CONNECTION ASSESSMENT & APPROVAL PROCESS

Applicant: Brookfield Renewable Power–Wawa Hydro Operations

Project: Excitation System Replacement for Steephill Falls GS

CAA ID: 2011-EX539

Final Report

IESO EXPEDITED SYSTEM IMPACT ASSESSMENT – 2011-EX539

1. Project Description

Brookfield Renewable Power-Wawa Hydro Operations plans to replace the excitation system for the Steephill Falls unit from the present ABB GMLb-SR-32 to ABB Unitrol-6080 full static excitation system due to equipment obsolescence.

The replacement is scheduled to be done in October, 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 Brookfield Renewable Power

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.

The excitation system as installed shall meet the applicable Market Rules for new excitation systems.

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 before the Approval to Connect is granted.

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

GENSAL: Salient Pole Generator Model

Description	Cons	Parameter	Value	Units
D-Axis O.C. Transient Time Constant	J	T'do (>0)	3.9	sec
D-Axis O.C. Sub-Transient Time Constant	J+1	T"do (>0)	0.045	sec
Q-Axis O.C. Transient Time Constant	J+2	T'qo (>0)	0.035	sec
Inertia	J+3	H	1.93	MW-s/MVA
Speed Damping	J+4	D	0	pu
D-Axis Synchronous Reactance	J+5	Xd	0.953	pu
Q-Axis Synchronous Reactance	J+6	Xq	0.723	pu
D-Axis Transient Reactance	J+7	X'd	0.362	pu
D-Axis/Q-Axis Sub-Transient Reactance	J+8	X"d = X"q	0.227	pu
Leakage Reactance	J+9	Xl	0.134	pu
Open Circuit Saturation factor	J+10	S(1.0)	0.0866	pu
Open Circuit Saturation factor	J+11	S(1.2)	0.2996	pu

Verification of the generator model provided by the applicant has shown that the use of GENSAE model is more appropriate than the GENSAL model.
By plotting the V-curves using the PSSE V-curves module it is seen that the $E_{fd\ rated}$ matches closely with the $E_{fd\ rated}$ provided by the applicant along with the SIA application. Figure1 and 2 shows the V-curves for GENSAL and GENSAE models.

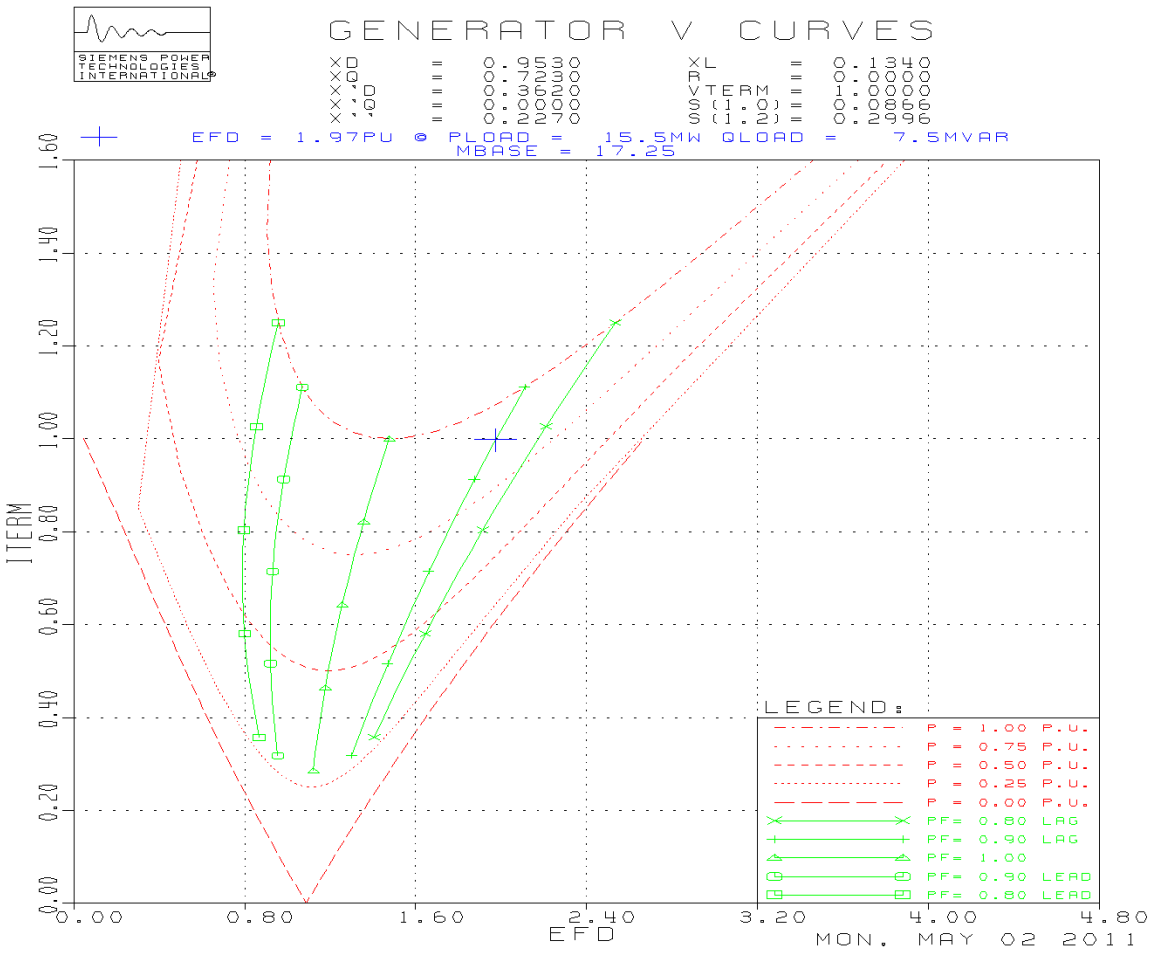


Figure 1- V-curve using Quadratic saturation (GENSAL)

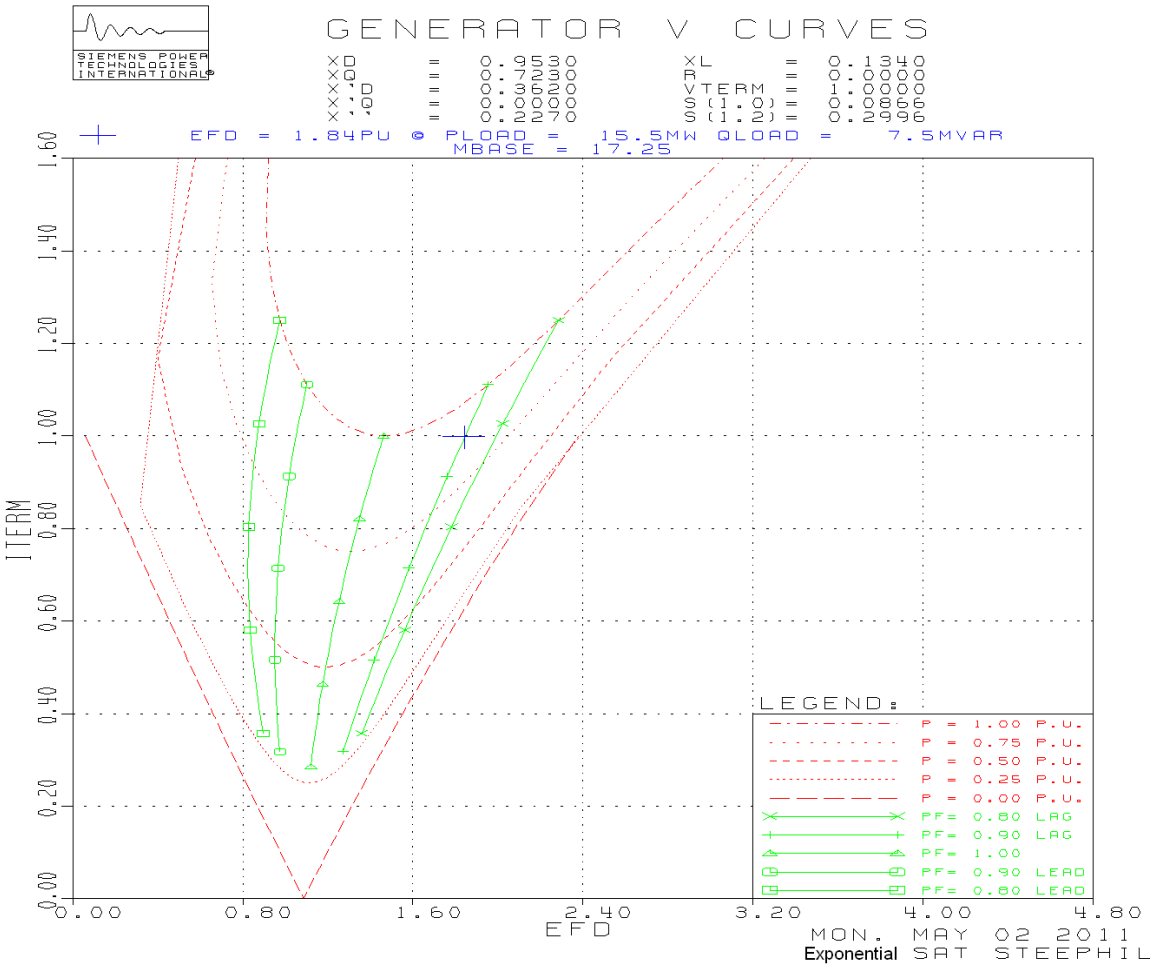


Figure 2- V-curve using Exponential saturation (GENSAE)

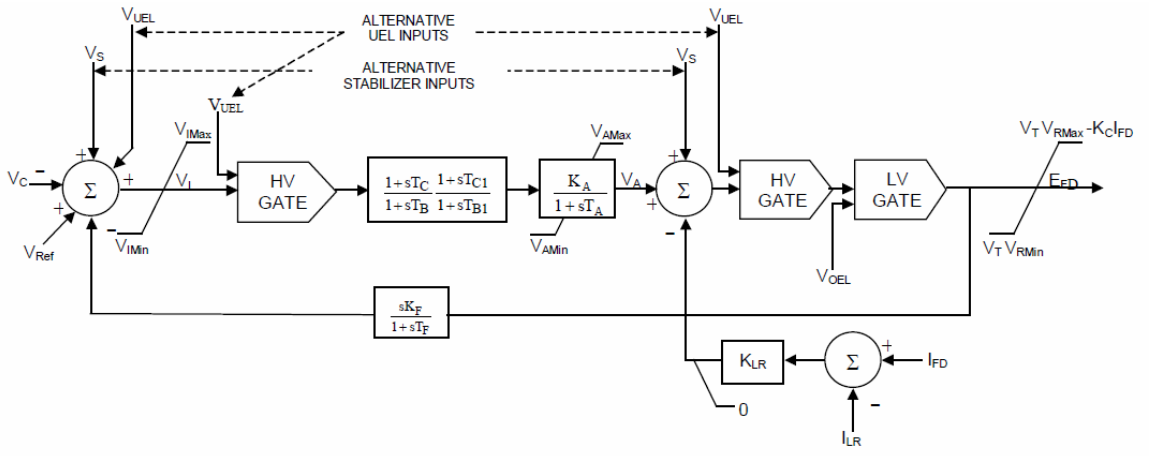
Throughout the report GENSAE model is used for the purpose of the simulations.

3.2. Excitation System Model

ESST1A (IEEE Type ST1A Model)

Description	ICONS	Parameter	Value
Alternate UEL inputs	IC	UEL (1,2, or 3)	1
Alternate stabilizer inputs	IC+1	VOS(1 or 2)	1

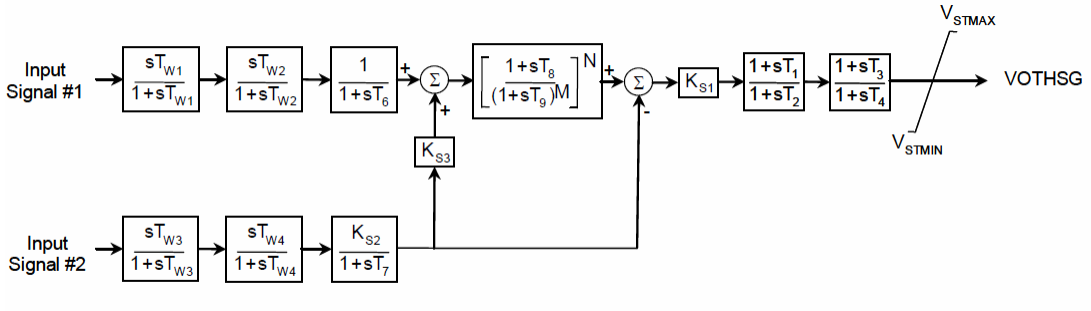
Description	CONs	Parameter	Value	Units
Terminal voltage transducer T.C.	J	Tr	0.01	s
AVR upper limit	J+1	VIMAX	0.04	pu
AVR lower limit	J+2	VIMIN	-0.04	pu
AVR lead time constant	J+3	TC	1	s
AVR lag time constant	J+4	TB	2	s
AVR lead time constant	J+5	TC1	1	s
AVR lag time constant	J+6	TB1	1	s
AVR gain	J+7	KA	300	pu
AVR time constant	J+8	TA	0	s
Positive regulator output limit	J+9	VAMAX	5.63	pu
Negative regulator output limit	J+10	VAMIN	-5.37	pu
Positive exciter output limit (ceiling)	J+11	VRMAX	5.63	pu
Negative exciter output limit (ceiling)	J+12	VRMIN	-5.37	pu
Rectifier regulation	J+13	KC	0.06	pu
Exciter feedback gain	J+14	Kf	0	pu
Exciter feedback time constant	J+15	Tf (>0)	1	s
Field current limiter gain	J+16	KLR	75	pu
Field current limiter max setting; pu Efd	J+17	ILR	2.92	pu



3.3. Power System Stabilizer Model

IEEE TYPE PSS2A DUAL-INPUT STABILIZER MODEL

Description	CONS	Parameter	Value	Units
First stabilizer input code	IC	ICS1	1	Rotor speed deviation (pu)
First remote bus number	IC+1	REMBUS1	0	remote sensing bus (not used)
Second stabilizer input code	IC+2	ICS2	3	Generator electrical power on MBASE base (pu)
Second remote bus number	IC+3	REMBUS2	0	remote sensing bus (not used)
Ramp tracking filter order	IC+4	M	5	
Ramp tracking filter order	IC+5	N	1	
Washout time constant	J	Tw1 (>0)	10	sec
Washout time constant	J+1	Tw2	10	sec
Filter time constant	J+2	T6	0	sec
Washout time constant	J+3	Tw3 (>0)	10	sec
Filter time constant [block bypassed]	J+4	Tw4	0	sec
Washout time constant	J+5	T7	10	sec
Gain	J+6	KS2 (= T7/2H)	2.160	
Gain	J+7	KS3	1	
Ramp-tracking filter time constant	J+8	T8	0.5	sec
Ramp-tracking filter time constant	J+9	T9 (>0)	0.1	sec
Stabilizer gain	J+10	KS1	12.5	
Phase lead time constant	J+11	T1	0.08	sec
Phase lag time constant	J+12	T2	0.02	sec
Phase lead time constant	J+13	T3	0.08	sec
Phase lag time constant	J+14	T4	0.02	sec
Output limits	J+15	VSTMAX	0.1	pu Etref
Output limits	J+16	VSTMIN	-0.1	pu Etref
Generator Apparent Power		MBASE	17.25	MVA
Turbine Generator Inertia		H	1.93	MW-s/MVA



4. Assessments

4.1. Exciter performance

Section 2 of this report outlines the performance requirements for the synchronous generator excitation systems. Exciter performance for Steephill Falls unit was checked to verify the positive and negative ceilings of the exciter, voltage response time of the excitation system and its performance under the high field current condition.

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 Brookfield Renewable Power. $E_{fd\ rated}$ for Steephill Falls unit is shown in the table below.

Description	Value	Units
Rated Voltage	1.0	pu
Rated Active Power	15.5	MW
Maximum Reactive Power	7.5	Mvar
Rated Field Voltage	1.84	pu
Rated Field Current	1.84	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 1.845=3.69 p.u

Exciter positive ceiling response= 5.5113 p.u

Simulation shows that the excitation system positive ceiling response meets the Market rule requirement.

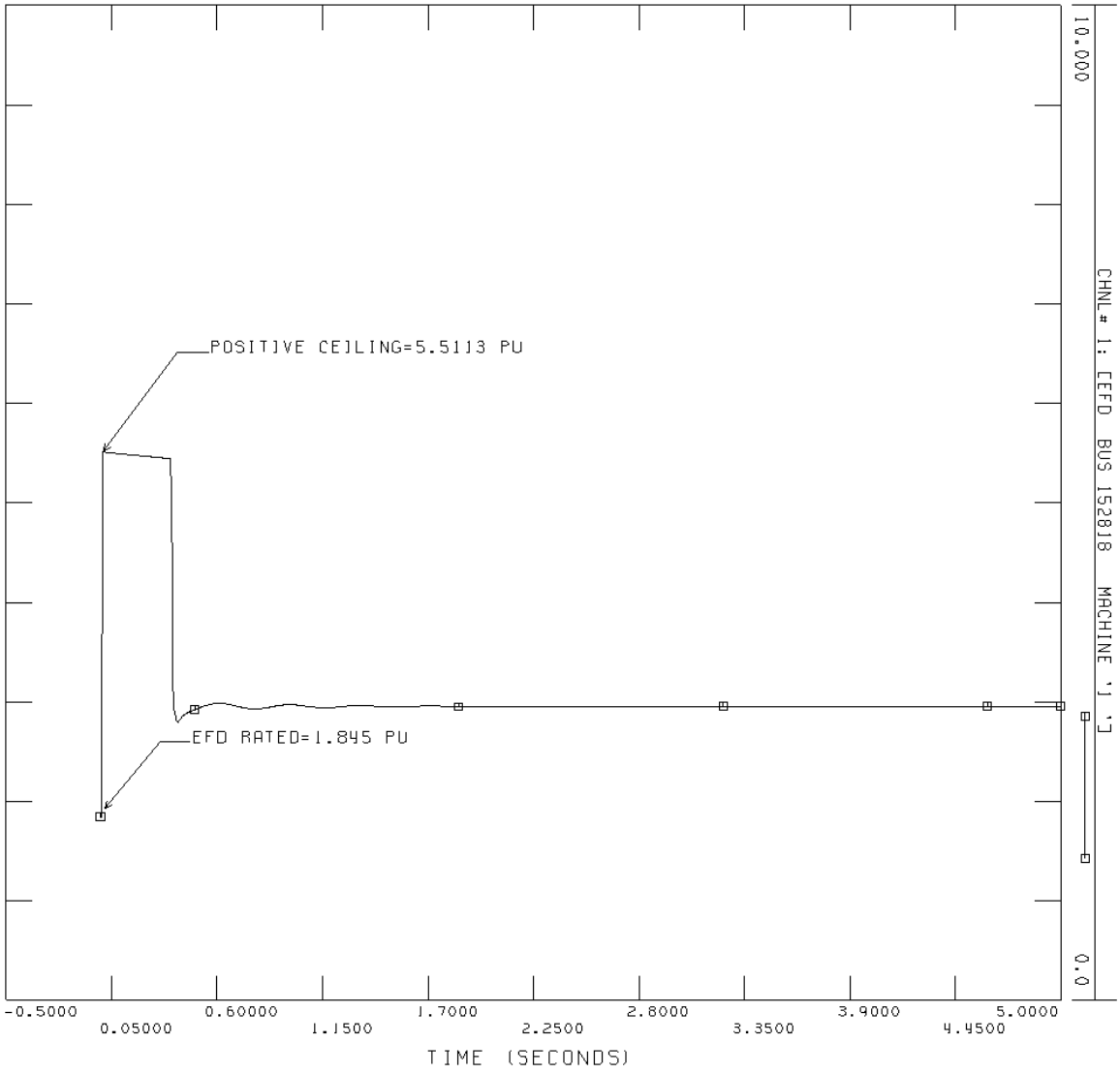


Figure 3: Positive ceiling

Negative ceiling test

Market rules stipulate that excitation system for the synchronous generators should be able provide a negative ceiling of 140% of the $E_{fd\ rated}$. Response ratio test shows that the excitation system for Steephill Falls unit meets the negative ceiling requirement. Results of the simulation given below shows that excitation system negative ceiling limit meets the Market rule requirement.

Required negative ceiling= - ($E_{fd\ rated}$ x 1.4) = -1.845 x1.4= -2.583 p.u

Exciter negative ceiling response= -5.3698 p.u

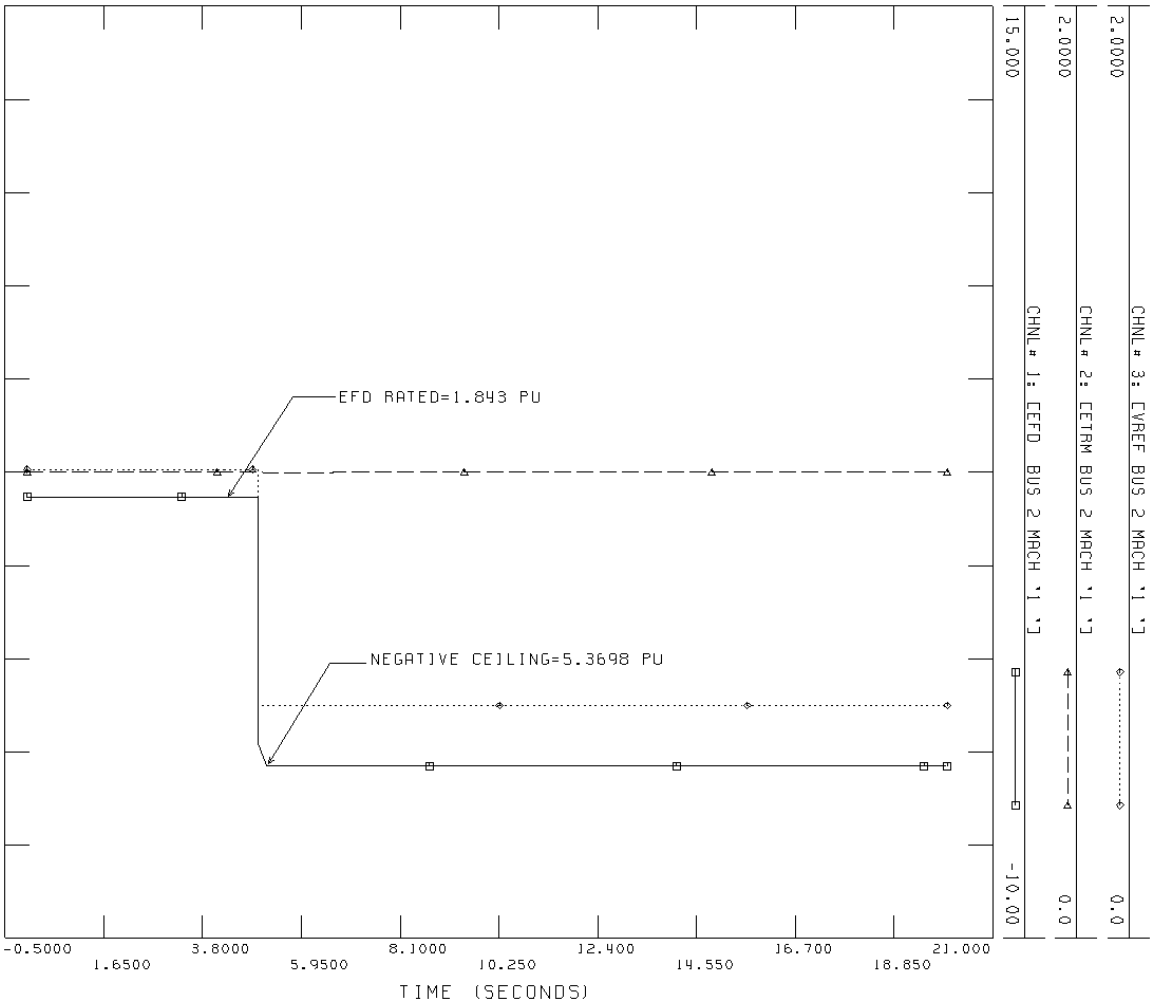


Figure 4: Negative ceiling

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 Steephill Falls unit.

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 Efd_{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 ($E_{fd\ oc}$)

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

RT_{OC_POS}=73.69 ms

Required E_{fd} (positive) ceiling =1.95 x $E_{fd\ rated}$ = 1.95x1.845 =3.6153 p.u within 71.64 ms

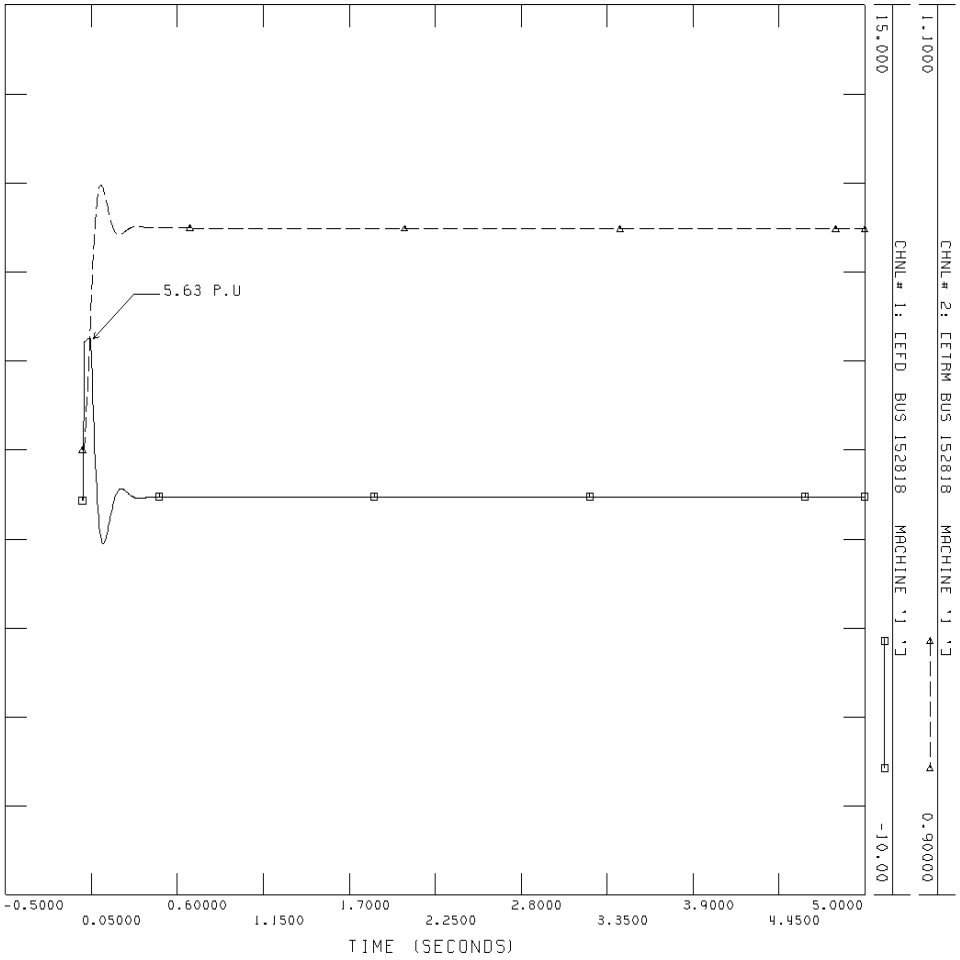


Figure 5: Positive ceiling voltage response time

Plot for open circuit test (Figure 3) shows that excitation system reaches the Efd of 5.63 p.u in 29.2 milliseconds for a voltage reference step change of +5 %. It is concluded that excitation system is able to provide the required positive ceiling within the specified time.

Negative ceiling voltage response time

Starting from $E_{fd\ rated}$, 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

RT_{OC_NEG}=39.74 ms

Required Efd (negative) ceiling= -1.28 x $E_{fd\ rated}$=- 2.361 p.u

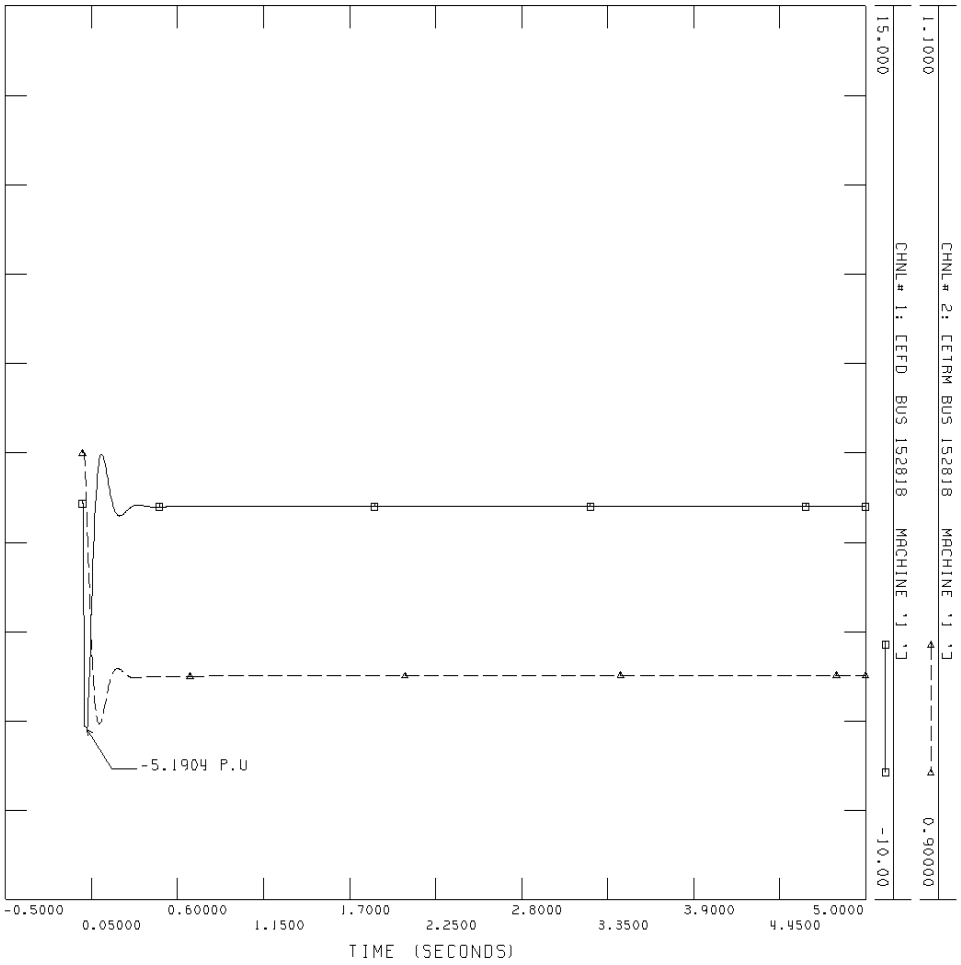


Figure 6: Negative ceiling voltage response time

Figure 4 depicts that excitation system reaches a negative ceiling of -5.1904 p.u in 20.8 milli-secs for voltage reference step change of -5%. It is concluded that excitation system meets the voltage response time requirement for negative ceiling specified in the Market rules.

Performance under high field current

Market rules requires that, at rated terminal voltage the excitation system should be able to reach the positive ceiling of 170% of $E_{fd\ rated}$ when the field current is 160% of $I_{fd\ rated}$.

The excitation system is required to have a positive ceiling of 3.136 p.u. Test results depicted in Figure 5 shows that the exciter is able to produce E_{fd} up to 3.225 p.u (175.2% of $I_{fd\ rated}$). Hence, the excitation system meets this requirement.

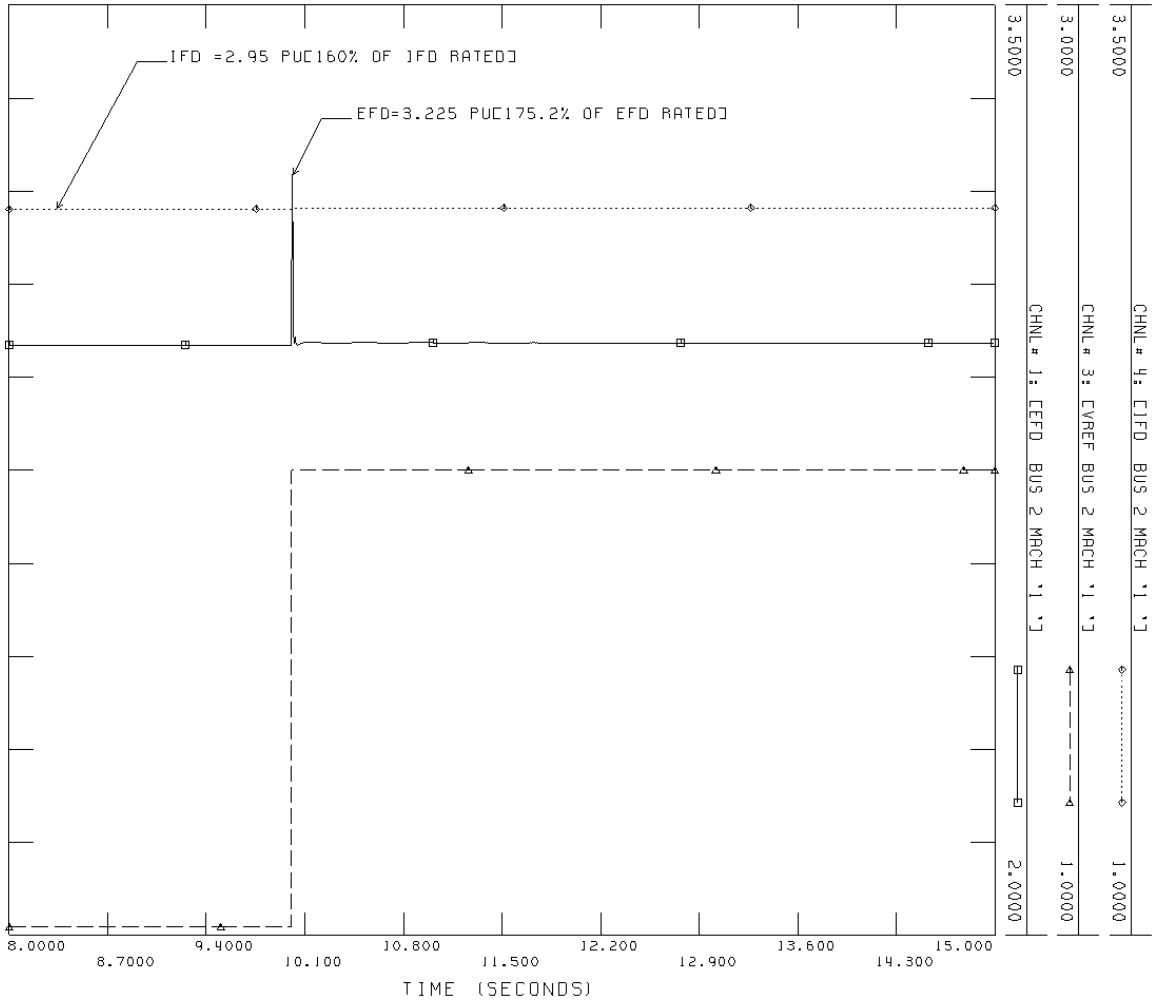


Figure 7: Exciter response with high field current

5. Rotor angle stability at nearby generating stations

Rotor angle stability of the nearby generators is checked for a system fault which does not remove the Steephills GS unit by configuration.
A three phase fault simulated on the 115 kV circuit No.2 from Watson TS to Anjigami TS with the fault clearing time of 134 milli-secs confirms that the Steephill Falls unit and the units at the surrounding generating stations remain stable.

6. Conclusions and Requirements

This assessment concluded that the Steephill Falls GS will not have adverse impact on the reliability of the IESO-controlled grid.

During the Market Entry process, the applicant is required to update the data and models of Steephill Falls 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 Steephill Falls 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 and the PSS of Steephill Falls 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 Steephill Falls generating station.

Appendix

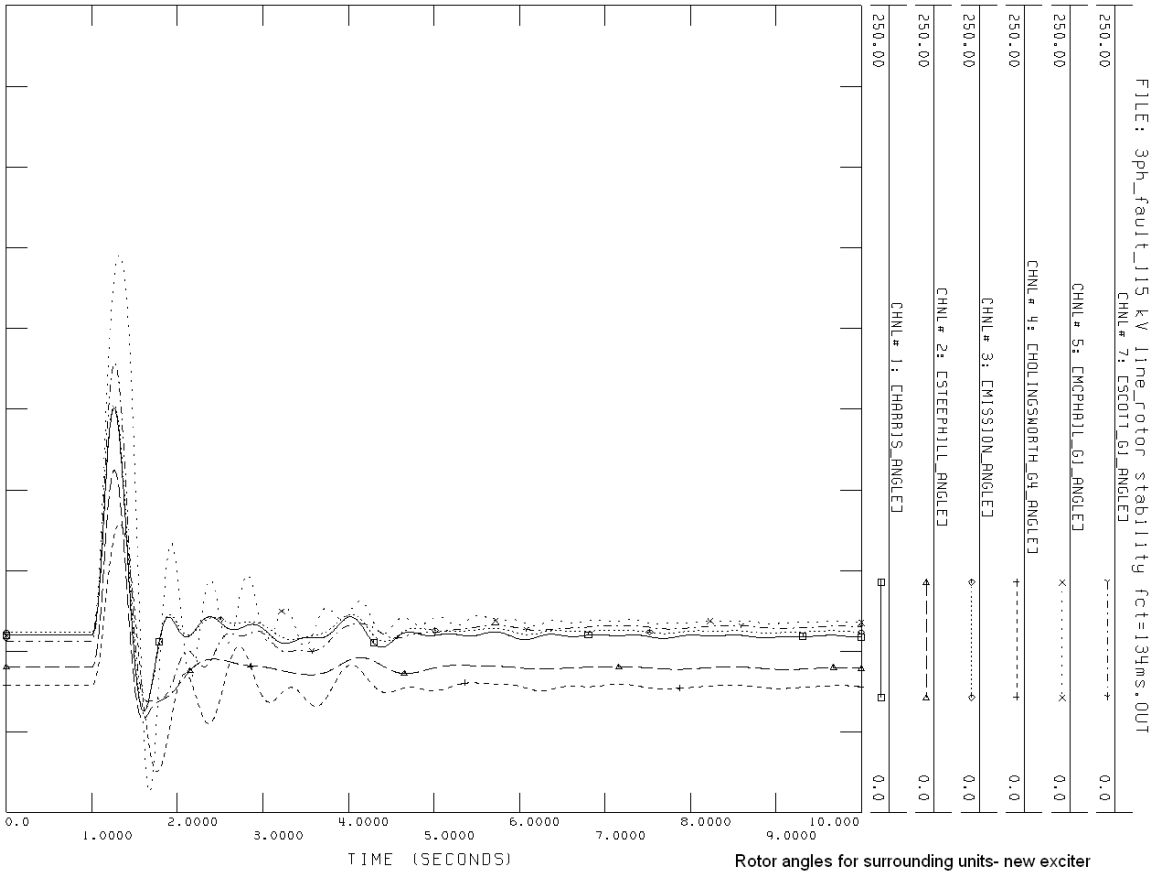


Fig. 1 – Surrounding units rotor angle- with new exciter

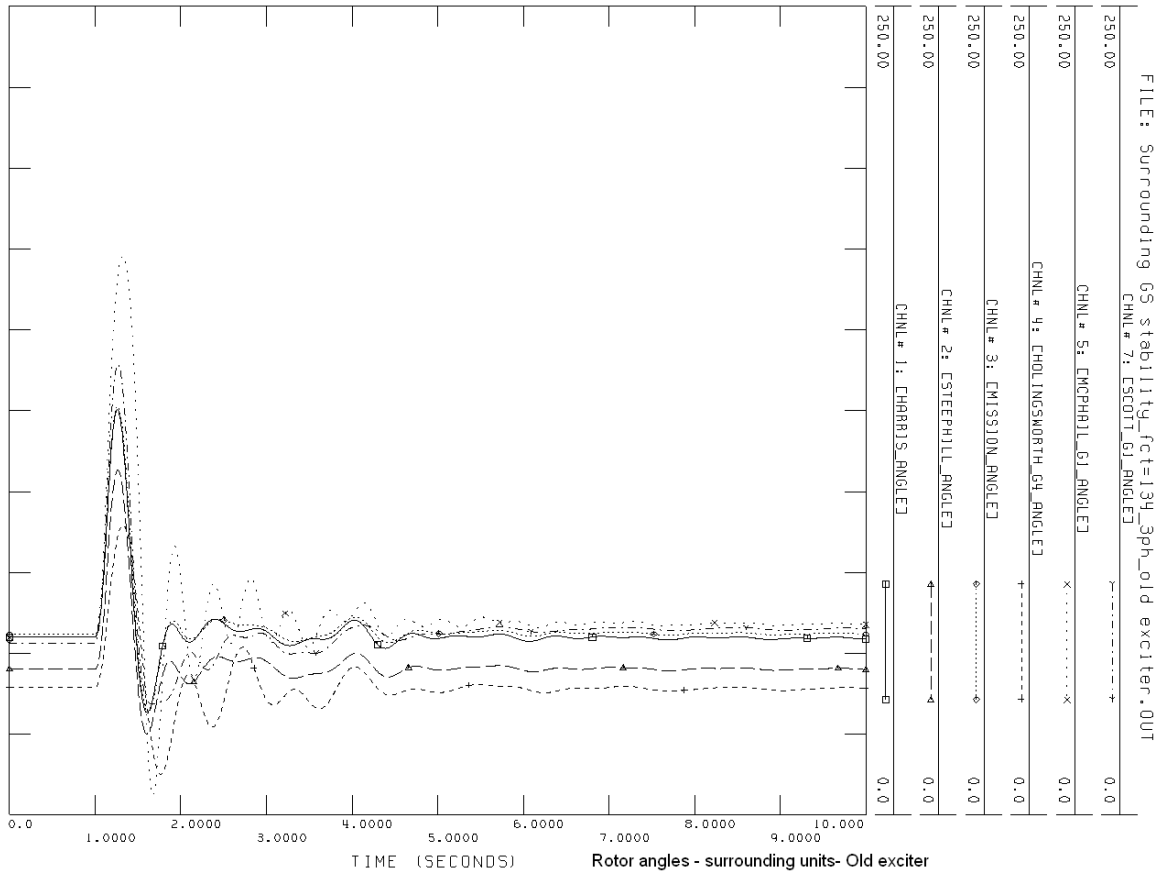


Fig. 2 – Surrounding units rotor angle- with old exciter

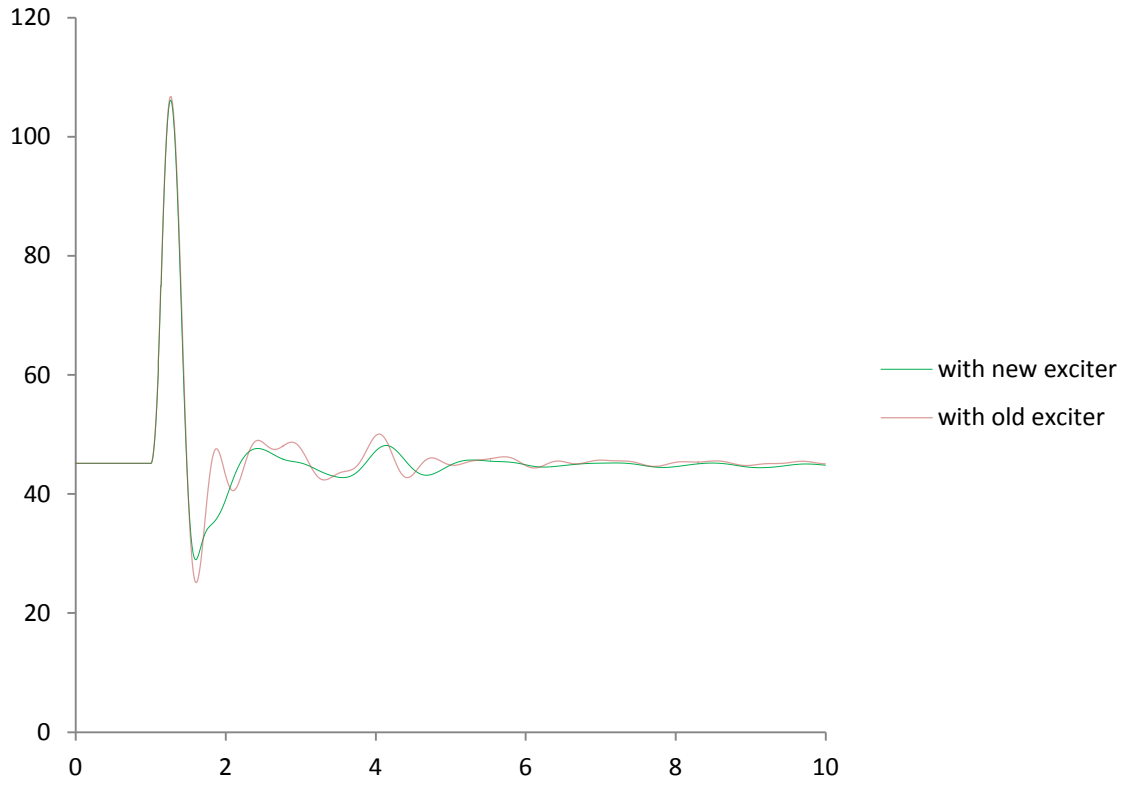


Fig. 3 - Steephill Falls Unit- Rotor angle comparison for a 3 phase fault[1]

[1] Fault simulated on 115 kV circuit No.2 from Anjigami TS to Watson TS