CONNECTION ASSESSMENT & APPROVAL PROCESS

ASSESSMENT SUMMARY

Applicant: Northland Power Inc

Project: AVR Replacement for Kirkland Lake G1, G2 and G4

CAA ID: 2011-EX559

Final Report

IESO EXPEDITED SYSTEM IMPACT ASSESSMENT – 2011-EX559

1. Project Description

Northland Power Inc plans to replace the AVR for the Kirkland Lake Units G1, G2 and G4 The replacement is scheduled to be done sometime during September, 2011.

2. Market Rule Requirements for excitation systems

The requirements for exciters on Generation facility directly connected to the IESO-controlled grid are listed in Appendix 4.2 in the Market Rules, as follows:

An excitation system should be able to provide:

(a) Positive and negative ceilings not less than 200% and 140% of rated field voltage at rated terminal voltage and rated field current.

(b) A positive ceiling not less than 170% of rated field voltage at rated terminal voltage and 160% of rated field current.

(c) A voltage response time to either ceiling not more than 50 ms for a 5% step change from rated voltage under open-circuit conditions.

(d) A linear response between ceilings.

The requirements for Power System Stabilizer (PSS) on Generation facility directly connected to the IESO-controlled grid are listed in Appendix 4.2 in the Market Rules, as follows:

Power system stabilizer should be able to provide:

(a) A change of power and speed input configuration.

(b) Positive and negative output limits not less than ±5% of rated AVR voltage.

(c) Phase compensation adjustable to limit angle error to within 30° between 0.2 and 2.0Hz under conditions specified by the IESO.

(d) Gain adjustable up to an amount that either increases damping ratio above 0.1 or elicits exciter modes of oscillation at maximum active output unless otherwise specified by the *IESO*. Due consideration will be given to inherent limitations.

3. Requirement for Northland Power Inc

Since the connection applicant plans to replace just the AVR portion of the rotating excitation system, which is considered a non-major change, the excitation system has to maintain existing performance as approved for the initial connection, as opposed to meeting the prevailing market rules.

The connection applicant must complete the IESO Facility Registration/Market Entry process in a timely manner before IESO final approval for connection is granted. Models and data, including any controls that would be operational, must be provided to the IESO.

If the submitted models and data differ materially from the ones used in this assessment, then further analysis of the project will need to be done by the IESO.

4. Data Verification

The connection applicant provided the existing dynamic models for generator, excitation system, PSS, and turbine-governor as follows.

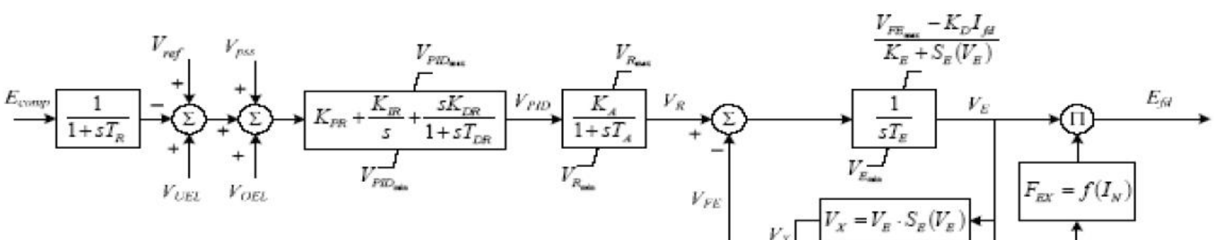
3.1. Generator Model

CONs	Value	Description
J	7.0	T'_{do} (>0) (sec)
J+1	0.04	T'_{do} (>0) (sec)
J+2	1.0	T'_{qo} (>0) (sec)
J+3	0.05	T''_{qo} (>0) (sec)
J+4	2.3	H, Inertia
J+5	0.0	D, Speed damping
J+6	2.06	X_d
J+7	1.94	X_q
J+8	0.17	X'_d
J+9	0.25	X'_q
J+10	0.141	$X''_d = X''_q$
J+11	0.121	X_l
J+12	0.078	S(1.0)
J+13	0.233	S(1.2)

3.2. Replacement Excitation System Model

AC8B: IEEE 421.5 2005 AC8B Excitation System

CONs	Value	Description
J	0	T_R (sec) regulator input filter time constant
J+1	84	K_{PR} (pu) regulator proportional gain
J+2	5	K_{IR} (pu) regulator integral gain
J+3	10	K_{DR} (pu) regulator derivative gain
J+4	0.1	T_{DR} (sec) regulator derivative block time constant
J+5	86.22	V_{PIDMAX} (pu) PID maximum limit
J+6	0	V_{PIDMIN} (pu) PID minimum limit
J+7	1	K_A (pu) voltage regulator proportional gain
J+8	0	T_A (sec) voltage regulator time constant
J+9	86.22	V_{RMAX} (pu) regulator output maximum limit
J+10	0	V_{RMIN} (pu) regulator output minimum limit
J+11	0.9	K_C (pu) rectifier loading factor proportional to commutating reactance
J+12	2.36	K_D (pu) demagnetizing factor, function of AC exciter reactances
J+13	1	K_E (pu) exciter constant related fo self-excited field
J+14	1	T_E (pu) exciter time constant
J+15	14.3	V_{FEMAX} (pu) exciter field current limit (> 0)
J+16	0	V_{EMIN} (pu)
J+17	12	E1
J+18	0.53	S(E1)
J+19	16.0	E2
J+20	4.4	S(E2)



$$F_{EX}(I_N)=\begin{cases}1 & I_N\le 0\\ 1-0.577I_N & 0<I_N\le 0.433\\ \sqrt{0.75-I_N^2} & 0.433<I_N<0.75\\ 1.732(1-I_N) & 0.75\le I_N\le 1\\ 0 & I_N>1\end{cases}$$

4. Assessments

4.1. Exciter performance

Section 2 of this report outlines the performance requirements for the synchronous generator excitation systems. Exciter performance for Kirkland Lake units G1, G2 and G4 were checked to verify the positive and negative ceilings of the exciter, voltage response time of the excitation system.

Positive ceiling test

Rated field voltage ($E_{fd\ rated}$) was determined using the IESO controlled grid base case and the generator and the new excitation system models provided by the Northland Power. $E_{fd\ rated}$ for Kirkland Lake units is shown in the table below.

Description	Value	Units
Rated Voltage	1.0	pu
Rated Active Power	25.5	MW
Maximum Reactive Power	12.3	Mvar
Rated Field Voltage	2.76	pu
Rated Field Current	2.76	pu

Table 1: Rated Field voltage and current

Response ratio test was performed to determine the positive ceiling limit for the excitation system. Market Rule requires that the excitation system should be able reach a positive ceiling of 200% of the $E_{fd\ rated}$.

Required Positive ceiling = 2 x $E_{fd\ rated}$ = 2x 2.76 = 5.52 p.u

Exciter positive ceiling response = 5.84 p.u

Simulations show that the excitation system positive ceiling response meets the Market rule requirement.

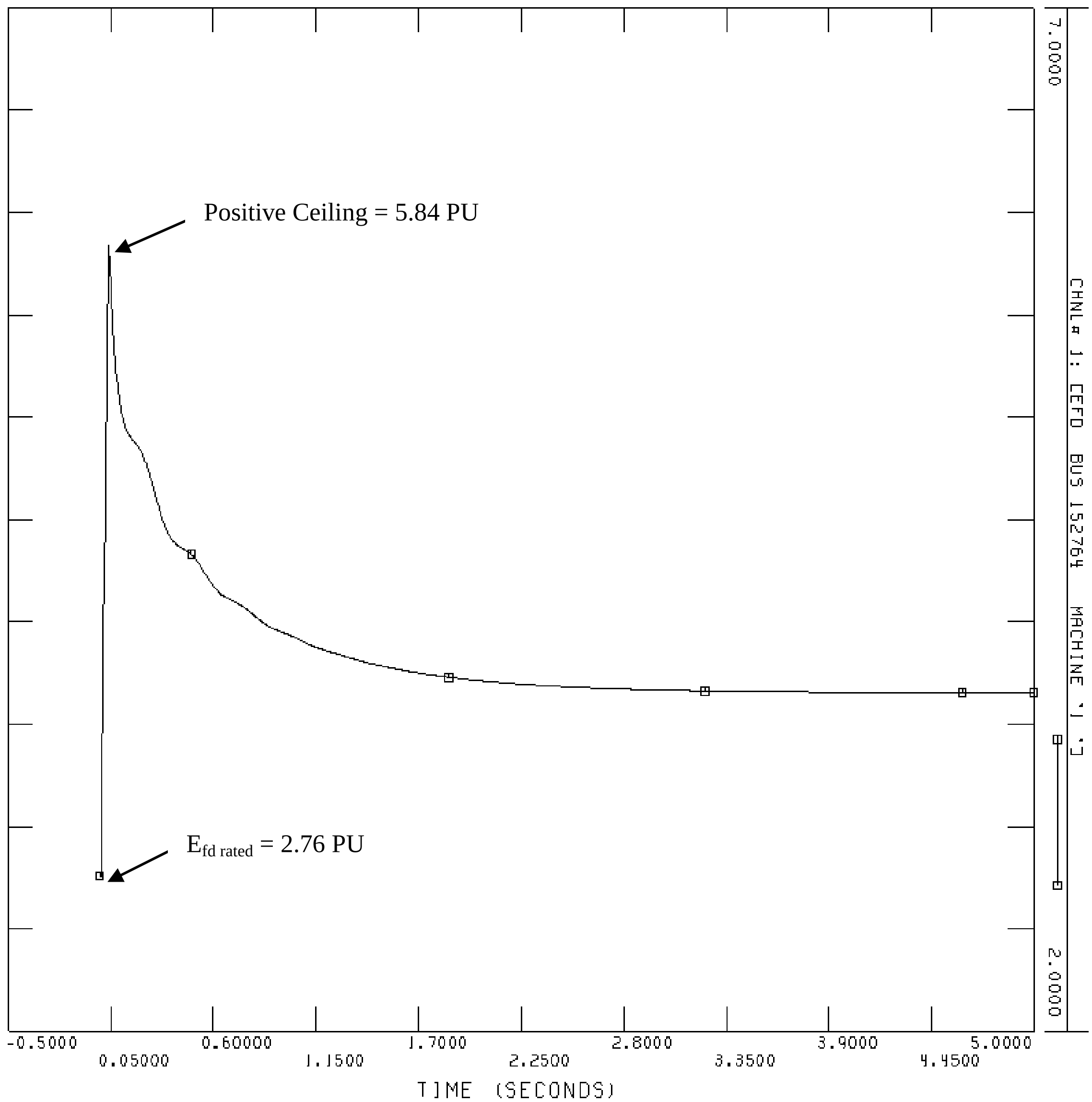


Figure 1: Positive ceiling

Negative ceiling test

Market rules stipulate that excitation system for the synchronous generators should be able provide a negative ceiling of 140% of the $E_{fd\ rated}$.

Required negative ceiling= - ($E_{fd\ rated}$ x 1.4) = - (2.76 x1.4) = -3.864 p.u

Exciter negative ceiling response= 0.0 p.u

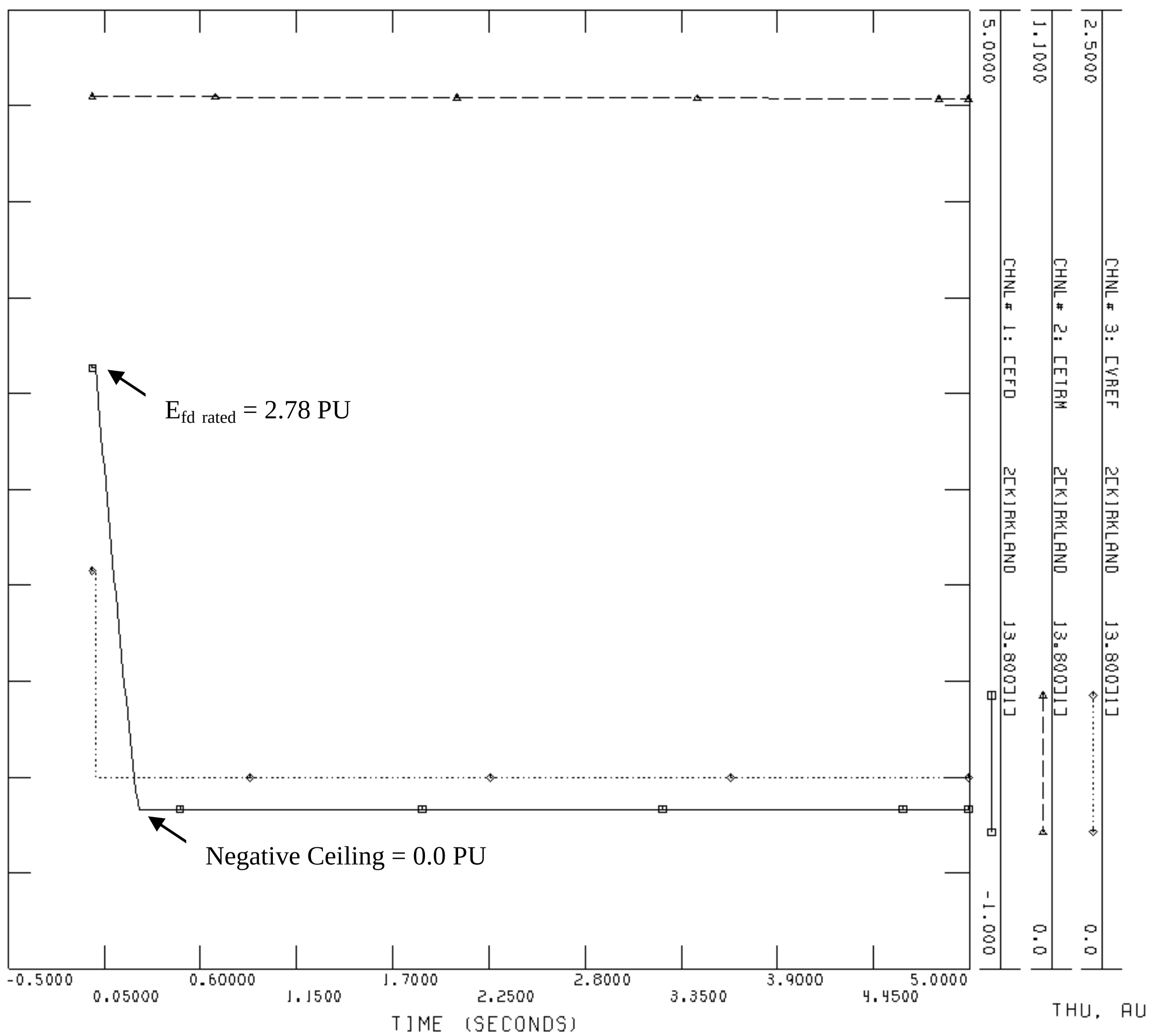


Figure 2: Negative ceiling

Voltage response time

Market rules requires that the voltage response time to either ceiling should be not more than 50 ms for a 5% step change from rated voltage under open-circuit conditions. An open circuit test was performed to verify the voltage response time for the excitation system for Kirkland Lake unit G1.

Positive ceiling voltage response time

For positive ceiling a reference voltage step change of 5% was simulated to verify that the excitation system is capable of reaching 1.95 x $E_{fd\ rated}$ within 50 ms.

Using the equation given below voltage response time for field voltage at $E_{fd\ rated}$ is converted to voltage response time for open circuit field voltage ($E_{fd\ oc}$)

$E_{fd\ oc}$= 1.0780 p.u

RT_{OC_POS}=82.07 ms

Required E_{fd} (positive) ceiling =1.95 x $E_{fd\ rated}$ = 1.95x 2.76 =5.382 p.u within 82.07 ms

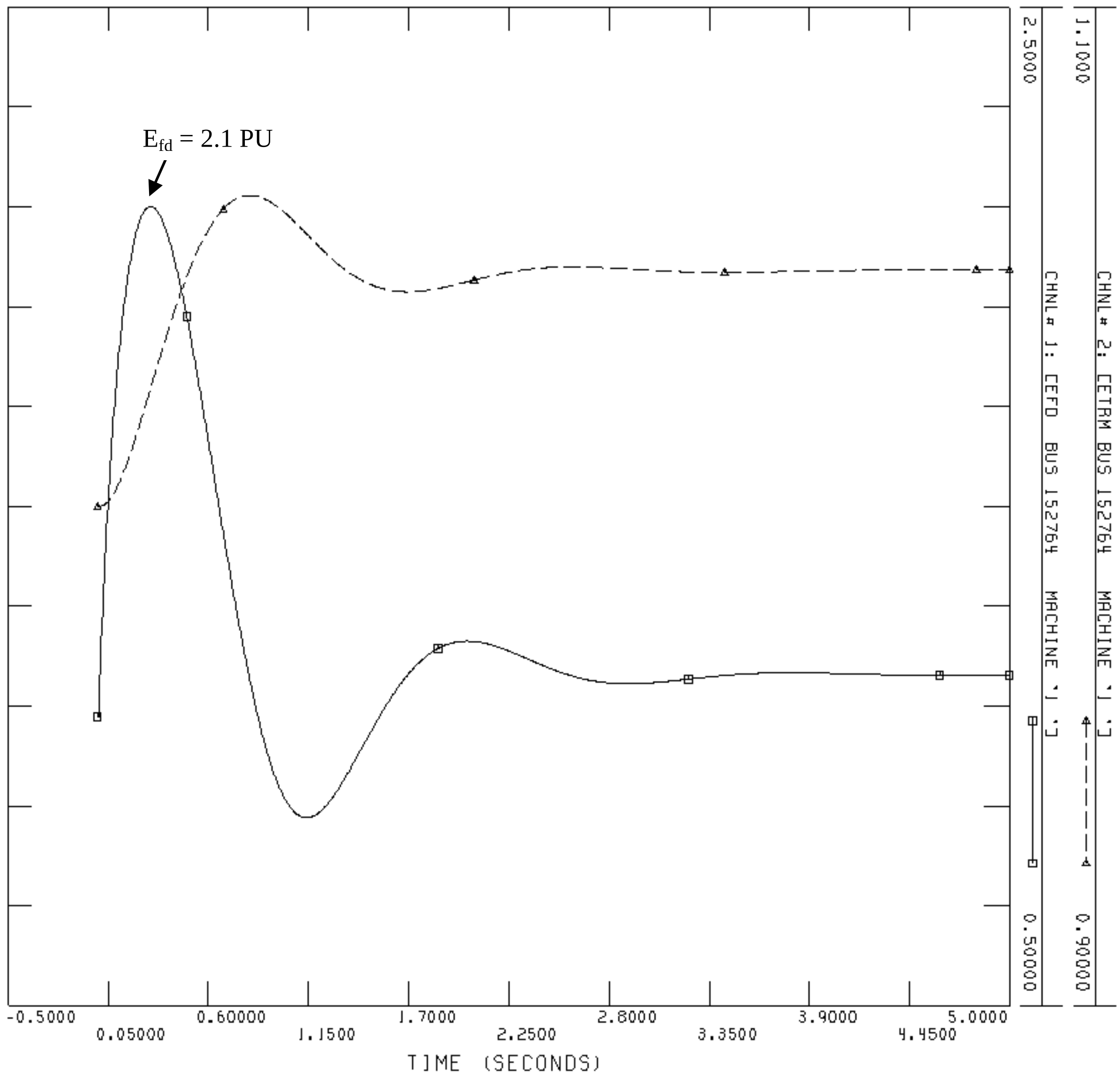


Figure 3: Positive ceiling voltage response time

Plot for open circuit test (Figure 3) shows that excitation system reaches the E_{fd} of 2.1 p.u in 25.2 milliseconds for a voltage reference step change of +5 %.

Negative ceiling voltage response time

Starting from $E_{fd\ rated}$, the excitation system should be able to reach a negative ceiling of 128% within 50 ms for a voltage reference step change of -5%. Test results are translated to open circuit voltage response time by using the equation given below.

From the open circuit test, with -5 % step change in voltage reference following results were obtained.

$E_{fd\ oc}$=1.0866 p.u

Required E_{fd} (negative) ceiling= -1.28 x $E_{fd\ rated}$= - 3.53 p.u

RT_{OC_NEG} = 36.70 ms

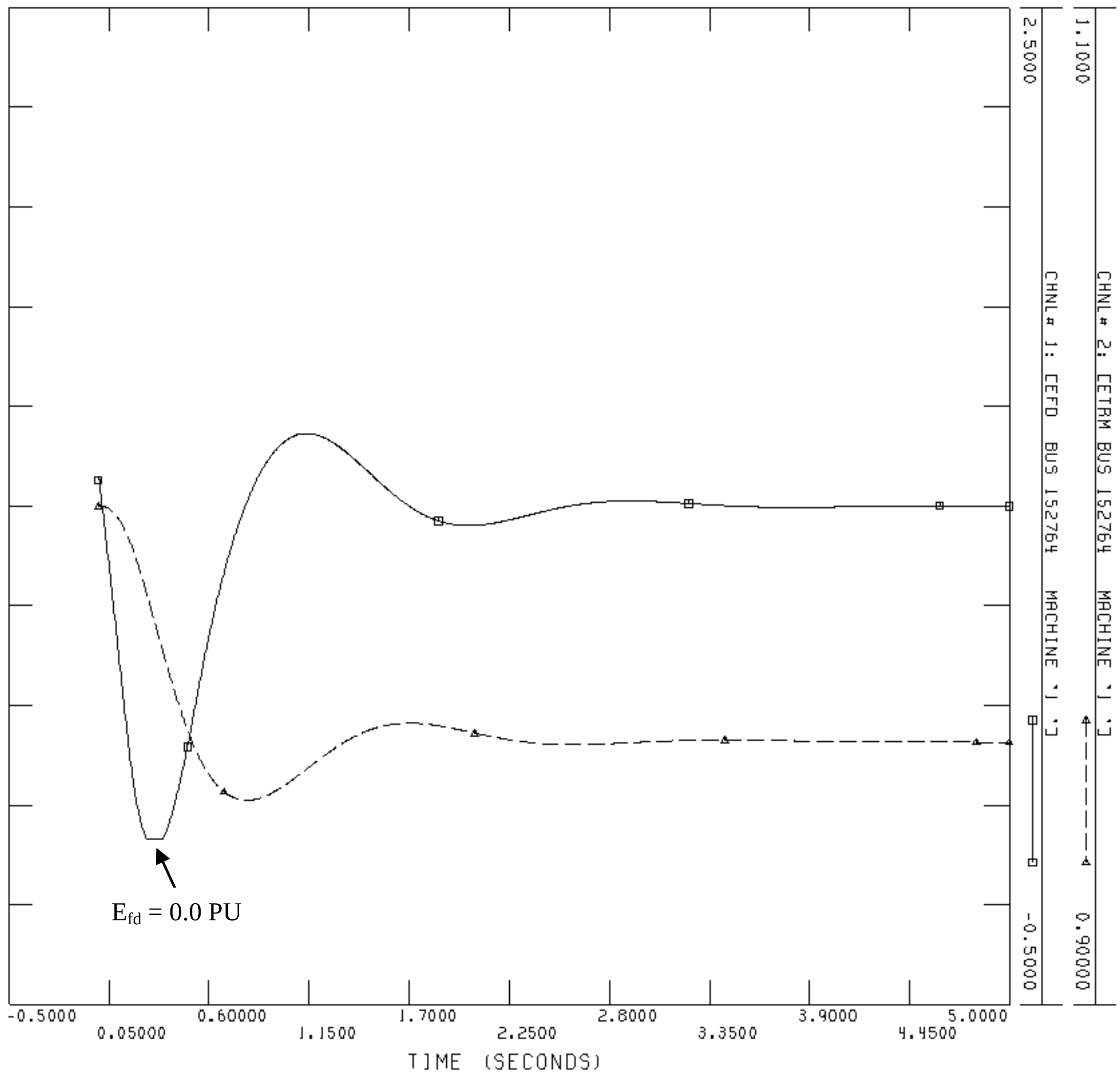


Figure 4: Negative ceiling voltage response time

Figure 4 depicts that excitation system reaches a negative ceiling of 0.0 p.u in 25.7 mili seconds for voltage reference step change of -5%.

5. Conclusions and Requirements

During the Market Entry process, the applicant is required to update the data and models of Kirkland Lake GS based on the latest field testing results.

The applicant is required to ensure that the performance of the equipment that is eventually supplied and installed at Kirkland Lake GS is similar to or exceeds the performance of the existing system. As soon as the commissioning tests are completed and actual data is available, the connection applicant is required to provide an updated model of the excitation system at Kirkland Lake GS. Using these data the IESO will perform studies to verify the behavior of the excitation system and establish the need for any new control and adjustment, as part of the Facility Registration Process.

5. Notification of Approval

It is recommended that for the proposed modification a Notification of Conditional Approval be issued to the applicant for the replacement of excitation system at Kirkland Lake GS.