Interconnection Feasibility Study Report

GIP-163-FEAS-R3

System Interconnection Request #163

60.0 MW Biomass Generating Facility

Richmond County (47C)

2009 06 26

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The interconnection Customer submitted an Interconnected Request to NSPI for a proposed 60.0 MW biomass generation facility interconnected to the NSPI 138kV transmission system at the existing substation 47C-NewPage. One new 138kV circuit breaker at 47C-NewPage and associate switches and protection are required, which must be designed to meet the NPCC Bulk Power System criteria.

No concern regarding short-circuit or voltage flicker was found for this project on its own, provided that the project design meets NSPI requirements for low-voltage ride-through, reactive power range and voltage control system. Harmonics must meet the Total Harmonics Distortion provisions of IEEE 519.

There is a potential to exceed the summer overload rating on L-6517 for loss of L-6518 or overload on L-6518 for loss of L6517 if the combined load at 1C, 46C, and 47C is below 25 MW. The existing Strait Area Transmission Overload Special Protection System must be modified to provide generation runback as well as load runback.

Loss of the Strait of Canso crossing double circuit tower with L-8004 and L-7005 results in exceeding the summer overload rating of L-7004 and L-6511 with two Lingan units rejected by SPS, and the arming level of the SPS must be reduced, unless the circuits are separated, which would require a new Strait Crossing to be constructed.

Increased flow across the Onslow Import and Onslow South interfaces requires 100 Mvar of switched capacitor banks at 120H-Brushy Hill. It can be located on either the 138kV or the 230kV bus, but is more economically situated on the 138kV bus.

Fault on the circuit breaker 67N-812, which results in the loss of L-8003 plus L-8002, requires at least 50 Mvar of dynamic reactive capability at 67N-Onslow, unless the 345kV bus at 67N-Onslow is re-configured with a new 345kV circuit breaker to ensure that no two lines share a common breaker.

The loss factor for IR #163 is approximately 10.5%.

Assuming that other projects with a higher queue position do not proceed, the direct cost of interconnection is estimated to be $28,604,000.00. This non-binding estimate will be further refined in the System Impact Study, and the Facility Study.

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1 Introduction

The Interconnection Customer submitted an Interconnection Request for Network Resource Integration Service to NSPI for a proposed 60.0 MW biomass generation facility interconnected to the NSPI 138kV transmission system at the existing 47C-NewPage substation in Richmond County.

The Interconnection Customer signed a Feasibility Study Agreement to study the connection of their proposed generation to the NSPI transmission system, dated 2008 05 16, and this report is the result of that Study Agreement. This project is listed as Interconnection Request #163 in the NSPI Interconnection Request Queue, and will be referred to as IR #163 throughout this report.

2 Scope

The Interconnection Feasibility Study (FEAS) report shall provide the following information:

1. Preliminary identification of any circuit breaker short circuit capability limits exceeded as a result of the interconnection;
2. Preliminary identification of any thermal overload or voltage limit violations resulting from the interconnection;
3. Preliminary description and non-bonding estimated cost of facilities required to interconnect the Generating Facility to the Transmission System, the time to construct such facilities, and to address the identified short circuit and power flow issues.

The Scope of this FEAS includes modeling the power system in normal state (with all transmission elements in service) under anticipated load and generation dispatch conditions.

For Network Resources Integration Service (NRIS), the FEAS will identify any transmission upgrades required as the result of thermal overload, voltage violation, or equipment rating. The FEAS will attempt to provide high level cost estimates for such upgrades and direct interconnection costs.

A more detailed analysis of the technical implications of this development will be included in the System Impact Study (SIS) report. This will include system stability analysis, single contingencies (including contingencies with more than one common element), off-nominal frequency operation, off-nominal voltage operation, low voltage ride through, harmonic current distortion, harmonic voltage distortion, system protection, special protection systems (SPS), automatic generation control (AGC) and islanded operation. The impacts on neighboring power systems and the requirements set by reliability authorities such as Northeast Power Coordinating Council (NPCC), North American Electric Reliability Corporation (NERC), and NSPI will be addressed at that

time. The SIS may identify additional costs and upgrades that were not identified in this FEAS.

A separate Facilities Study will follow the SIS in order to ascertain the final cost estimate for the transmission upgrade requirements.

3 Assumptions

The Point of Interconnection (POI) and configuration studied is as follows:

1. 60.0 MW biomass with a single synchronous generator, and has requested NRIS service type.
2. The generation technology used must meet NSPI requirement for reactive power capability of 0.95 capacitive to 0.95 inductive at the 47C-NewPage 138kV bus. The generator is specified for 60 MW at a rated power factor of 0.85. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the generator terminals during and following disturbances.
3. The Interconnection Customer indicated interconnection at the 138kV bus of 47C-NewPage substation. The biomass generating facility will be connected by approximately 500m of 138kV cable to the 47C-Newpage Substation, with a low voltage generator circuit breaker.
4. Preliminary data was provided for the generator step-up transformer. Modeling was conducted using a 138kV-13.8kV 60/80 MVA transformer with a positive sequence impedance of 12% on the ONAN rating of 60 MVA. It was indicated that the step-up transformer is configured as a wye-delta-wye configuration with on-load tap on the 138kV side with the range of +/- 15% in 21 taps.[1]
5. The FEAS analysis is based on the assumption that IR's higher in the Generation Interconnection Queue (Queue) will not proceed; however, in accordance with UARB Order P890 projects IR #45, IR #82, IR #84, IR #114, IR #137/150 and IR #141 are included in this study.
6. The existing generation at 47C-NewPage (approximately 25 MW) is operating coincident with IR #163.
7. The load at 47C-NewPage is considered interruptible, and therefore this study assumes that this load is at minimum (10 MW).

[1] It should be noted that this is an unusual configuration for a synchronous generator, which generally are equipped with off-load taps.

4 Projects with Higher Queue Positions

As of 2009 06 10 the following projects can proceed ahead of this project, due to their position in the Generation Interconnection Request Queue, and have the status (as of 2009 05 19) indicated.

In-service and committed generation projects

- Wind Generation - 30.5 MW - connected to L-5027 (in-service)
- Wind Generation – 15 MW – connected to L-5573 (in-service)
- Wind Generation – 25MW - distribution connected (in-service)
- IR #45 Wind – Cumberland County L-6535 30 MW – GIA Tendered
- IR #82 Wind – Colchester County L-5040 45 MW – GIA Executed
- IR #84 Wind – Pictou County L-7004 50 MW – GIA Executed
- IR #114 Wind – Pictou, L-6511, 60MW – FAC in Progress
- IR #137/150 Wind – Richmond, 1C, 22MW – FAC in Progress
- IR #141 Wind – Digby, 77V, 30MW – FAC in Progress

Generation projects with a higher Queue position, not yet committed:

- IR #8 Wind – Guysborough County L-5527B 15 MW – GIA Tendered
- IR #56 Wind – Cumberland County L-5058 34 MW – FAC in Progress
- IR #67 Wind – Annapolis County L-5026 40 MW – SIS in Progress
- IR #68 Wind – Digby County L-5533 35 MW – SIS in Progress
- IR #86 Wind – Pictou County L-7003 50MW – SIS in Progress
- IR #115 Wind – Pictou, L-7003, 120MW – SIS in Progress
- IR #117 Wind – Shelburne, L-5027, 10MW – SIS Agreement Complete
- IR #126 Wind – Cumberland, L-6513, 70MW – SIS Agreement Complete
- IR #128 Wind – Cumberland, L-6536, 40.5MW – SIS Agreement Complete
- IR #130 Wind /hydro pumped storage – Cape Breton, L-6516, 200MW – SIS Agreement Complete
- IR #131 Wind – Cape Breton, L-5580, 11.5MW – SIS Agreement Complete
- IR #140 Wind – Antigonish, L-7004, 30MW – SIS Agreement Complete
- IR #149 Wind – Cumberland, L-6536, 70MW – SIS Agreement Complete
- IR #151 Steam Turbine – Halifax, 91H, 50 MW – SIS Agreement Complete
- IR #156 Wind – Antigonish, L-6511, 49.5 MW – FEAS in progress
- IR #157 Wind – Guysborough, L-6515, 100 MW – FEAS in progress
- IR #160 Wind – Colchester, L-5040, 45 MW – Interconnection Request Valid

There are various congested interfaces that will be affected by this IR# 163 and also other projects which have not yet been committed, but are ahead of IR#163 in the queue, as noted below.

Interface	Projects Influencing Interface (not yet committed)
Cape Breton Export	IR #130, IR #131, IR #163
Onslow Import	IR #8, IR #86, IR #115, IR #130, IR #131, IR #140, IR #156, IR #157 and IR #163
Onslow South	IR #8, IR #56, IR #86, IR #115, IR #126, IR #128, IR#130, IR#131, IR#140, IR #149, IR#156, IR#157, IR #160 and IR #163

If any of the projects ahead of IR #163 proceed, the results of this feasibility study must be updated to reflect the impact of increased interface flow on IR #163, and any transmission upgrades that might be required for this or other projects ahead in the queue.

The SIS[2] will be based on the assumption that all the projects that are ahead of this project in the Queue are in-service. Should any project that is ahead of this project be withdrawn, or changed, within the established procedures then the SIS for this project must be updated accordingly, at the Interconnection Customer's expense.

5 Objective

The objective of this feasibility study is to determine the primary physical requirements to interconnect 60.0 MW of generation at the designated location. The assessment will identify potential impacts on the loading of transmission elements, which must remain within their thermal limits. Any potential violations of voltage criteria will be identified and addressed. If the proposed new generation increases the short-circuit duty of any circuit breakers beyond their rated capacity, the circuit breakers must be upgraded. Single contingency criteria[3] are applied for the Network Resource Interconnection Service assessment.

This FEAS does not produce a binding estimate of all costs and changes that may be required to interconnect the facility. These costs are limited to facility additions/changes that are in the immediate vicinity of the proposed generating facility and any other system costs that are foreseen at the time this report is completed.

This assessment does not include a complete determination of facility changes/additions required to increase system transfer capabilities that may be required to the Bulk Power System to meet the design and operating criteria established by the Northeast Power Coordinating Council (NPCC) and/or the North American Reliability Corporation (NERC) or required to maintain system stability. These requirements will be determined by the subsequent interconnection System Impact Study (SIS).

[2] This process could change depending on the decision of the UARB with regard to "NSPI Application to Amend the Generation Interconnection Procedures (GIP) - P890"

[3] The Single Contingency Criteria is defined by NPCC in its A-7 Document, and may involve more than one transmission element.

6 Short-Circuit Duty

The maximum (future) expected short-circuit level on 138kV systems is 5000 MVA. The short-circuit levels in the area before and after this development are provided in Table 5-1 below.

Table 6-1: Short-Circuit Levels. Three-phase MVA [1]		
Location	**IR #163 in service**	**IR #163 not in service**
All transmission facilities in service		
47C-NewPage 138kV	2088	1938
1C-Point Tupper 138kV	2110	1975
2C-Port Hastings 138kV	2522	2400
Minimum Conditions		
138kV Interconnection Point	1466	1235

[1] Classical fault study, flat voltage profile

The maximum short-circuit level at the POI is presently 1938 MVA. After installing IR #163 the increase will bring the short-circuit level to 2088 MVA at the POI. Under contingency operation, with the generator at 1C-Point Tupper and the generators and synchronous motors off-line at 47C-Newpage and L-6518 open at 2C-Port Hastings, the short-circuit level will be approximately 1235 MVA at the POI. This translates into maximum equivalent system impedance at the POI of 0.081 per unit on 100 MVA base.

The interrupting capability of 138kV circuit breakers in the vicinity of 47C-NewPage is at least 3500 MVA which will not be exceeded by the addition of IR #163 on its own.

7 Voltage Flicker and Harmonics

The generator is a conventional synchronous machine with a high-speed excitation system and therefore voltage flicker is not expected to be not a concern for this project. The generator is expected to meet IEEE Standard 519 limiting Total Harmonic Distortion (all frequencies) to a maximum of 5%, with no individual harmonic exceeding 1%.

8 Thermal Limits

Line L-6517 and L-6518 have a continuous summer rating of 215 MVA based on an ambient temperature of 25ºC. The total net generation in the area is currently 202 MW, rising to 262 MW with the addition of IR #163. The summer overload rating of each of these lines is 236 MVA, so when the total load at 1C, 46C and 47C is less than 26 MW, there is the potential for overload of a circuit for contingency loss of the other circuit. Since these lines were uprated to their maximum capacity as part of the SEPH upgrade,

there is no opportunity for further upgrade. For ambient temperatures above 25º (historically less than 50 hours per year), the rating of the lines in the area would be further reduced.

It should be noted that the load itself at 47C-NewPage can exceed the thermal rating of these circuits for the same contingencies; however this is presently managed through the use of a Special Protection System (SPS) which automatically curtails non-firm load at 47C-NewPage if the contingencies of concern result in line overload. If the overload occurs due to excess generation instead of excess load, then the existing SPS would make the situation worse, and therefore it must be modified. The details of this modification will be developed in the SIS and FAC.

IR #163 adds 60 MW to the Onslow Import interface, which is currently limited to 1050 MW. If the interface is operated at 1106 MW (1150 + 60 – incremental losses), then loss of the double-circuit tower at the Strait of Canso trips L-8004 plus L-7005 resulting in line L-7019 loaded to 115% of its normal summer rating, following activation of the SPS which trips two units at Lingan and a pre-contingency curtailment of IR-84 to 30 MW.

With generation at 50N-Trenton reduced by one unit, increased generation at 47C-NewPage results in a higher percentage of the power from Cape Breton to flow on the 138kV system. The Strait of Canso double-circuit tower contingency results in line L-6511West loading to 125% of its normal summer rating as well as L-7019 loaded to 115% of its normal summer rating (following the activation of the SPS that trips two Lingan units).

The present setting for the SPS associated with the loss of the double-circuit Strait of Canso crossing requires tripping one Lingan unit when Cape Breton Export exceeds 600 MW and two Lingan units when Onslow Import exceeds 900 MW. The addition of IR #114 and IR #137/150 requires a reduction of 100 MW to each of these arming levels (to 500 MW and 800 MW respectively). If these changes are not made because of a change in the status of prior projects, the setting changes would be required for IR #163.

The recommended solution to these overloads is the re-configuration of the lines L-8004 and L-7005 that currently share common towers at the Strait of Canso. This will require the construction of a new Strait Crossing, and moving one of the circuits to the new tower circuit. This is estimated to cost $20,974,000.

9 Voltage Limits

This project, like all new generating facilities must be capable of providing both lagging and leading power factor of 0.95, measured at the 138kV terminals of the biomass substation, at all production levels up to the full rated load of 60.0 MW. The generator must be equipped with a high-speed continuously-acting automatic voltage regulator set to control its 13.8kV terminals to a value established by the NSPI System Operator. The

details of the specific control features, control strategy and settings will be reviewed and addressed in the SIS, as will the dynamic performance of the generator and its excitation.

The NSPI System Operator must have manual and remote control of the voltage set-point and the reactive set-point of this facility to coordinate reactive power dispatch requirements.
This facility must be capable of staying on-line during and following a three-phase fault on the 138kV bus at 47C-NewPage, cleared in 100ms (6 cycles). The performance of the generator controls to meet this requirement will be studied in detail in the SIS.

With the proposed generator step-up transformer impedance of 12% on 60 MVA, and the rated generator power factor of 0.85 measured at the machine 138.kV terminals, the net power factor requirements of 0.95 measured at the Point of Interconnection can be achieved.

The Onslow Import and Onslow South interfaces are both stability limited and voltage limited. IR #163 will increase flows across these interfaces, exceeding present limits. Stability will be addressed in Section 10 below, and voltage violations are addressed in this section. The Onslow South interface limit is a function of the reactive power (Mvar) dispatch and associated reactive power reserve in the Metro area. Higher transfer levels are possible if reactive power is kept in reserve to respond to contingencies. However, as power transfer increases across the Onslow South Interface, the resulting increase in steady-state reactive power requirements reduces the available reserve. It is recommended that 100 Mvar of switched reactive power be added in the Metro Area (FEAS assumed 120H-Brushy Hill 138kV bus) to ensure the existing reactive power is available to respond to contingencies. The cost of this capacitor bank and associated switchgear is estimated to be $2,760,000.

The two 345kV transmission line L-8003 and L-8002 share a common circuit breaker 67N-812 at 67N-Onslow. NPCC requires that systems remain stable and all bulk power transmission voltages remain within emergency limits following a single phase fault on a circuit breaker, or a single phase fault on a transmission line combined with the failure of a circuit breaker to operate. Loss of L-8003 and L-8002 due to fault or failure of 67N-812 breaker is the most limiting fault for the Onslow Import and Onslow South interfaces, resulting in voltage collapse in Metro or instability in eastern NS. Two alternatives were examined for IR #163: addition of a Static Var Compensator (SVC) at 67N-Onslow or the reconfiguration of the 345kV bus at 67N-Onslow to eliminate the contingency of most concern. If an SVC is installed at Onslow, it would need to be rated at 50 Mvar[4] at an estimated cost of $8,200,000. The second alternative includes the addition of a new 345kV circuit breaker at 67N-Onslow and swapping the connection points of L-8003 and 67N-T82 such that no two lines share a common breaker. The latter option is estimated to cost $3,720,000, and is the recommended action.

[4] The SVC size is based on the assumption that 100 Mvar of switched capacitors are added to 120H-Brushy Hill.

10 System Security / Stability Limits

The NSPI transmission system has limited east to west transfer capability. Transmission corridors between Sydney and Halifax are often operated to security limits. This project increases flow across the Cape Breton Export, the Onslow Import, and the Onslow South interfaces. Generation rejection Special Protection Systems[5] (SPS's) are utilized to increase system stability limits to maximize east to west power transfers. Depending on the impact of other generation additions ahead of this project in the Interconnection Request Queue, the additional generating capacity that this facility provides may not be integrated into the NSPI system under all dispatch conditions without system upgrades.

Under some dispatch conditions with certain contingencies, transmission corridors become overstressed, which may require transmission system upgrades. Section 9 demonstrated the issues associated with thermal overload of transmission for the loss of the double circuit tower at the Strait of Canso, for which it is recommended that the circuits be separated. The SIS will determine if this action solves the stability issues associated with the congested interfaces.

Section 9 recommended the addition of a switched capacitor bank at 120H-Brushy Hill and the reconfiguration of the 67N-Onslow 345kV bus to increase the Onslow Import and Onslow South interface flow limits. The SIS will examine the stability aspects of these changes, and any change in setting of SPS's that might be affected.

In general, the SIS will determine the facility changes that are required to permit higher transmission loadings while maintaining compliance with NERC/NPCC standards and in keeping with good utility practice.

11 Expected Facilities Required for Interconnection

We expect the following facilities will be required assuming that the projects ahead of this project in the Interconnection Request queue, except IR# 45, IR #82, IR #84, IR #114, IR #137/150 and IR #141, do not proceed.

Additions/Changes to NSPI systems

1. One new 138kV circuit breaker and associated switches at 47C-NewPage ring bus, between breakers 47C-605 and 47C-673[6] .
2. Protection systems designed to NPCC Bulk Power System criteria,

[5] Also known as Remedial Action Schemes, SPS's are defined by NPCC as "A protection system designed to detect abnormal system conditions, and take corrective action other than the isolation of faulted elements." *NPCC Document A7 - Glossary of Terms*.

[6] 138kV cable to generator step-up transformer is not included in this estimate.

3. Construct new transmission structures across the Strait of Canso, and relocate L-7005 to the new structures,
4. Addition of 100 Mvar capacitor bank at 120H-Brushy Hill 138kV with associated switchgear and protection, designed to NPCC BPS criteria.
5. New 345kV circuit breaker and associate switches at 67N-Onslow, at the node between breaker 67N-815 and bus 67N-B82. Breaker node swap at 67N-Onslow for L-8003 and 67N-T82, with associated protection and SPS modifications.
6. Modification of the Strait Area Overload Protection SPS (NPCC designation #139) to accommodate excess generation in addition to excess load.

Requirements for the Generating Facility

1. Facilities to provide 0.95 leading and lagging power factor when delivering rated output (60.0 MW) all at the 138kV bus when the voltage at that point is operating between 95 and 105 % of nominal.
2. Centralized controls. These will provide centralized voltage set-point controls and reactive power set-point controls acting to control the voltage on the 138kV system and the reactive output of the machines. Responsive (fast-acting) controls are required. The controls will also include a curtailment scheme which will limit or reduce total output from the facility, upon receipt of a telemetered signal from NSPI's SCADA system. The controller will also limit the load ramp rate of the facility to within limits set by NSPI and/or telemetered from NSPI's SCADA system.
3. NSPI to have control and monitoring of reactive output of this facility, via the centralized controller. This will permit the NSPI Operator to raise or lower the voltage set-point and change the status of any reactive power controls, remotely.
4. Low voltage ride-through capability equivalent to FERC Order 661a[7] .
5. Real-time monitoring (RTU's) of the interconnection facilities for NSPI to execute high speed rejection of generation (transfer trip).

12 NSPI Interconnection Facilities Cost Estimate

Estimates for NSPI Interconnections Facilities are included in Table 12-1.

[7] FERC Order 661A addresses the requirement for wind-powered generation to ride-through faults in a manner similar to traditional synchronous generator. This reference is meant to indicate that IR #163 must meet the same requirement to remain on-line during and following a fault.

Table 12-1: Cost Estimates		
	Determined Cost Items	**Estimate**
i	Strait of Canso crossing, separate L-7005 and L-8004	$20,974,000
ii	Install 100 Mvar switched capacitor bank and associated switchgear and protection at 120H-Brushy Hill	$2,760,000
iii	New circuit breaker and node swap at 67N-Onslow 345kV	$3,720,000
iv	138kV circuit breaker at 47C-NewPage	$1,000,000
v	SPS Modification	$50,000
vi	Protection, control, communication	$100,000
	Total of Determined Cost Items	$28,604,000
	To be Determined Costs	
vii	System additions to address potential stability limits	TBD (SIS)

13 Issues to be Addressed in SIS

The SIS must determine the facilities required to operate this facility at full capacity, withstand the contingencies as defined by NPCC/NERC and identify any restrictions that must be placed on the system following a first contingency loss. The SIS will be conducted with the assumption that all projects higher-queued will proceed and the facilities associated with those projects are installed.

The assessment will consider but not be limited to the following. The facility additions/changes required to increase NSPI east to west transfers under system normal conditions (all transmission in) over the range of NSPI loads and with interruptible loads on or off. Some of the constrained interfaces that will be included in the assessment are as follows.

1. Cape Breton Export
2. Onslow Import
3. Onslow South
4. Metro reactive reserve requirements
5. NS – NB export/import

Steady-State Post-contingency Analysis

All elements within acceptable voltage and thermal limits under the following single contingencies, in accordance with NPCC[8] and NERC[9] criteria

1. L-6517
2. L-6518

[8] NPCC criteria are set forth in it's A-2 Document *Basic Criteria for Design and Operation of Interconnected Power Systems*

[9] NERC transmission criteria are set forth in *NERC Reliability Standards TPL-001, TPL-002, TPL-003*

3. 2C-Port Hastings 138kV bus outage
4. L-8004
5. Hopewell transformer 79N-T81
6. L-8003
7. Circuit breaker 67N-812 (L-8002 plus L-8003)

System stability for the following faults

Loss of any element without a fault

1. L-8004
2. Hopewell transformer 79N-T81
3. L-8003

Three-phase fault cleared in normal time:

1. L-6518 at 47C-NewPage
2. L-8004 at Woodbine end
3. L-8004 at Hopewell end
4. L-8003 at Onslow end
5. L-8003 at Hopewell end
6. 79N-T81 transformer at 345kV (trip L-8004 + L-8003)
7. L-8001 at import (NS islanded with under-frequency) and export limits

Single-phase to ground fault cleared in backup time (Breaker Failure)

1. L-8003 at Onslow with failure of 79N-803 (lose L-8004)
2. L-8003 at Onslow with failure of 67N-811 (lose 67N-T82)

Single-phase to ground fault on separated circuits of double-circuit tower:

1. L-7003 plus L-7004 at Canso Causeway

Aside from the required change to the Strait Area Overload Protection SPS, any changes to SPS schemes required for operation of this generating facility, in addition to existing generation and facilities that can proceed before this project, will be determined by the SIS as well as any required additional transmission facilities. The determination will be based on NERC and NPCC criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

The SIS will calculate the unit loss factor, which is a measure of the percentage of the net output of IR #163 which is lost through the transmission system. Preliminary value is calculated to be 10.5% (system losses increase by 6.3 MW when IR #163 is operated at 60 MW.

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