</td><td></td></tr>
<tr><td colspan="3">Map showing facility location</td><td></td></tr>
<tr><td colspan="3">Electrical single line diagram</td><td></td></tr>
<tr><td colspan="3">Site layout plan</td><td></td></tr>
<tr><td colspan="3">Type of Load</td><td></td></tr>
<tr><td colspan="3">Total Connected Load (MW and MVAr)</td><td></td></tr>
<tr><td colspan="3">Facility scheduled in-service date</td><td></td></tr>
<tr><td colspan="3">MW/MVAr Forecast of load (gross and net) for 10 years</td><td></td></tr>
<tr><td colspan="3">Monthly peak hour forecast demand in MW for next 2 years</td><td></td></tr>
<tr><td colspan="3">Monthly net energy forecast for load in GWh for next 2 years</td><td></td></tr>
<tr><td colspan="3">Annual peak hour forecast demand (summer) in MW for next 10 years</td><td></td></tr>
<tr><td colspan="3">Annual peak hour forecast demand (winter) in MW for next 10 years</td><td></td></tr>
<tr><td colspan="3">Annual net energy forecast for load in GWh for next 10 years</td><td></td></tr>
<tr><td rowspan="11">Details of Load</td><td colspan="2">Interruptibility</td><td></td></tr>
<tr><td colspan="2">Phase Unbalance (%)</td><td></td></tr>
<tr><td colspan="2">Individual harmonic or interharmonic voltage distortion (%)</td><td></td></tr>
<tr><td colspan="2">Total voltage distortion THD (%)</td><td></td></tr>
<tr><td colspan="2">High frequency harmonic noise maximum balanced IT</td><td></td></tr>
<tr><td rowspan="6">Load Composition and Load Data</td><td>Furnace Load (Size, usage, load modelling data)</td><td></td></tr>
<tr><td>Welding Equipment (Size, usage, load modelling data)</td><td></td></tr>
<tr><td>Motor Loads (for each motor give HP, Type, Function, Starts/day, modelling data; for motors larger than 200 Hp, detailed modelling data is required</td><td></td></tr>
<tr><td>Co-Generation (Size, usage; detailed modelling data is required as per Section 3.27)</td><td></td></tr>
<tr><td>Fluorescent Lighting (Size, usage, load modelling data)</td><td></td></tr>
<tr><td>Other loads (Type, size, usage, rate of fluctuation, load modelling data for each type)</td><td></td></tr>
<tr><td rowspan="9">Step-down Transformer</td><td colspan="2">Type, make, model</td><td></td></tr>
<tr><td colspan="2">MVA rating—Normal</td><td></td></tr>
<tr><td colspan="2">MVA rating—Emergency</td><td></td></tr>
<tr><td colspan="2">Voltage rating of each winding</td><td></td></tr>
<tr><td colspan="2">Connection configuration of each winding</td><td></td></tr>
<tr><td colspan="2">Saturation Characteristics</td><td></td></tr>
<tr><td colspan="2">Tap changer nominal tap, tap step size and tap range</td><td></td></tr>
<tr><td colspan="2">Positive sequence impedance on own base (p.u.) at nominal tap for each winding</td><td></td></tr>
<tr><td colspan="2">Zero sequence impedance on own base (p.u.) at nominal tap for each winding</td><td></td></tr>
<tr><td colspan="3">Circuit Breakers: type, make, model, interrupting capability, continuous current rating, tripping and closing times</td><td></td></tr>
</table>

Surge arresters: Type, make, model and rating	
Description of protection and control provided including block diagrams and schematic diagrams	
List of protection and control settings	
Description of interface provided for remote control and monitoring	
Description of facilities for metering	
Description of communication facilities	

7.3 Transmission Line Owner Interconnection Facility Technical Data

Overhead Transmission Line	Nominal Voltage (kV)	
	Length (km)	
	Route Map (including transposition locations)	
	Plan and profile drawings	
	Electrical single line diagram showing transmission line and any other associated devices required for switching, reactive compensation, protection and control and communication and the interface to the generator or end-user facility	
	Nominal power transfer rating	
	Emergency power transfer rating	
	Conductor type and size	
	Overhead ground wire type and size	
	Configuration of conductors and overhead ground wires on tower (include diagram showing phase spacing and clearances to ground)	
	Positive Sequence R_1, X_1 and B_1 (ohms/km)	
	Zero sequence R_0 and X_0 (ohms/km)	
	Description of protections provided	
	Description of communication systems	
Reactive Compensation device (if applicable)	Connection Location	
	Type, make, model	
	Configuration	
	Rated Voltage (kV)	
	Size (MVAr)	
	Switching device: type, make, model, interrupting capability, continuous current rating, tripping and closing times and any switching restrictions	
	Criteria for automatic switching	
	Description of protections provided	
Intermediate or terminal substation (if applicable)	Electrical single line diagram	
	Circuit Breakers: type, make, model, interrupting capability, continuous current rating, tripping and closing times	
	Description of protections	

Transformer (if applicable)	Type, make, model	
	MVA rating—Normal	
	MVA rating—Emergency	
	Voltage rating of each winding	
	Connection configuration of each winding	
	Saturation Characteristics	
	Tap-changer nominal tap, tap step size and tap range	
	Positive sequence impedance on own base (p.u.) at nominal tap for each winding	
	Zero sequence impedance on own base (p.u.) at nominal tap for each winding	
Circuit Breakers: type, make, model, interrupting capability, continuous current rating, tripping and closing times		
Surge arresters: Type, make, model and rating		
Description of protection and control provided including block diagrams and schematic diagrams		
List of protection and control settings		
Description of interface provided for remote control and monitoring		
Description of facilities for metering		
Description of communication systems provided		

This page intentionally blank

8.0 FIGURES.

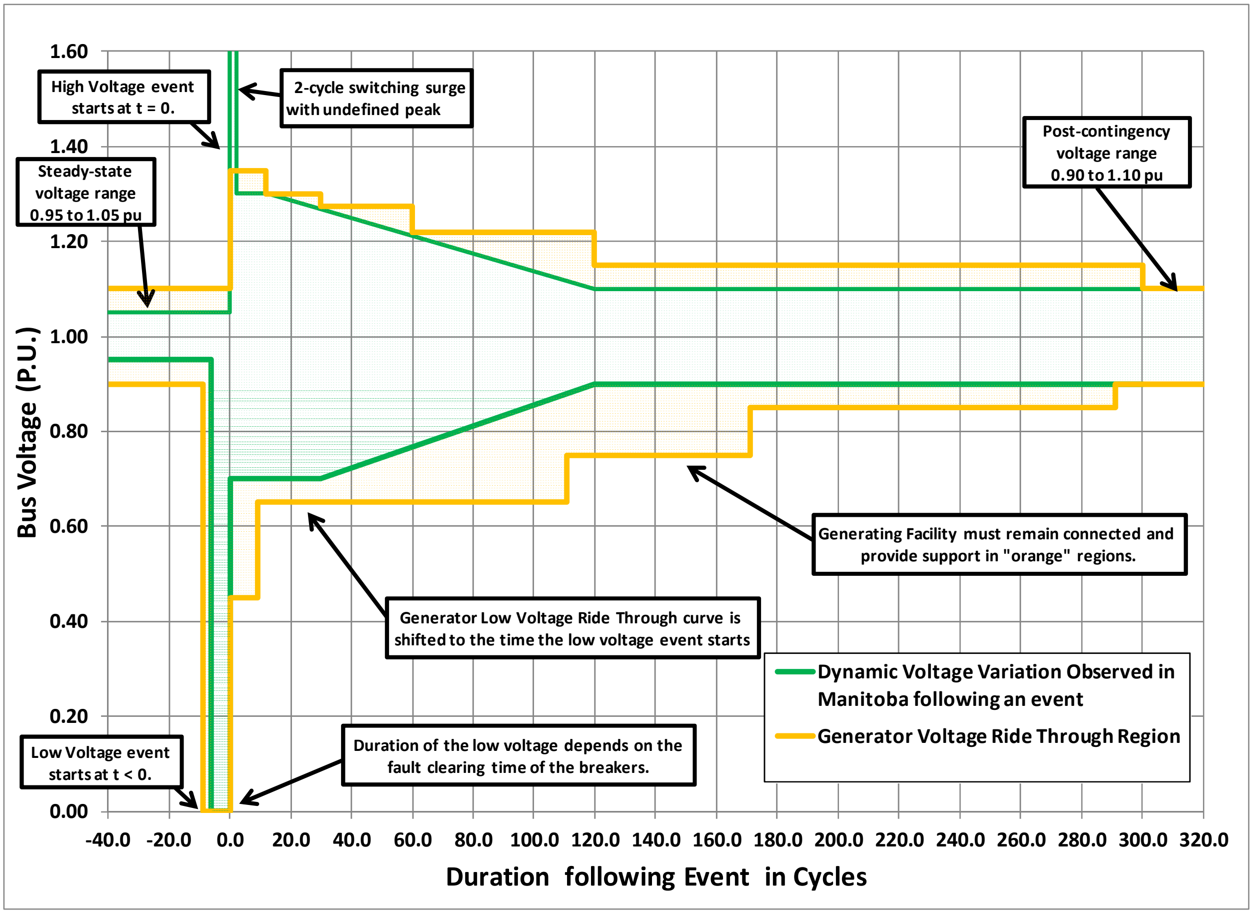


Figure 1: MH transient voltage performance criteria (green region) following an "event" with GENERATOR FACILITY voltage ride-through (orange region) overlaid.

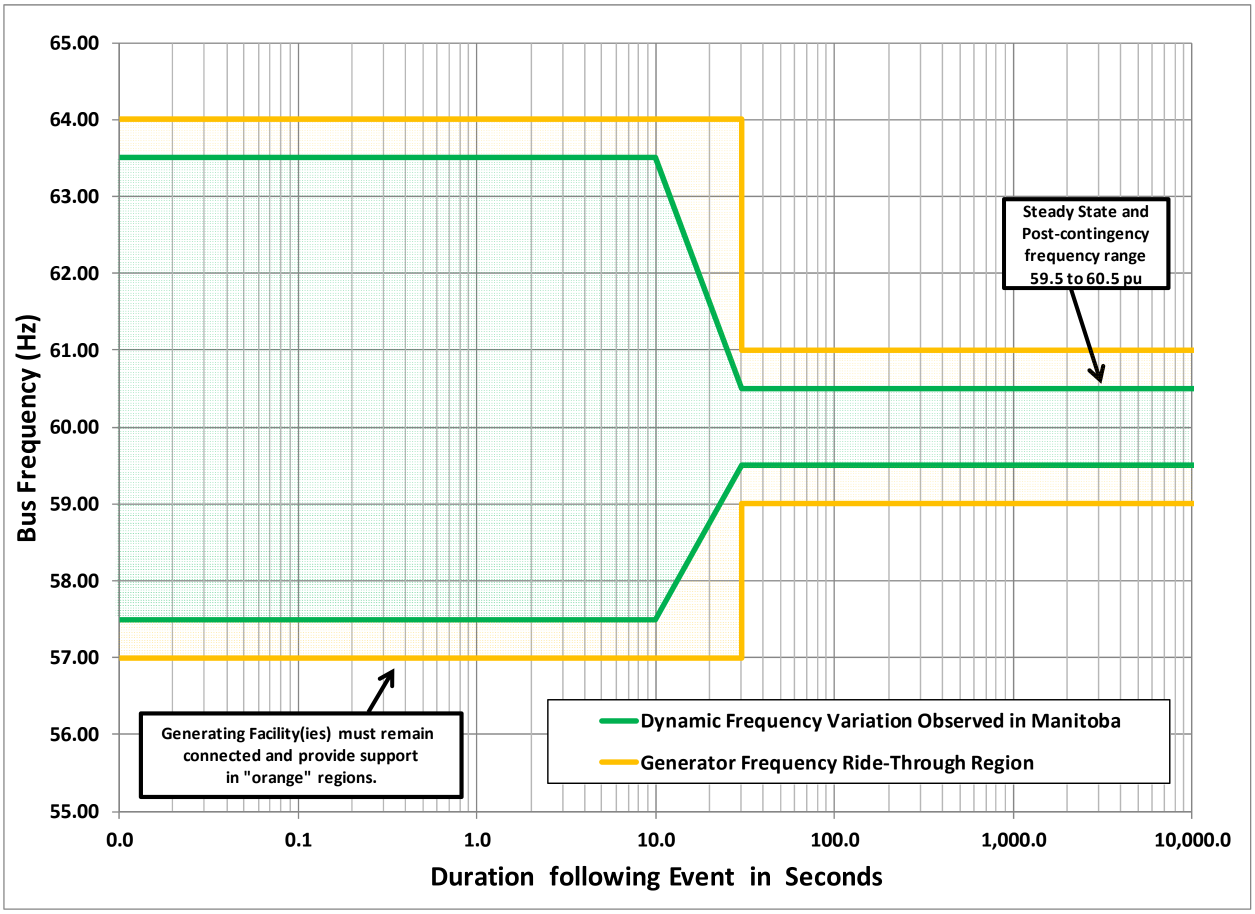
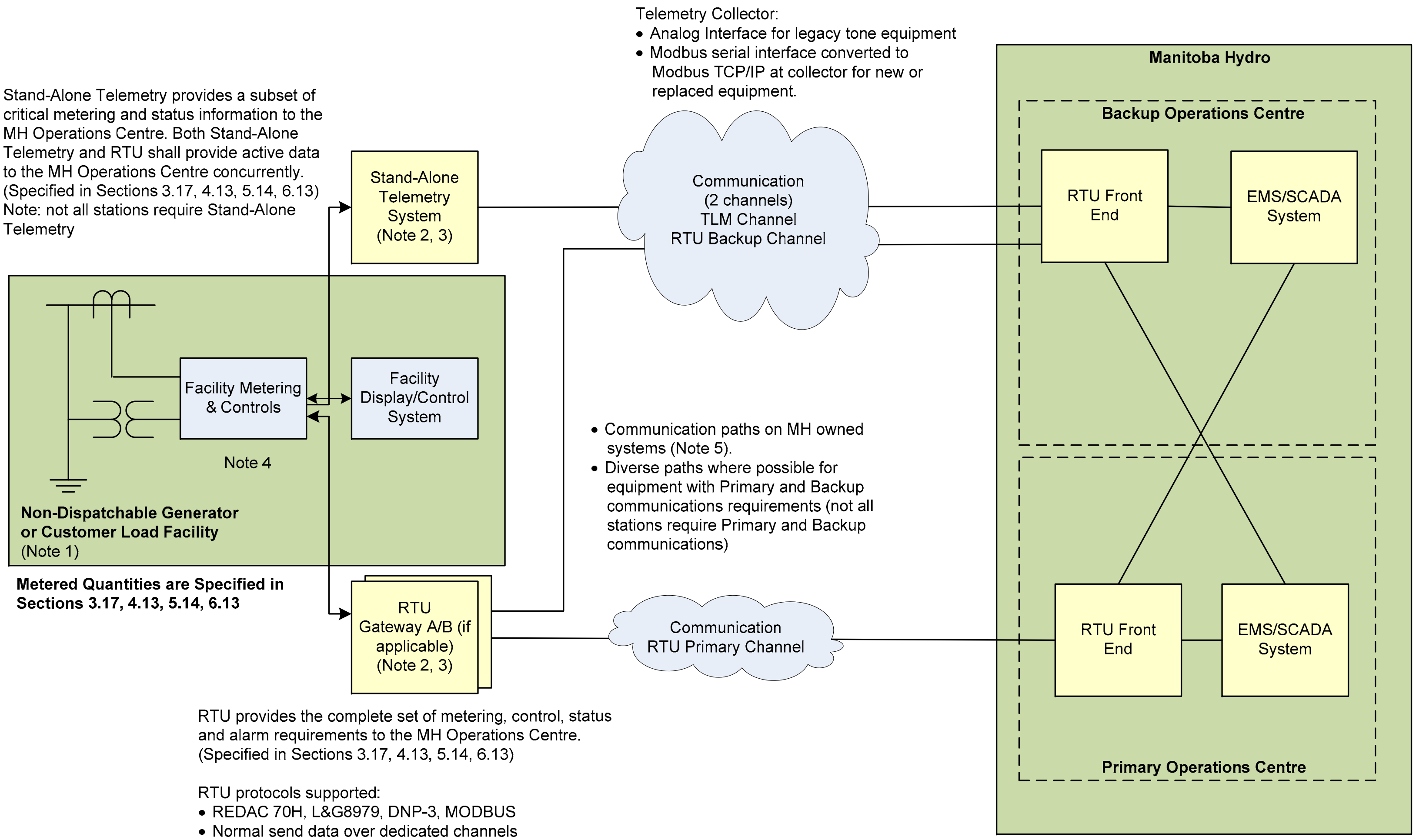
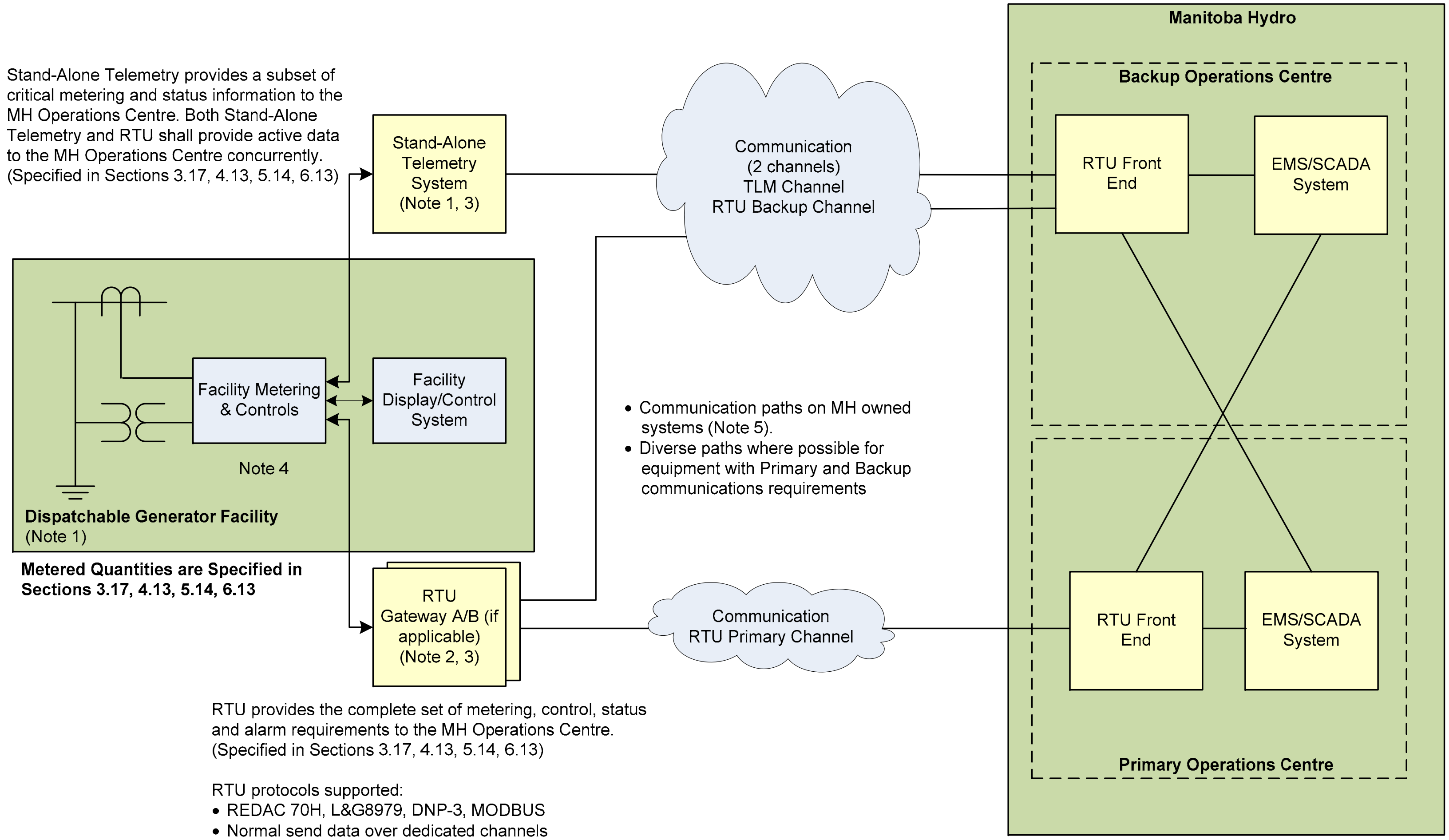


Figure 2: MH dynamic frequency performance criteria (green region) following an "event" with GENERATOR FACILITY frequency ride-through (orange region) overlaid.



NOTES:
1. All metering, RTU, telemetry, communications and display equipment shall continue to operate on loss of station service supply.
2. RTU/Telemetry equipment may be located at Generator/Customer Load Facility or at adjacent Transmission Owner Facility.
3. Separate system such that a single contingency planned or unplanned outage to the Transmission Owner equipment shall not result in a loss of specified critical data.
4. No control by MH.
5. Communication paths and redundancy shall be specified by MH.

Figure 3: Manitoba Hydro Non-Dispatchable GENERATOR FACILITY or CUSTOMER LOAD FACILITY Telemetering Block Diagram.



NOTES:
1. All metering, RTU, communications and display equipment shall continue to operate on loss of station service supply.
2. RTU equipment may be located at Generator/Customer Load Facility or at adjacent Transmission Owner Facility.
3. Separate system such that a single contingency planned or unplanned outage to the Transmission Owner equipment shall not result in a loss of specified critical data.
4. Facility shall be equipped with dual control as specified by MH.
5. Communication paths and redundancy shall be specified by MH.

Figure 4: Manitoba Hydro Dispatchable GENERATOR FACILITY Telemetering Block Diagram

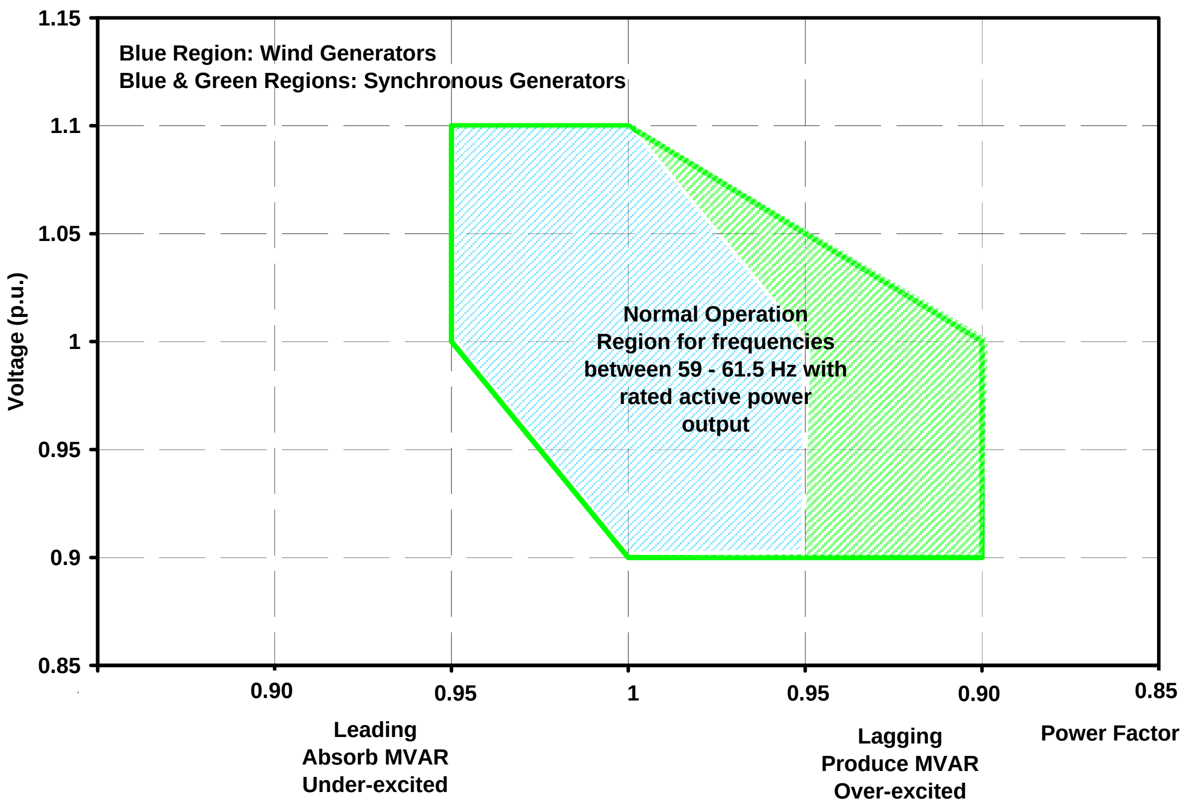


Figure 5: Minimum Reactive Power Requirements for GENERATOR FACILITIES.

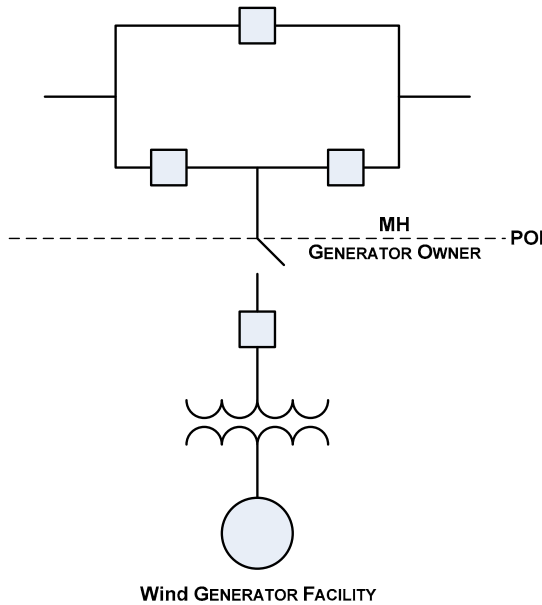


Figure 6: Default line tapping configuration for GENERATOR FACILITIES.

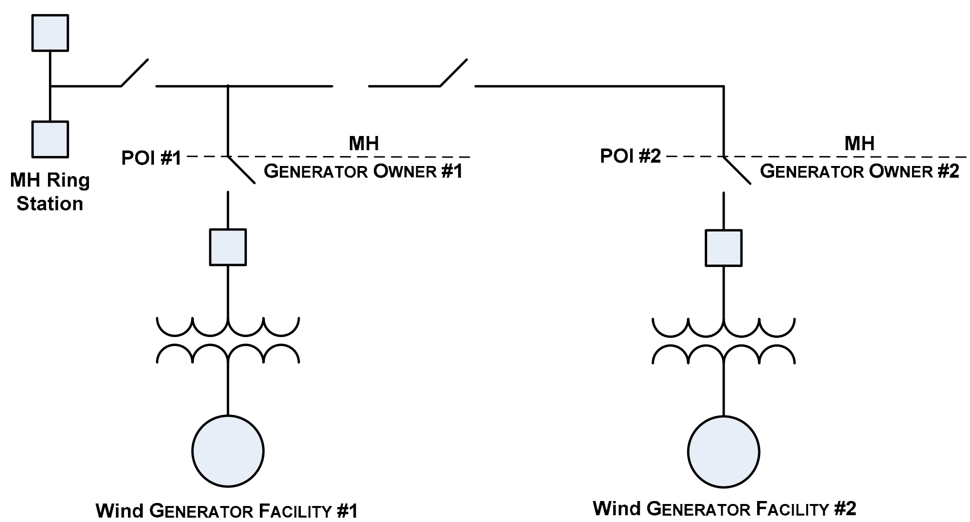


Figure 7: Special radial interconnection that may be considered for wind GENERATOR FACILITIES (CUSTOMER LOAD FACILITY(IES) will not be permitted to tap onto this radial configuration).

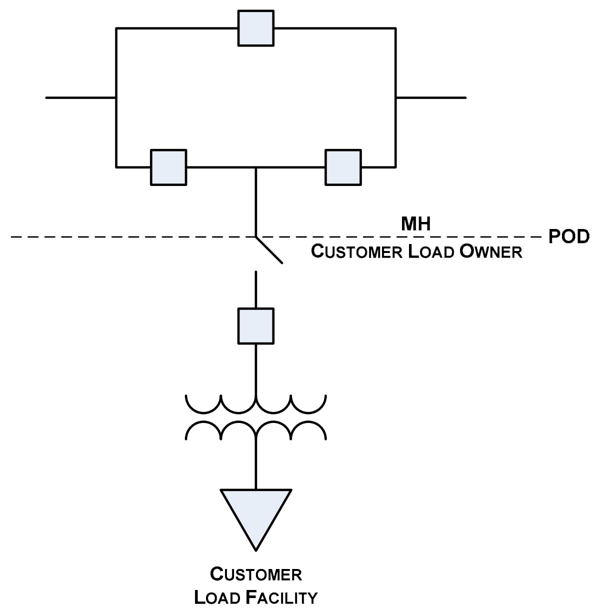


Figure 8: 230 kV line tapping configuration for CUSTOMER LOAD FACILITIES above 100MVA.

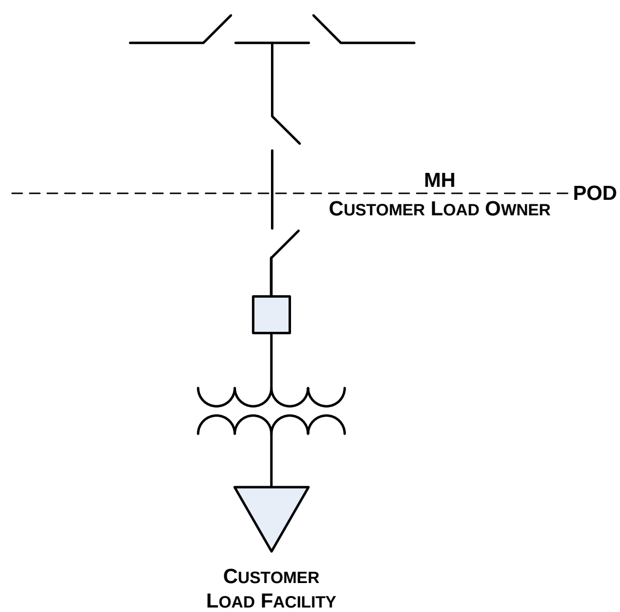


Figure 9: 230 kV line tapping configuration for CUSTOMER LOAD FACILITIES between 30 MVA and 99MVA.

This page intentionally blank

9.0 REFERENCES

[1] Manitoba Laws, C.C.S.M. c. H190, *The Manitoba Hydro Act*, http://web2.gov.mb.ca/laws/statutes/ccsm/h190ei.php

[2] *"Power Quality Specification for Interconnection to Manitoba Hydro's Electrical System, PQS2000."* http://coil.hydro.mb.ca/Dist_PD_Div/Service_Quality/Index.htm

[3] *"Facility Ratings Methodology for Manitoba Hydro's Bulk Electric System"*

[4] "Station Design Department – DME Design Process-rev01.

[5] Station Design Department – DME Functional Requirements.

[6] IEEE Standard C50.12, *"IEEE Standard for Salient-Pole 50 HZ and 60 Hz Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications Rated 5 MVA and Above."*

[7] IEEE Standard C50.12, *"IEEE Standard for Salient-Pole 50 HZ and 60 Hz Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications Rated 5 MVA and Above."*

[8] IEEE Standard C50.13, *"IEEE Standard for Cylindrical-Rotor 50 HZ and 60 Hz Synchronous Generators Rated 10 MVA and Above."*

[9] IEEE Standard 125, *"Recommended Practice for Preparation of Equipment Specifications for Speed Governing of Hydraulic Turbines Intended to Drive Electric Generators."*

[10] IEEE Standard 122, *"Recommended Practice for Functional and Performance Characteristics of Control Systems for Steam Turbine-Generator Units"*

[11] IEEE Standard 421.4, *"Guide for the Preparation of Excitation System Specifications"*

[12] IEEE Standard 421.1, "*IEEE Standard Definitions for Excitation Systems for Synchronous Generators"*

[13] ANSI/IEEE Standard C37.102, *"IEEE Guide for AC Generator Protection"*.

[14] *"MH Customer Metering Standards."* http://www.hydro.mb.ca/customer_services/permits_and_inspections/electrical/inspections.shtml

[15] Customer Policy Application Manual, General Services Electricity Billing (2110 VI), available at the web site: http://coil.hydro.mb.ca/cpa/2110vi.htm

[16] CAN/CSA-C60044-1:07, *"Instrument Transformers – Part 1: Current transformers."*

[17] CAN/CSA-C60044-2:07, *"Instrument Transformers – Part 2: Inductive voltage transformers."*

[18] Electricity and Gas Inspection Act, R.S.C. 1985, c.E-4 available at the web site: http://www.ic.gc.ca/eic/site/mc-mc.nsf/eng/lm00115.html

[19] *"Manitoba Hydro Generator Interconnection Operating Requirements."* http://www.oasis.oati.com/woa/docs/MHEB/MHEBdocs/MH_Gen_Interconnection_Operational_Requirements_v3_July_7_2011_.pdf

[20] CSA C22.1, C22.2 and C22.3-Canadian Electrical Code Parts I, II & III.

[21] ANSI/IEEE Standard C62.92, *"IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems Part II—Grounding of Synchronous Generator Systems"*.

[22] IEEE Standard 80, *"IEEE Guide for Safety in AC Substation Grounding"*.

[23] Manitoba Hydro Corporate Safety and Occupational Health Rules , available at the web site: http://coil.hydro.mb.ca/esh/.

[24] IEEE Standard C57.116, *"Guide for Transformers Directly Connected to Generators*".

[25] MH Open Access Interconnection Tariff, available at the web site: http://oasis.midwestiso.org/documents/mheb/MH%20OAIT%20FINAL%20JUN%2009.pdf

[26] International Standard IEC 61400-21, *"Measurement and Assessment of Power Quality Characteristics of grid Connected Wind Turbines"*.

[27] CSA Standard CAN/CSA-C61400-12-1-07, *"Power Performance Measurements of Electricity Producing Wind Turbines"* (Adopted IEC 61400-12-1:2007, first edition, 2005-12).

[28] MH Typical Underground Trench Cross-Sections, Direct Buried System, CD 205-14.

[29] Manitoba Hydro Design of Transmission Towers and Foundations, TCD-CD-001.

[30] IEEE Standard 656-1992, *"IEEE Standard for the Measurement of Audible Noise From Overhead Transmission Lines."*

[31] Industry Canada's *ICES-004, "Alternating Current High Voltage Power Systems, Interference-Causing Equipment Standards."*

[32] CSA Standard CAN3-C108.3.1-M84 R2009, *"Limits and Measurement Methods of Electromagnetic Noise from AC Power Systems, 0.15-30 MHz."*

[33] IEEE Standard C95.6-2002*, "Safety Levels with respect to human exposure to Electromagnetic Fields, 0-3kHz."*

[34] IEEE Standard 421.5, *"IEEE Recommended Practice for Excitation System Models for Power System Stability Studies"*.

[35] IEEE Standard C37.118, *"IEEE Standard for Synchrophasors for Power Systems"*.

NERC documentation is available at web site **http://www.nerc.com/**.

10.0 DOCUMENT CHANGE HISTORY

Version	Date	Technical Review Committee (TRC) Approval	Brief Description of Change/Review
0	2003 12 12	TRC-166	Initial Publication.
1	2007 07 12	TRC-170	Major revision including updated or new material. **Section 1.1 Definitions: (updated and new material)** 1.1.16 Emergency Operating Guides 1.1.17 Interconnection System Upgrades 1.1.18 IOA 1.1.19 MAPP 1.1.27 MRO 1.1.36 Operating Procedures 1.1.39 Standing Operating Guides 1.1.41 Temporary Operating Guides. 1.1.45 Wind Data. 1.3 Applicability 1.5 Procedure for Interconnecting and Modifying Existing Facilities 1.6 Inspection and Review **Section 2 System Information and Design Practices: (updated and new material)** 2.1 Reliability Criteria 2.3 Voltage Variations 2.6.3 System Damping 2.6.5 Monitoring Facilities 2.10 Insulation Levels 2.12 Communication Systems 2.13Automatic Generation Controls 2.15 Station Battery 2.16 Operating Studies and Procedures 2.17 Modelling Data **Section 3 Generator Interconnection Requirements: (updated and new material)** 3.1 Interconnection Location and Voltage Level 3.2 Sealing of Technical Reports, Drawings, Memos, etc. 3.3 Operating Procedures 3.4 Reactive Power Requirements 3.5 Dynamic Reactive Power Requirements 3.6 Voltage Variations 3.7 Frequency Variations 3.9.5 Power Ramp Rates 3.9.6 Maximum Power Limit 3.9.8 Automatic Generation Control (AGC) 3.10 Synchronizing Facilities 3.11 Special Protection Systems (RAS) or Remedial Action Schemes (RAS) 3.12 Black Start Capability 3.13.1 Power Quality 3.14 Protection Requirements 3.16.1General (Revenue Metering) 3.16.2 Accuracy 3.16.7 Meter Seals 3.16.8 Meter Tests 3.16.9 Security Audit 3.17 Telemetering, Metering, and Supervisory Control and Data Acquisition (SCADA) 3.29 Modelling Data and Special Tests 3.34 Special Interconnection Requirements 3.35 Generation Forecasting **Section 4 Wind Generator Interconnection Requirements: (new**

			section). **Section 5 Customer Load Interconnection Requirements: (updated and new material)** 5.2 Sealing of Technical Reports, Drawings, Memos, etc. 5.6 Power Quality 5.8 Underfrequency Load Shed (UFLS) 5.12.1General (Revenue Metering) . 5.12.2 Accuracy 5.12.7 Meter Seals 5.12.8 Meter Tests 5.12.9 Security Audit 5.16 Insulation Levels 5.18 Lightning (Surge) Protection 5.19 Safety 5.20 Design Standards 5.23 Isolation 5.24 Transformer Connections 5.25 Verification of Load Demand Characteristics 5.26 Testing and Maintenance Coordination 5.29 Notification of New or Modified Facilities **Section 6 Transmission Owner Interconnection Requirements: (updated and new material)** 6.2 Sealing of Technical Reports, Drawings, Memos, etc. 6.12.1General (Revenue Metering) 6.12.2 Accuracy 6.12.7 Meter Seals 6.12.8 Meter Tests 6.12.9 Security Audit **Section 8 Figures (new)** **Section 9 References (updated)**
2	2009 04 17	N.A.	Update Document Change History. Add Section 2.18 Equipment Ratings. Modify Sections: 3.32, 5.28, 6.25 Coordinated Joint Studies. 3.33, 5.29, 6.26 Notification of New or Modified Facilities.
3	2010-09-15	N.A.	Move Document Change History to back. 1.1.20 MH (definition change) 1.1.25 MH Transmission System (definition change) 1.3 Applicability (Revised) 1.8 Disclaimer (New) 2.2 Voltage Levels (Revised) 2.3 Voltage Variations (Revised) 2.6.4 Transmission Line Protection Systems (Revised) 2.6.5 Bus Protection (New) 2.6.7 Special Protection Systems (New) 2.10 Insulation Levels (Revised) 2.11 Short Circuit Levels (Revised) 2.16 System Studies (Revised) 2.17 Reactive Power Margins (New) 2.18 Out-of-Step Relay Margins (New) 3.5 Dynamic Power Requirements (Revised) 3.7 Frequency Variations (Revised) 3.11 Special Protection Systems or Remedial Action Schemes (RAS). (Revised) 3.14 Protection Requirements (Revised) 3.16.2 Accuracy (Revised) 3.16.3 Metering configuration (Revised) 3.30 Commissioning Tests (New) 4.4 Reactive Power Capability/Control (Revised) 4.5.2 Frequency Response (Revised) 4.6 Low Voltage Ride Through (Revised) 4.7 Post Disturbance Recovery (Revised) 4.9 Modelling Data (Revised)

			4.10 Modelling Data Verification (Revised) 4.11 Special Commissioning Tests (Revised) 4.13 Operational Monitoring and Wind Data (Revised) 5.12.2 Accuracy (Revised) 5.13 Telemetering and Metering, Supervisory Control and Data Acquisition (Revised) 6.6.2 Electrical Loading Design Criteria (Revised) 6.6.3 External Electrical Effects (Revised) 6.9 Reclosing (Revised) 6.11 Special Protection Systems or Remedial Action Schemes (Revised) 6.12.2 Accuracy (Revised) 8.0 Figures (Revised) 9.0 References (Updated)
4	2016-01-14	TRC 179	1.1.40 Substantial Modification (Revised) Separate voltage criteria into separate sections (Revision): 2.2 Steady State 2.3 Transient 2.4 Post-contingency Separate frequency criteria into separate sections (Revision): 2.5 Normal and Variations 2.6 Transient 2.9, 3.16, 5.14 Protection and Control (Update) 2.9.2 Normal Fault Clearing Times (Update) 2.10 Under-frequency Load Shed (Update) 2.15, 3.14, 5.16 Communication Systems (Update) 2.20 Reactive Power Margins (Update) 2.21 Out-of-Step relay margins (New) 2.23 Equipment Ratings (Updated) 2.24 Station Ring Ratings (New) 2.25.3 GIC Monitoring (New) 2.27 HVDC Minimum Rating (New) 2.28 Domestic Load (New) 5.3 Customer Load Tapping (New) 5.8 Protection Requirements (Revised) 6.6.1 Structural Design Criteria (Update) Removal of process related items that are defined in other documents. Reverences to external documents included: Coordinated joint studies Notifications of modifications Distribution System Criteria Remove references to Individual NERC Standards instead refer to the Manitoba Hydro Act and the Reliability Standards Regulation throughout. Removal of generator modelling requirements as this is defined in the Reliability Standards Regulation.. Removal of the term "Network Load" as this scenario is not possible under The Manitoba Hydro Act. Complete Legal Review to ensure coordination with MH tariffs (OAIT & OATT).