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IMO_REP_0222

CONNECTION ASSESSMENT & APPROVAL PROCESS

SYSTEM IMPACT ASSESSMENT REPORT - Addendum

For the Proposed Greater Toronto Airports Authority Project

Applicant: Enersource Hydro Mississauga

CAA ID No. 2003-107

Transmission Assessments & Performance Department

FINAL Version

Date: 8th August 2005

ENERSOURCE HYDRO MISSISSAUGA: GTAA PROJECT

Addendum to the System Impact Assessment

1. Introduction

The Greater Toronto Airports Authority (the GTAA) has provided revised data for the 181.9MVA combined-cycle generating facility that they are in the process of installing at Toronto Pearson International Airport.

This Addendum summarises the results of the IESO's analysis with these new data.

2. Connection Arrangement

The new GTAA generating facility is to consist of two gas-turbine generating units that are to be incorporated into Bramalea TS and a single steam-turbine generating unit that is to be incorporated into Woodbridge TS. All three units are to be connected via extensions of existing 44kV feeders.

Diagrams 1 & 2 show the connection arrangements for the two gas-turbine generating units at Bramalea TS and the single steam-turbine unit at Woodbridge TS, respectively.

Diagram 3 shows the connection arrangement of the three generating units and of the existing GTAA loads at the new generating facility.

3. Data Provided by GTAA

Using the data that were provided by the GTAA, a series of studies were performed which yielded results that would not meet the requirements of the Market Rules.

With agreement from the GTAA, the IESO therefore proceeded to modify the data until satisfactory responses were obtained.

Diagrams 4 to 12, inclusive, summarise the data values that were eventually selected, with those changes that were required to obtain acceptable responses highlighted.

Specifically, the changes that were made were as follows:

For the gas-turbine generating units:

- Diagram 4 — a speed damping coefficient of 0 was selected.
- Diagram 6 — a value of 5.0 was selected for the gain, K_S, of the PSS for the gas-turbine unit, and values of 0.1 & -0.1 were selected for the output limits, L_{SMAX} & L_{SMIN}, respectively for the Power System Stabiliser.
- Diagram 7 — the IEESGO model was replaced with a GAST model to represent the gas-turbine governor, and typical data values were used.

For the steam-turbine generating unit:

- Diagram 9 — a value of 0.004 sec. was selected for the time constant, T_A, of the exciter on the steam-turbine unit, and
  an arbitrary value of 1.2 sec. was selected for the time constant, T_F.
  Since K_F is zero, the feedback loop has no effect.

4. *Results*

4.1 In response to a system contingency

Diagrams 12 to 20, inclusive, show the transient responses obtained for the following fault conditions:

- *For the gas-turbine units incorporated into Bramalea TS:*
  a normally-cleared three-phase fault on the 230kV circuit V72R at Claireville TS

- *For the steam-turbine unit incorporated into Woodbridge TS:*
  a normally-cleared three-phase fault on the 230kV circuit V74R at Claireville TS

The detailed responses that were obtained from the studies are shown in the following Diagrams:

Diagram No.	*Recorded Parameter*	
12.	Rotor Field Voltage	pu
13.	Rotor Field Current	pu
14.	Generator Terminal Voltage	pu
15.	Power System Stabiliser Output	pu
16.	Rotor Angle	degrees
17.	Speed Variation	pu
18.	$P_{MECHANICAL}$ mechanical power	pu on machine base
19.	$P_{ELECTRICAL}$ electrical power output	pu on system base (100MVA)
20.	$Q_{ELECTRICAL}$ reactive power output	pu on system base (100MVA)

Each Diagram shows the respective responses of the gas-turbine units (on the left) against that of the steam-turbine unit (on the right). While the responses are all deemed to be acceptable, the Diagrams clearly show the superior performance obtained from the steam-turbine unit with a static exciter compared to that from the gas-turbine units equipped with brushless exciters.

4.2 Gas-turbine Exciter Performance

Open-Circuit Step Response

Diagram 21 shows the open-circuit response to a step change of 5% in the generator terminal voltage.

This shows that the exciter of the gas-turbine unit will only reach a field voltage of 2.32 pu within 50-milliseconds, although it will eventually reach its peak value of 3.26 pu after 98 milliseconds.

Response Ratio Test

Diagram 22 shows the field voltage response to a large increase in the reference set points for the voltage regulators.

This shows that the field voltage at rated load would be 3.15 pu and that this would increase by 159% to 5.01 pu in response to the imposed change in the reference settings.

This Diagram also shows that the nominal response ratio of the exciters that are to be installed on the gas-turbine units would be 2.06.

Comments

The exciters that are to be installed on the gas-turbine generating units would therefore not meet the more-stringent requirements in the Market Rules, i.e.

- a voltage response time of less than 50 milliseconds, and
- a positive ceiling voltage of at least twice the rated field voltage.

However, the exciters would meet the *relaxed* Market Rule criteria for generators that the IESO has determined would not have an adverse impact on the reliable operation of the IESO-controlled grid. For these generators, the excitation system is required to have -

- a response ratio of at least 0.5, and
- a positive ceiling voltage of at least 150% of the rated field voltage.

Since the IESO's earlier studies have already confirmed that this embedded generating facility will have no adverse impact on the reliable operation of the IESO-controlled grid, and since the exciters have a response ratio of 2.06 and a positive ceiling voltage of 159% of the rated field voltage, then they would be acceptable to the IESO.

4.3 Steam-turbine Exciter Performance

Open-Circuit Step Response

Diagram 23 shows the open-circuit response to a step change of 5% in the generator terminal voltage.

This shows that the exciter of the steam-turbine unit will reach a field voltage of 7.40 pu within 50-milliseconds.

Response Ratio Test

Diagram 24 shows the field voltage response to a large increase in the reference set points for the voltage regulators.

This shows that the field voltage at rated load would be 2.73 pu and that this would increase by 268% to 7.31 pu in response to the imposed change in the reference settings.

This Diagram also shows that the nominal response ratio of the exciters that are to be installed on the gas-turbine units would be 6.72.

Comments

The Market Rules require a voltage response time of less than 50 milliseconds. To meet this requirement the field voltage in the open-circuit step response test would need to exceed 2.59 pu within 50 milliseconds. Since the field voltage reaches 7.40 pu within this time period, the exciter will more than satisfy this requirement.

Furthermore, with a positive ceiling voltage of 7.31 pu, the exciter to be installed on the steam-turbine unit would also satisfy the Market Rule requirement that its ceiling voltage be at least 200% of the rated field voltage of 2.73 pu.

Generator Data, Excitation Systems and Governors

Based on the data provided by the GTAA, and as modified by the IESO, the generating units together with their excitation systems and governors, would meet the requirements of the Market Rules.

5. IESO Requirements for the Proposed Modification of the Existing Connections to the IESO-controlled Grid

For reference, the IESO's requirements for modifying the existing connections at Bramalea TS and Woodbridge TS to the IESO-controlled grid resulting from the incorporation of the GTAA Project, as stated in the original SIA Report, have been repeated below:

IESO Requirements for Modifying the Connections of Bramalea TS & Woodbridge TS to the IESO-controlled grid

- Provide evidence that the generator data and the settings for the exciters, power system stabilisers and governors are not materially different from those used by the IESO in their analysis.
- Provide evidence that the 'composite' droop setting for the entire GTAA facility is 5%.
- Provide evidence that the generating facility is operating under 'voltage control' rather than 'power factor' control.
- If the GTAA facility is to be re-synchronised to the system via the breakers associated with the 44kV feeders, then suitable synchronising facilities will be required in each connection. In addition, the 44kV breakers that are to be used for synchronisation will need to be capable of withstanding a sustained 2 pu voltage across their open terminals.
- Suitable interlocks are to be provided to prevent inadvertent parallelling of the 44kV feeders from Bramalea TS and Woodbridge TS, as well as the parallelling of these 44kV systems with the existing 27.6kV feeders from Richview TS.

Cross-Tripping Scheme

Although not specifically required by the IESO, a Cross-Tripping Scheme is to be installed to initiate isolation of the GTAA generating units with the local load at the Airport in the event that the either of the 230kV connections to the system are lost.

Since this Scheme has gone through a number of revisions from the version that was included in the original SIA Report, a copy of the latest version is included as Diagram 25.

It is expected that during normal operation, with all transmission facilities in-service, that the Scheme would only be armed for double-circuit contingencies involving either circuits V72R & V73R (to Bramalea TS) or circuits V74R & V75R (to Woodbridge TS).

However, during the following outage conditions, the Scheme would need to be armed for a single-circuit contingency involving the 230kV companion circuit and/or the associated step-down transformer:

	Outage Condition	*Contingency for which the Scheme would be Armed*
For the two Gas-turbine units incorporated into Bramalea TS		
1.	Circuit V72R and/or Bramalea transformer T5	Companion circuit V73R and/or Bramalea transformer T6
2.	Circuit V73R and/or Bramalea transformer T6	Companion circuit V72R and/or Bramalea transformer T5
For the single Steam-turbine unit incorporated into Woodbridge TS		
1.	Circuit V74R and/or Woodbridge transformer T3	Companion circuit V75R and/or Woodbridge transformer T5
2.	Circuit V75R and/or Woodbridge transformer T5	Companion circuit V74R and/or Woodbridge transformer T3

The sole purpose of this Scheme is to allow the GTAA generating units to island and maintain the supply to the local loads at the Airport should either of the 230kV connections to the system be lost. However, should the Scheme fail to operate or should it mal-function it would have no adverse impact on the IESO-controlled grid. Consequently full duplication of the Scheme is not required.

However, the IESO has recommended that if Programmable Logic Controllers (PLCs) rather than latching relays are to be used for the arming portion of the Scheme, that they be duplicated and equipped with discrepancy monitoring.

6 Fault Level Issues

Since the projected fault level of 22kA on the 44kV EZ-busbar at Bramalea TS will exceed the 20kA maximum quoted in the Transmission System Code for this voltage level, Hydro One is to upgrade any of the existing equipment at Bramalea TS that is identified as being inadequate.

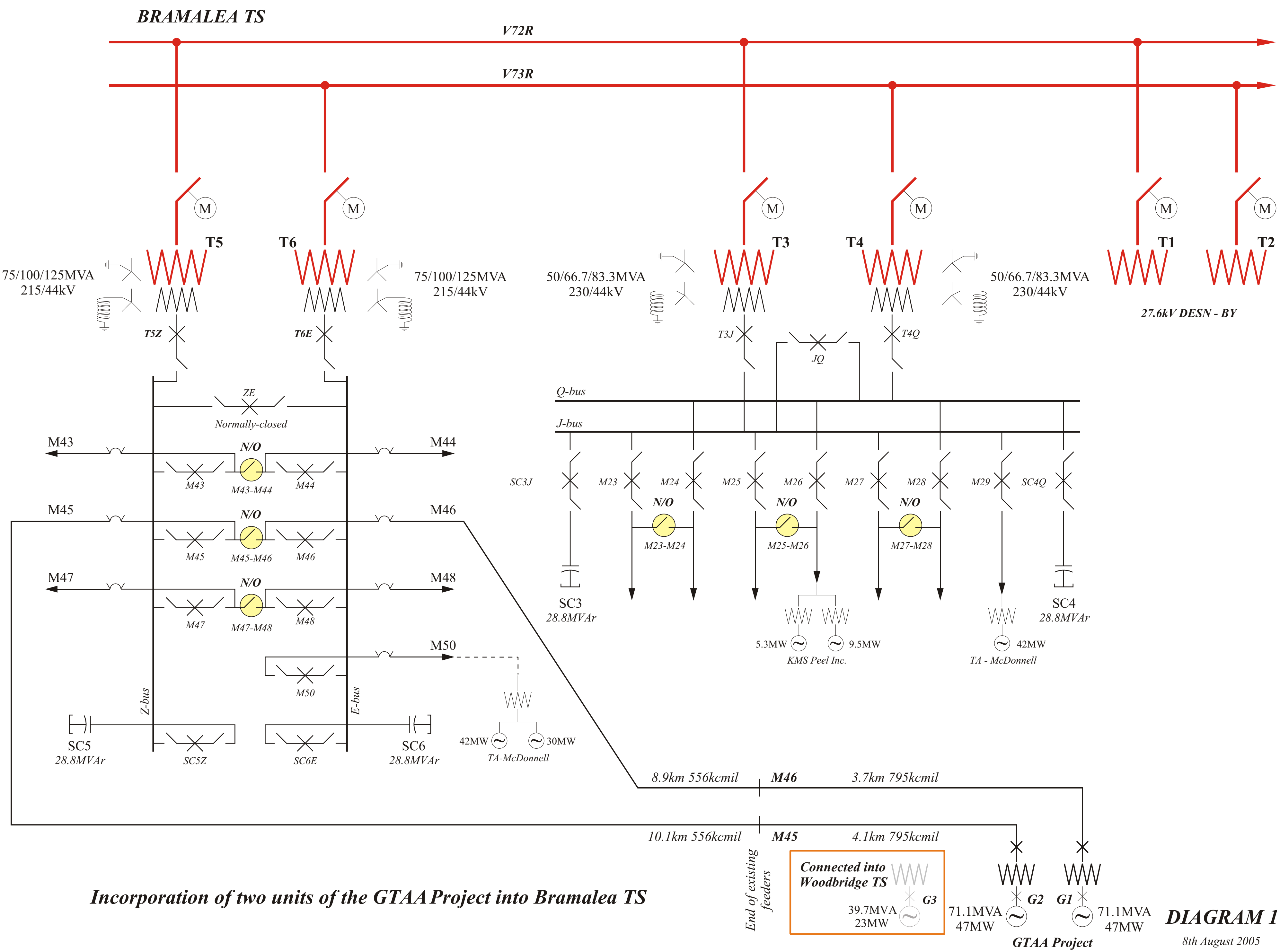
Enersource Hydro Mississauga has conducted their own studies and confirmed that none of their customers would be adversely affected by the higher fault level.

Similarly, the IESO understands that the higher fault level will not be a concern for the customers of Hydro One Brampton.

7. Notification of Approval

Subject to satisfying the IESO's requirements as detailed in Section 5, the IESO has determined that the modification of the existing connections at Bramalea TS and Woodbridge TS through the incorporation of the GTAA Project would have no adverse impact on the IESO-controlled grid, and it is therefore recommended that a revised Notification of Approval to Connect be issued. This Notification of Approval, based on the IESO's assessment using the revised data provided by the GTAA, will supersede the NOA that was issued on 12th January 2005.

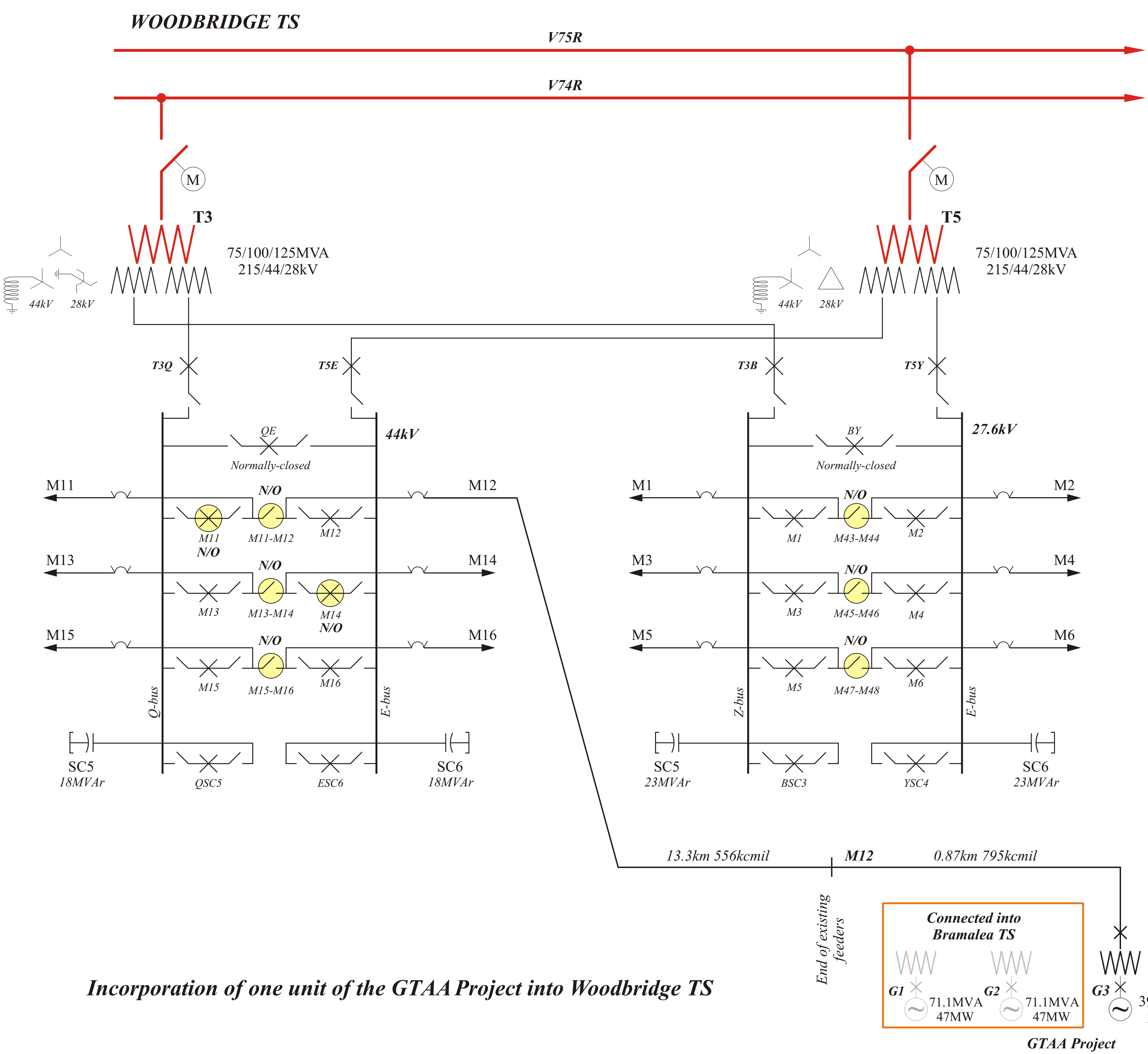
However, since it was determined that changes to these data were necessary in order for the performance of the generating units to comply with the requirements of the Market Rules, the IESO cautions that should the commissioning reports indicate materially different parameters to those that have been used in the IESO's analysis, that a new assessment will be required and this would void the Notification of Approval to Connect.



Incorporation of two units of the GTAA Project into Bramalea TS

DIAGRAM 1

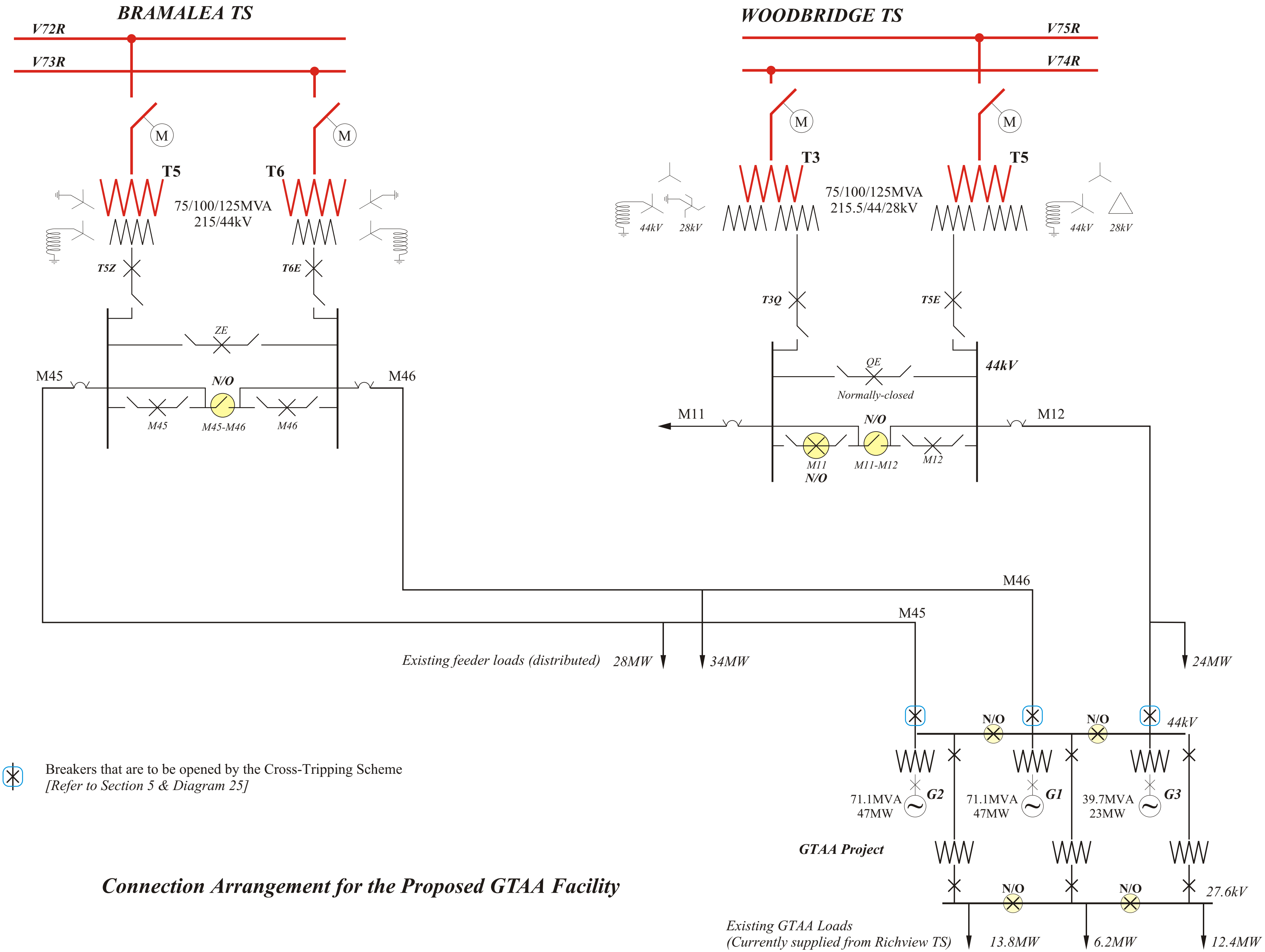
8th August 2005



Incorporation of one unit of the GTAA Project into Woodbridge TS

DIAGRAM 2

20th April 2005



Connection Arrangement for the Proposed GTAA Facility

DIAGRAM 3

8th August 2005

Values used in Transient Stability Analysis

GTAA PROJECT		*Gas-turbine Generating Units 71.2MVA*
Type		Round Rotor
Speed		3600 rpm
Power Factor		0.85
Terminal Voltage		13.8kV
Open-Circuit Transient Time Constant - direct axis	T'_{do}	9.67 secs
Open-Circuit Sub-Transient Time Constant - direct axis	T''_{do}	0.050 secs
Open-Circuit Transient Time Constant - quadrature axis	T'_{qo}	2.95 secs
Open-Circuit Sub-Transient Time Constant - quadrature axis	T''_{qo}	0.050 secs
Synchronous Reactance - direct axis (Unsaturated)	X_d	2.35 pu
Synchronous Reactance - quadrature axis (Unsaturated)	X_q	2.15 pu
Transient Reactance - direct axis (Unsaturated)	X'_d	0.245 pu
Transient Reactance - quadrature axis (Unsaturated)	X'_q	0.350 pu
Sub-Transient Reactance (Unsaturated)	$X''_d = X''_q$	0.181 pu
Leakage Reactance	X_l	0.130 pu
Inertia Constant	H	1.193kW-sec/kVA
Speed Damping	D	0.0
Saturation Factors	S (1.0)	0.120
	S (1.2)	0.457

970.0kg m^2 (generator)
216.5kg m^2 (turbine)
8.6kg m^2 (coupling)

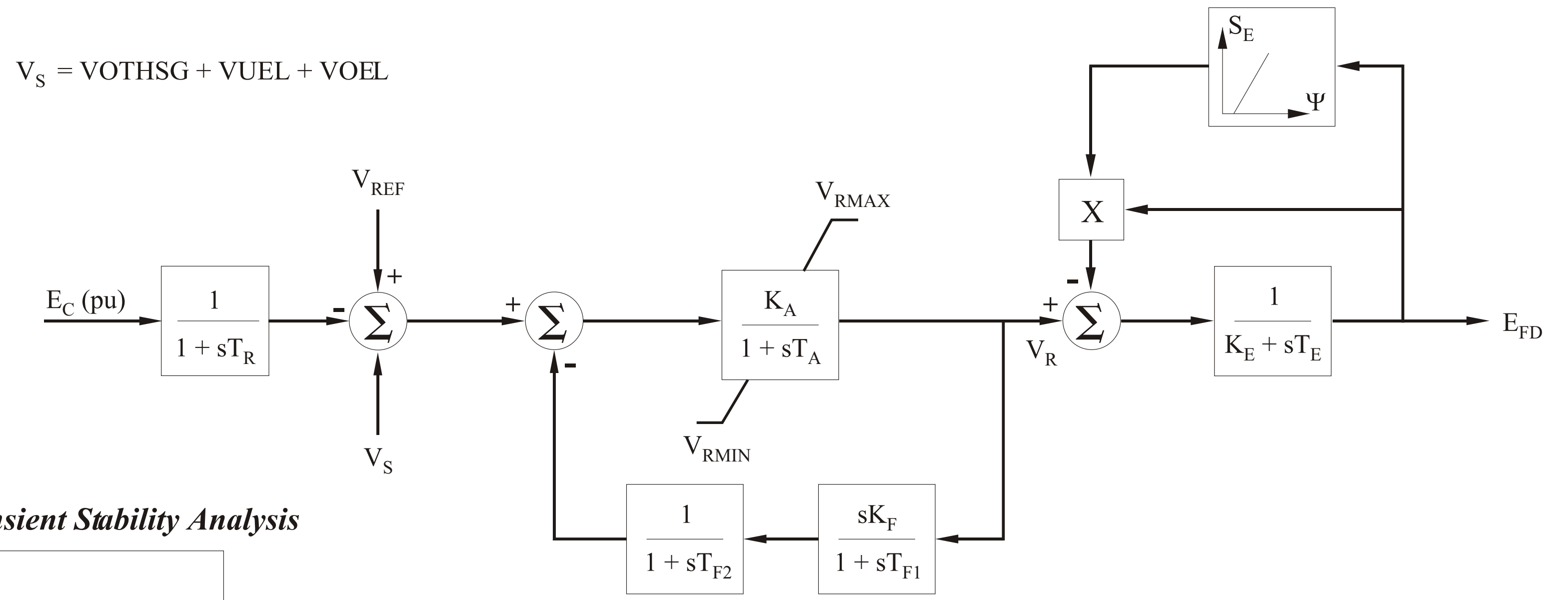
Greater Toronto Airports Authority Project

GENROU Model
(Round Rotor Generator Model)

Data used for the gas-turbine generating units

DIAGRAM 4

27th July 2005



Values used in Transient Stability Analysis

GTAA PROJECT	
	Gas-turbine Generating Units 71.2MVA
T_A	0.100 secs
T_E	1.200 secs
T_{F1}	0.600 secs
T_{F2}	1.200 secs
T_R	0.022 secs
K_A	2894.0
K_E	1.0
K_F	0.017
E_1	1.114
E_2	1.485
V_{RMAX}	47.0
V_{RMIN}	0.0
$S_E(E_1)$	0.09
$S_E(E_2)$	0.55

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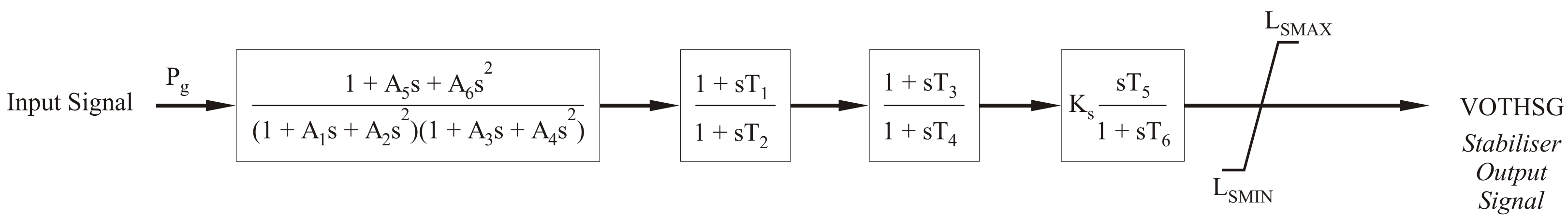
IEEET2 Model
(Type 2 Excitation System: Brushless Exciter)

Data used for the gas-turbine generating units

DIAGRAM 5

27th July 2005



Values used in Transient Stability Analysis

GTAA Project			
A_1	0.0	T_1	0.20 sec
A_2	0.0	T_2	0.02 sec
A_3	0.0	T_3	0.20 sec
A_4	0.0	T_4	0.02 sec
A_5	0.0	T_5	0.05 sec
A_6	0.0	T_6	0.05 sec
K_S	5.0	L_{SMAX}	0.100
ICS	1	L_{SMIN}	-0.100
IB	0		

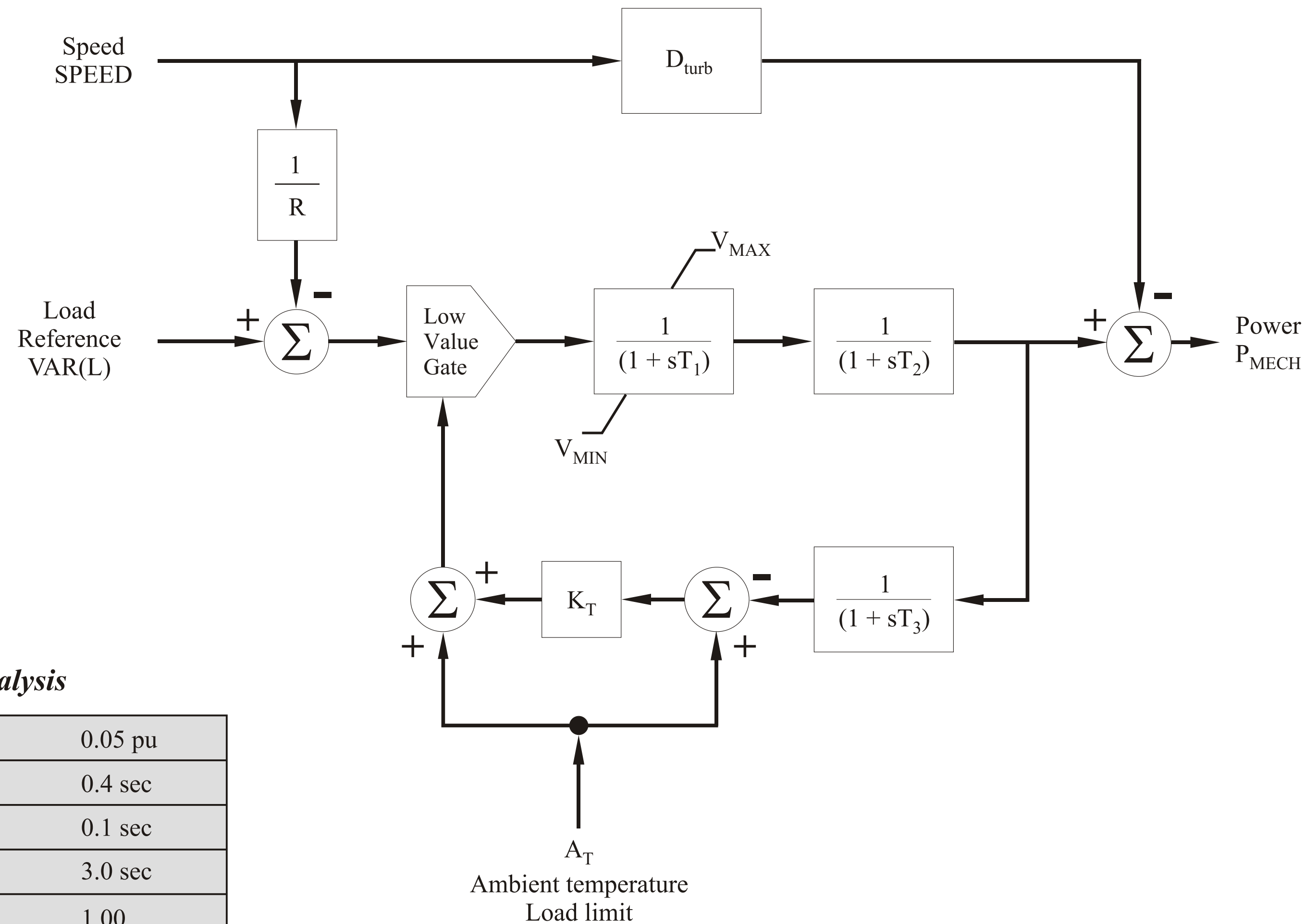
Greater Toronto Airports Authority Project

IEEEST Power System Stabiliser Model

Data supplied for the gas-turbine generating units

DIAGRAM 6

8th August 2005



Values used in Transient Stability Analysis

Speed droop	R	0.05 pu
Time constants	T_1	0.4 sec
	T_2	0.1 sec
	T_3	3.0 sec
Ambient temperature load limit	A_T	1.00
Constant	K_T	2.0
Maximum fuel valve opening	V_{MAX}	1.00 pu
Minimum fuel valve opening	V_{MIN}	-0.05 pu
Turbine damping factor	D_{turb}	0.0

Greater Toronto Airports Authority Project

GAST Model
(Gas Turbine Governor)

Data used for the two gas-turbine units

DIAGRAM 7

27th July 2005

Values used in Transient Stability Analysis

GTAA PROJECT		*Steam-turbine Generating Units 39.7MVA*	
Type		Salient Pole	
Speed		1800 rpm	
Power Factor		0.85	
Terminal Voltage		13.8kV	
Open-Circuit Transient Time Constant - direct axis	T'_{do}	10.1 secs	
Open-Circuit Sub-Transient Time Constant - direct axis	T''_{do}	0.060 secs	
Open-Circuit Sub-Transient Time Constant - quadrature axis	T''_{qo}	0.120 secs	
Synchronous Reactance - direct axis (Unsaturated)	X_d	2.03 pu	
Synchronous Reactance - quadrature axis (Unsaturated)	X_q	1.03 pu	
Transient Reactance - direct axis (Unsaturated)	X'_d	0.340 pu	
Sub-Transient Reactance (Unsaturated)	$X''_d = X''_q$	0.210 pu	
Leakage Reactance	X_l	0.140 pu	
Inertia Constant	H	5.243kW-sec/kVA	11716.7kg m^2 (turbine-generator)
Speed Damping	D	0.0	
Saturation Factors	S (1.0)	0.053	
	S (1.2)	0.19	

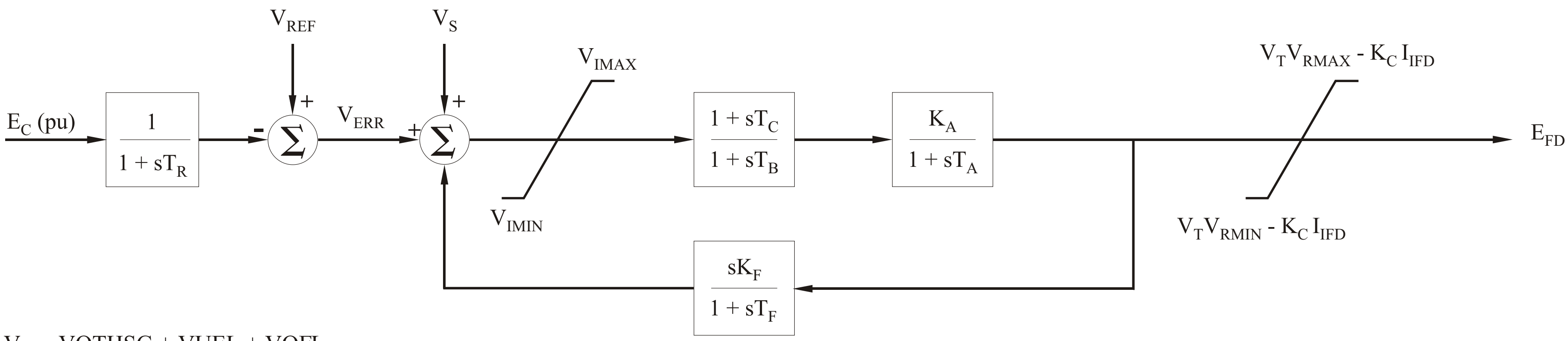
Greater Toronto Airports Authority Project

GENSAL Model
(Salient Pole Generator Model)

Data used for the steam-turbine generating unit

DIAGRAM 8

17th July 2005



V_S = VOTHSG + VUEL + VOEL

Values used in the Transient Stability Analysis

	GTAA Project
T_A	0.004 sec
T_B	0.100 sec
T_C	0.100 sec
$T_F > 0$	1.200 sec
T_R	0.020 sec
K_A	482.00
K_C	0.00
K_F	0.00
V_{RMAX}	7.31
V_{RMIN}	-5.85
V_{IMAX}	15.20
V_{IMIN}	-12.18

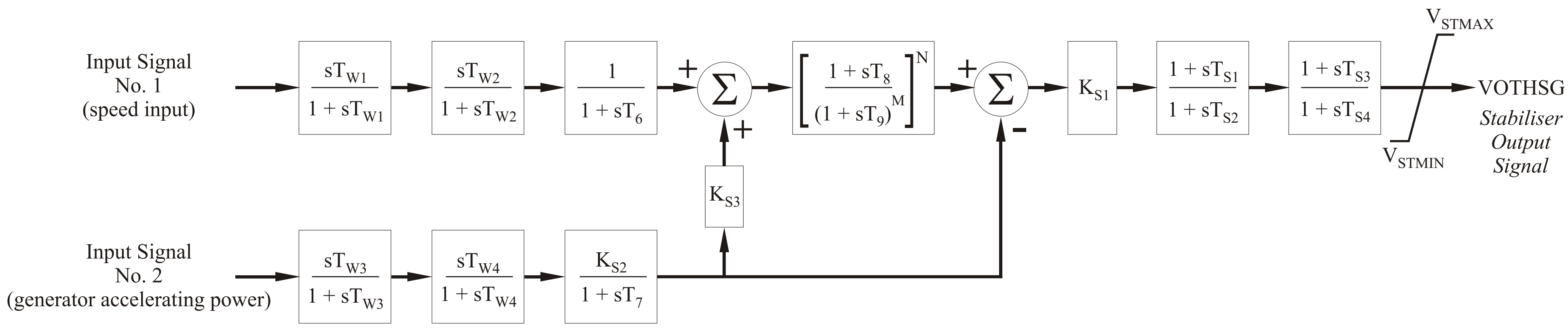
Greater Toronto Airport Authority Project

EXST1 Excitation System Model
(IEEE ST1 Model)

Data supplied for the steam-turbine generating unit

DIAGRAM 9

27th July 2005



Values used in Transient Stability Analysis

GTAA Project			
ICS1	1	T_1	0.120 sec
ICS2	3	T_2	0.040 sec
REMBUS1	0	T_3	0.280 sec
REMBUS2	0	T_4	0.040 sec
M	5	T_6	0.000 sec
N	1	T_7	2.000 sec
K_{S1}	10.621	T_8	0.000 sec
K_{S2}	0.189	T_9	0.100 sec
K_{S3}	1.000	T_{W1}	2.000 sec
V_{STMAX}	3.277*	T_{W2}	2.000 sec
V_{STMIN}	-3.277*	T_{W3}	2.000 sec
		T_{W4}	0.000 sec

* Maximum value

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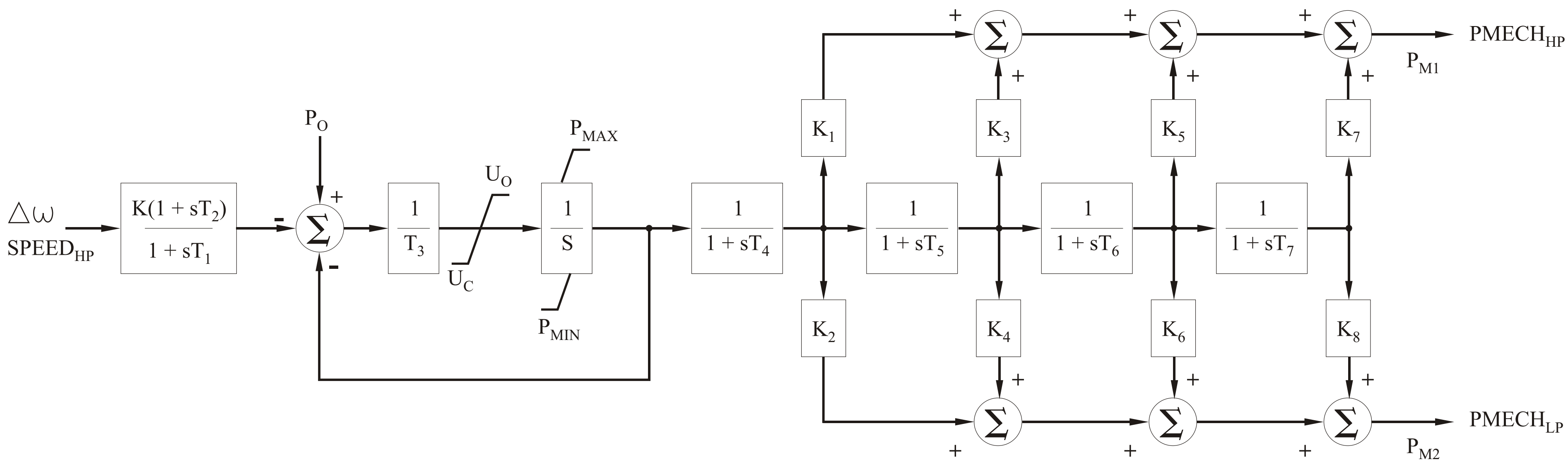
PSS2A Power System Stabiliser Model
(IEEE Dual-Input Stabiliser)

Data provided for the Steam-turbine unit

DIAGRAM 10

27th July 2005



Values used in Transient Stability Analysis

GTAA Project			
K	20.00	T_1	0.05 sec
K_1	0.33	T_2	0.00 sec
K_2	0.00	T_3	0.25 sec
K_3	0.67	T_4	0.10 sec
K_4	0.00	T_5	0.45 sec
K_5	0.00	T_6	0.00 sec
K_6	0.00	T_7	0.00 sec
K_7	0.00	U_O	0.50
K_8	0.00	U_C	-0.50
M	0.00	P_{MAX}	1.50
		P_{MIN}	0.05

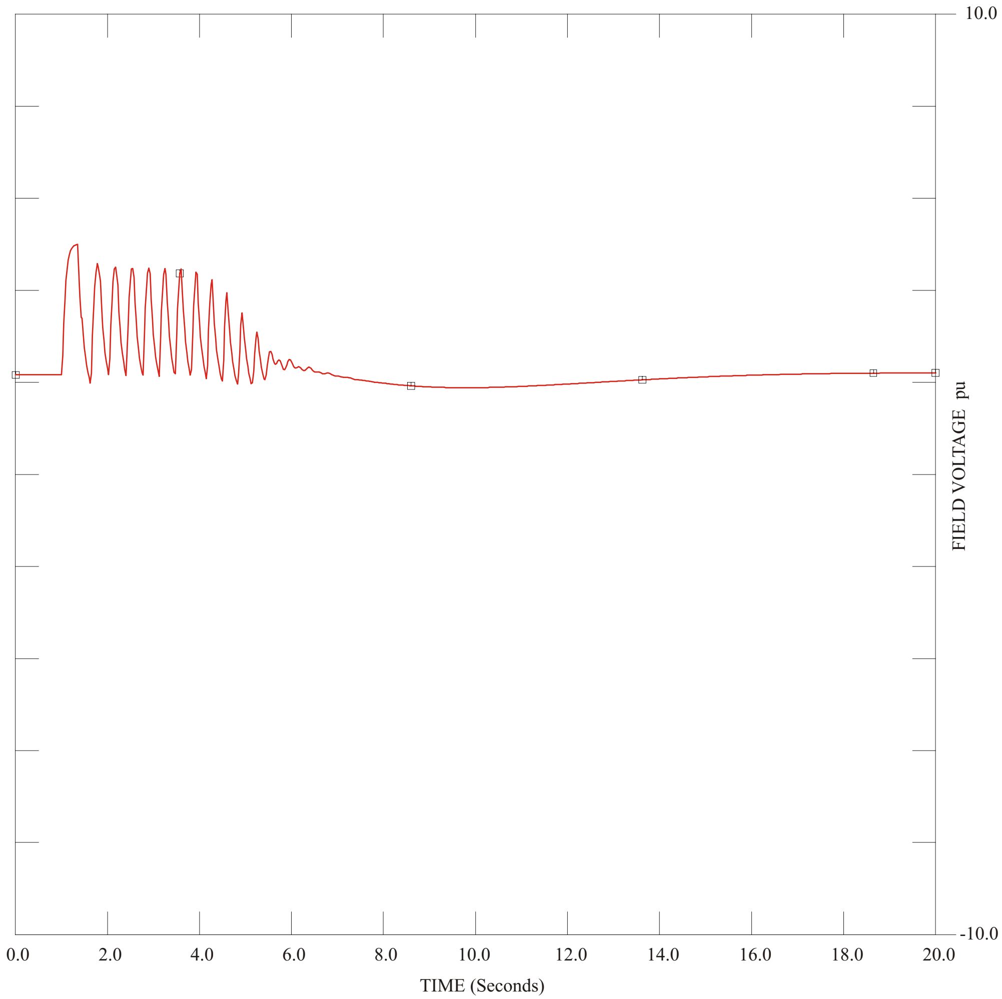
Greater Toronto Airports Authority Project

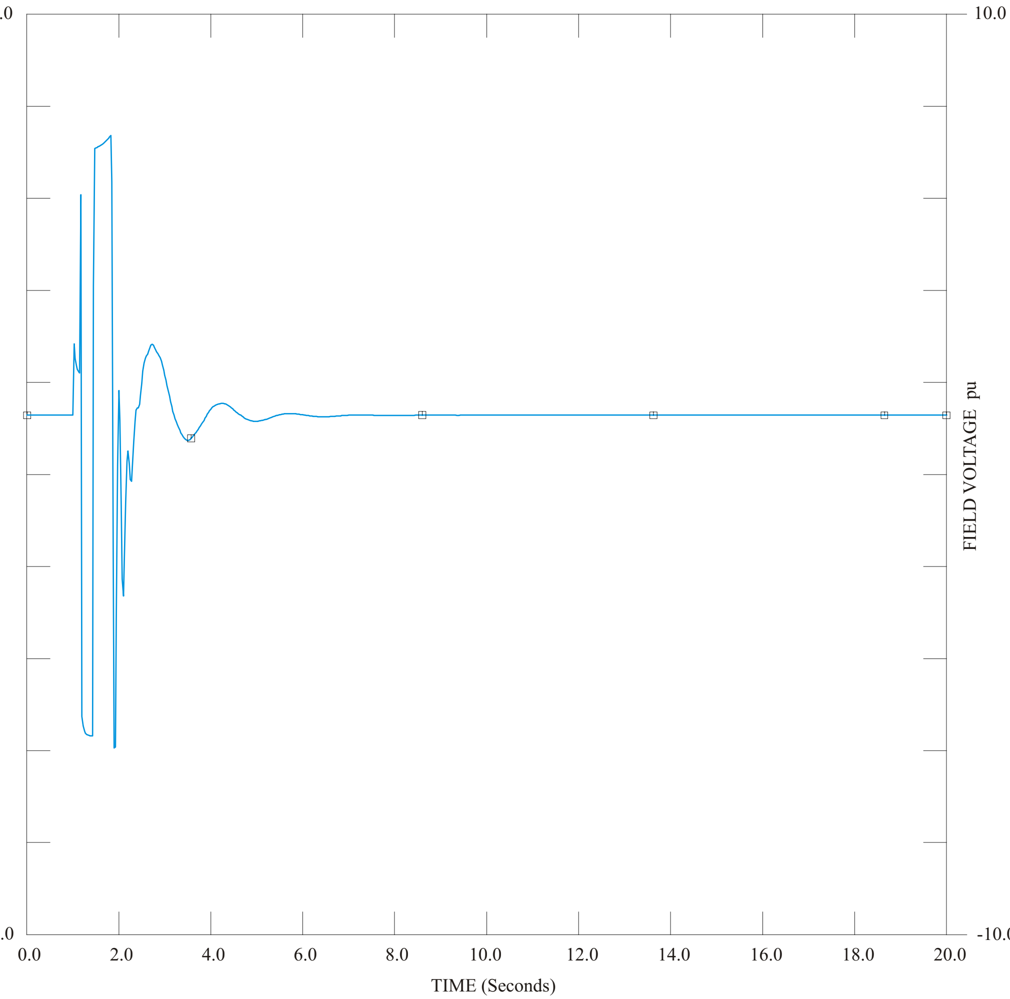
IEEEG1 Governor Model

Data provided for the steam-turbine unit

DIAGRAM 11

27th July 2005





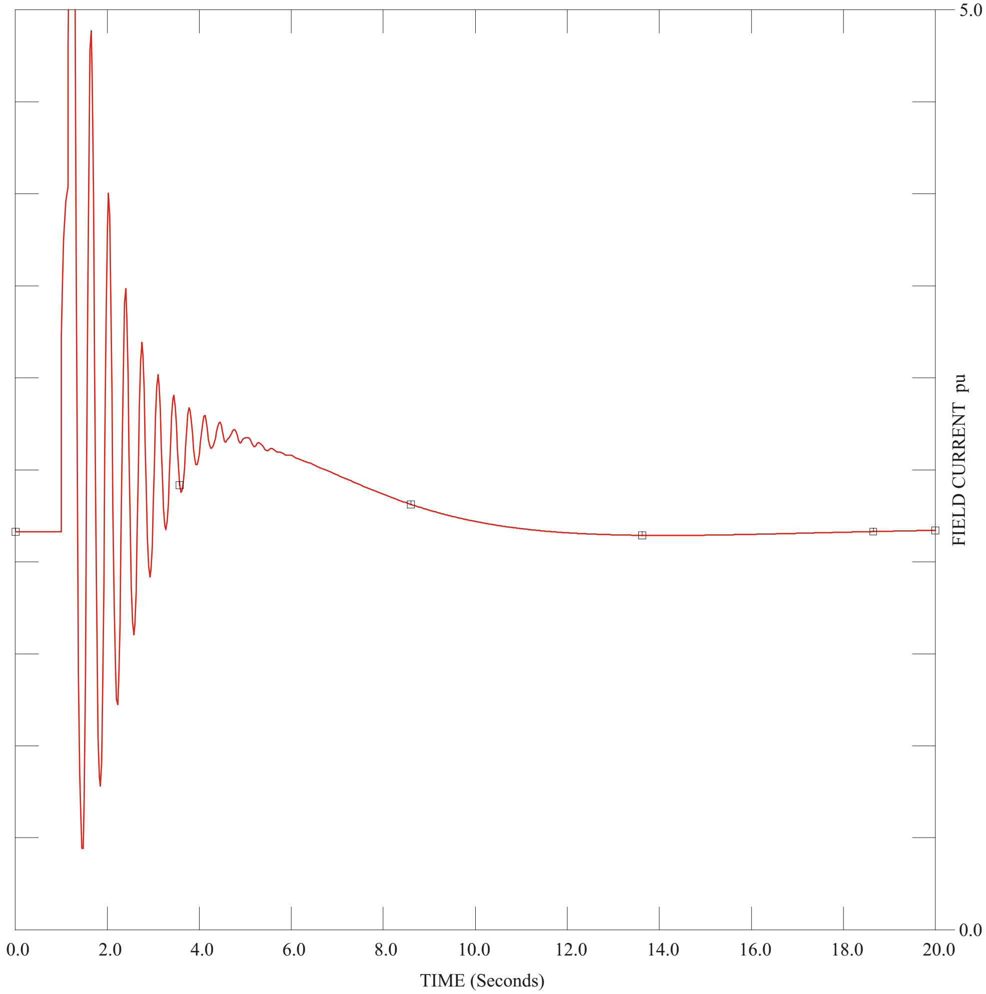
GTAA Project:

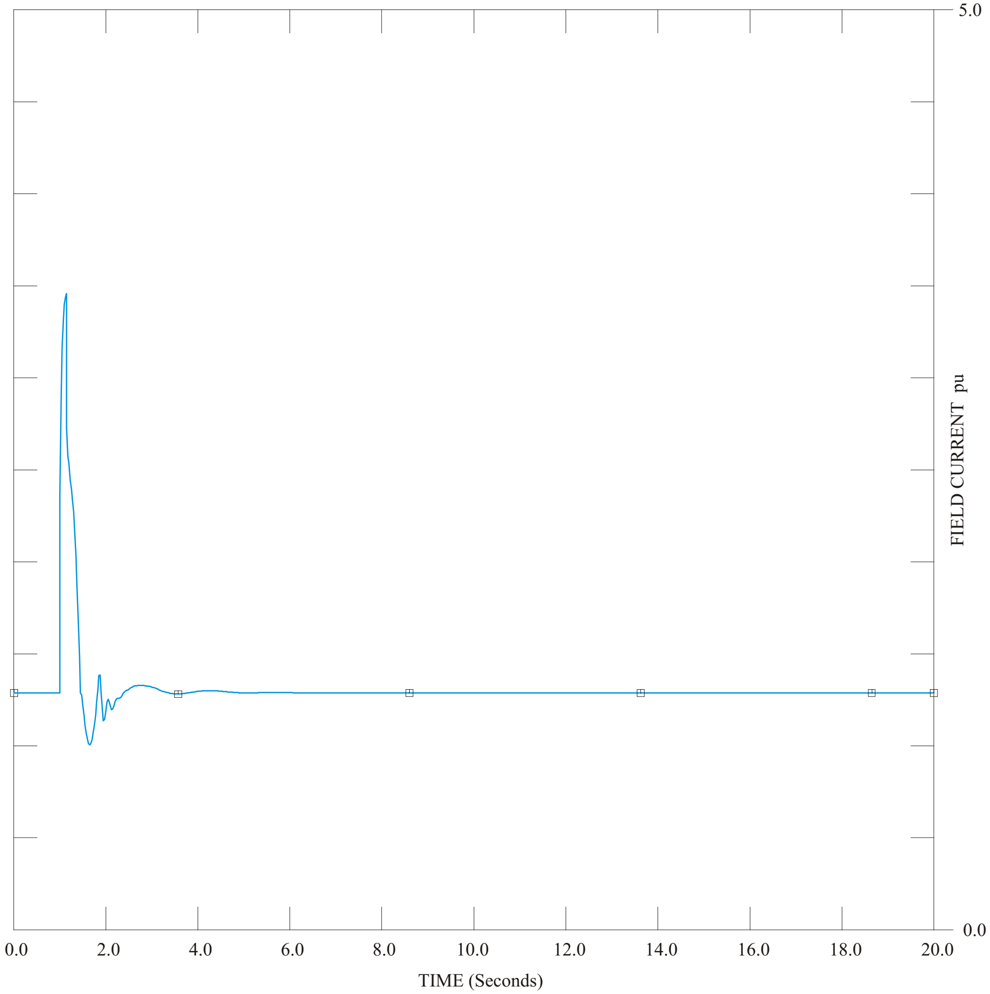
Field Voltage of the Gas-turbine Generating units in response to a three-phase fault on circuit V72R at Claireville TS

Field Voltage of the Steam-turbine Generating unit in response to a three-phase fault on circuit V74R at Claireville TS

DIAGRAM 12

28th July 2005





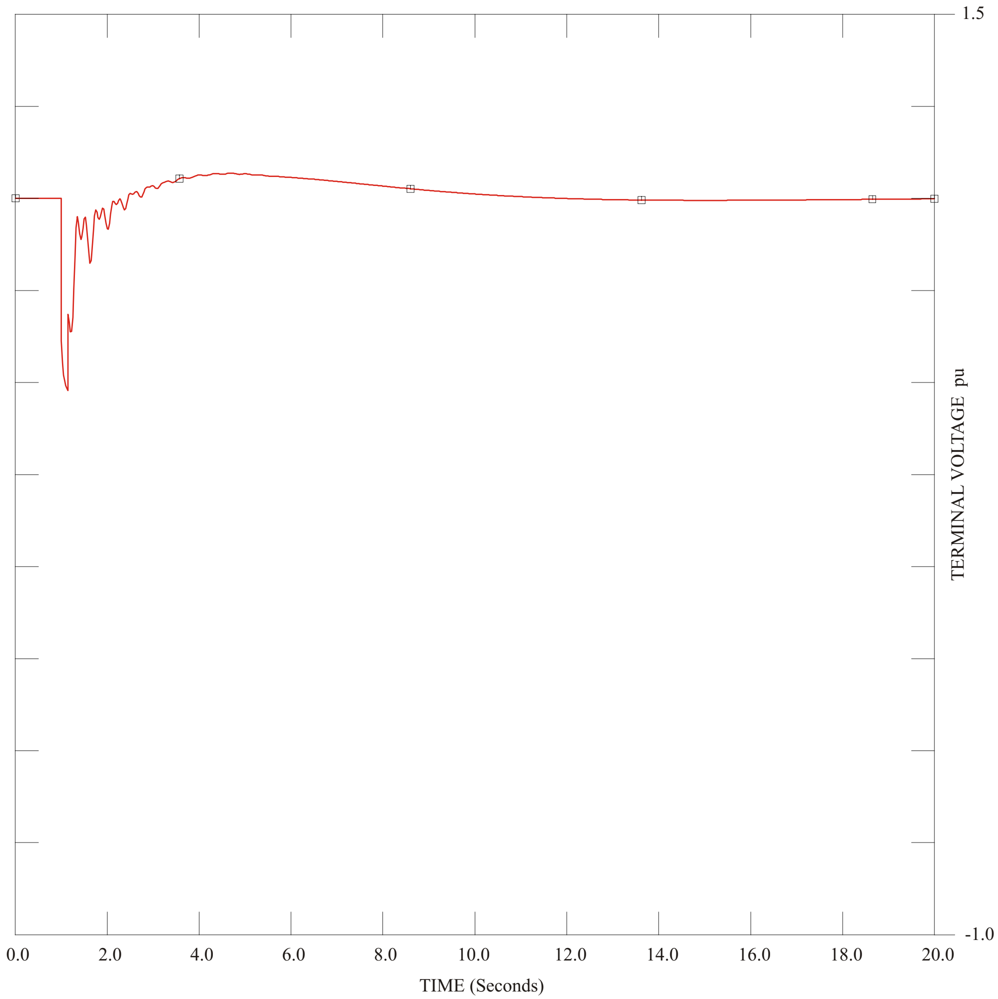
GTAA Project:

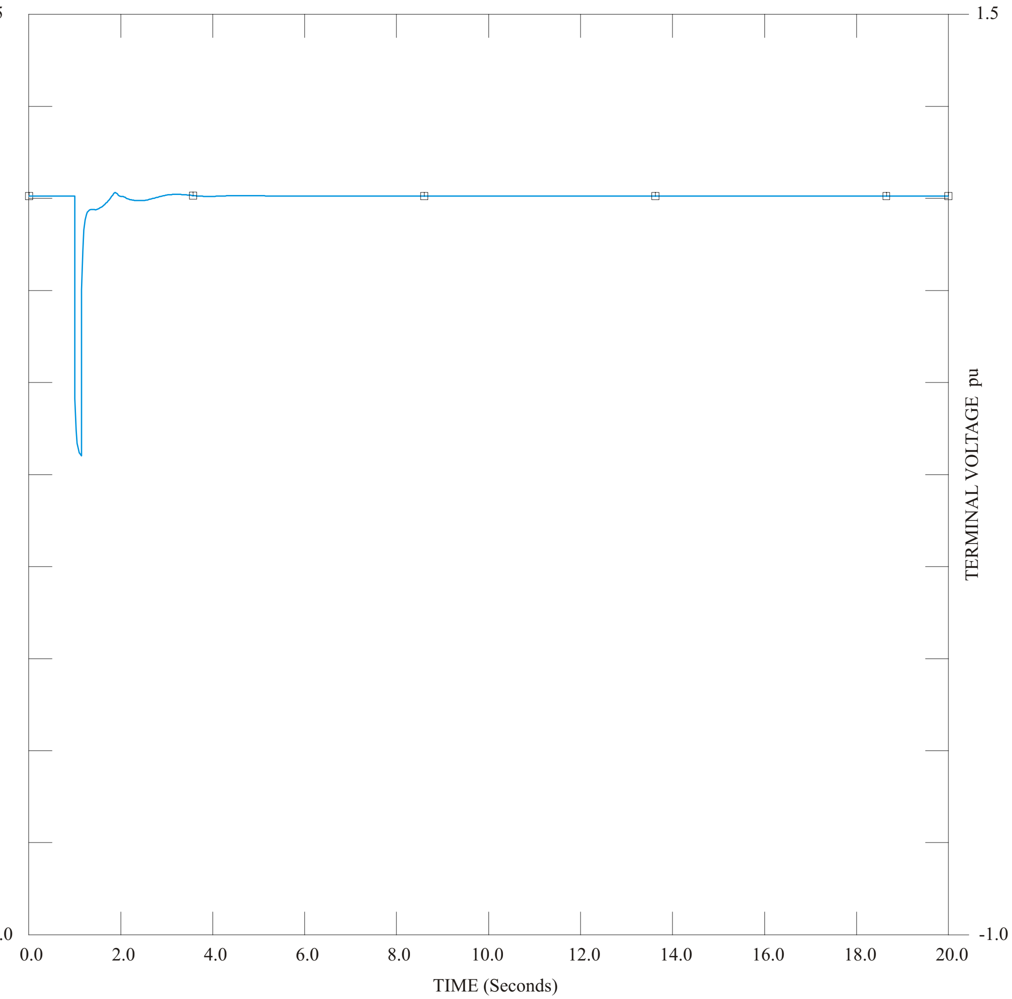
Field Current of the Gas-turbine Generating units in response to a three-phase fault on circuit V72R at Claireville TS

Field Current of the Steam-turbine Generating unit in response to a three-phase fault on circuit V74R at Claireville TS

DIAGRAM 13

28th July 2005





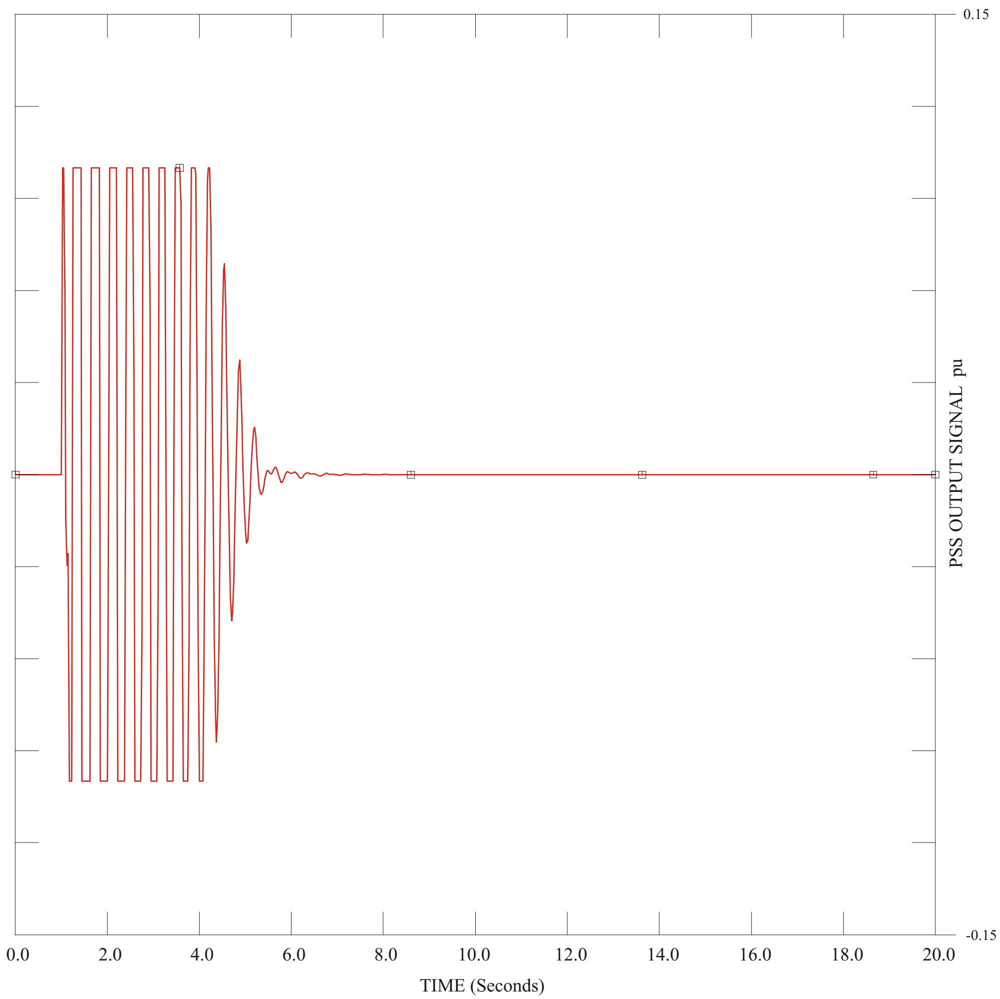
GTAA Project:

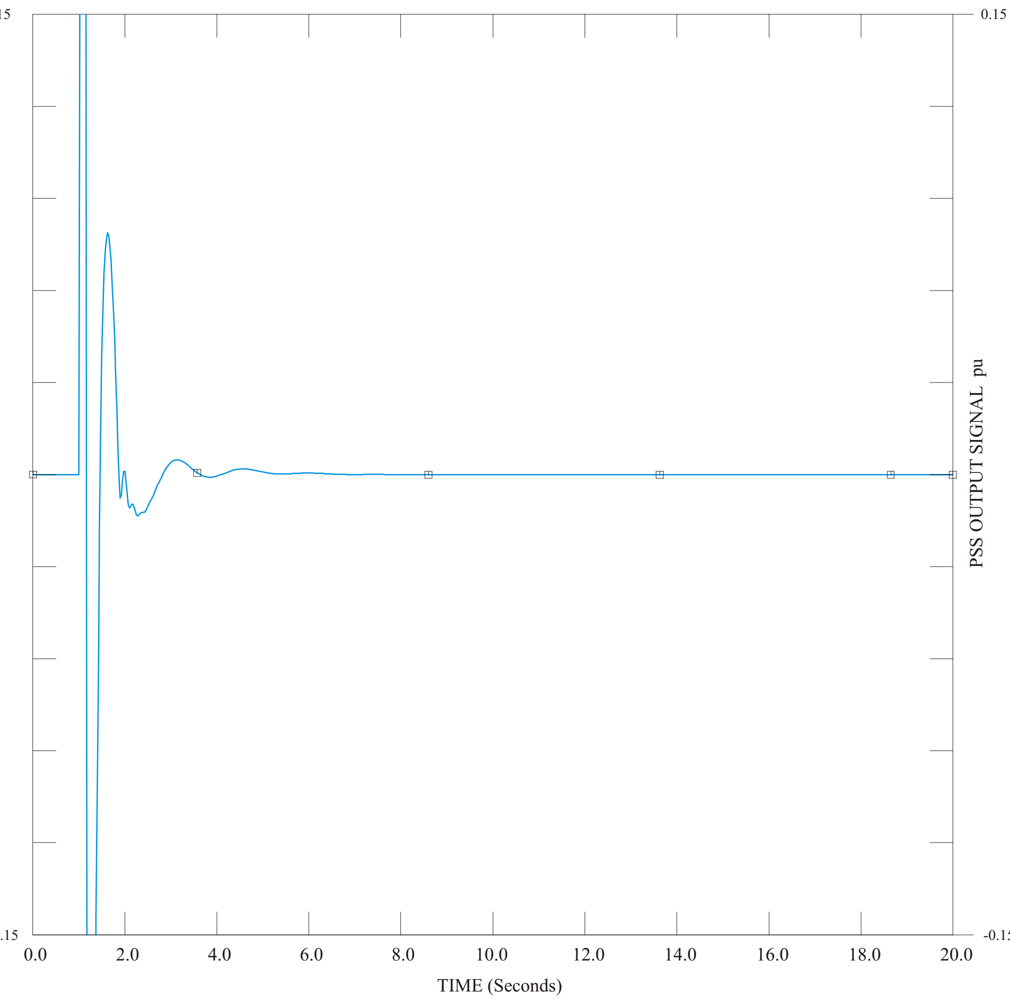
Terminal Voltage of the Gas-turbine Generating units in response to a three-phase fault on circuit V72R at Claireville TS

Terminal Voltage of the Steam-turbine Generating unit in response to a three-phase fault on circuit V74R at Claireville TS

DIAGRAM 14

28th July 2005





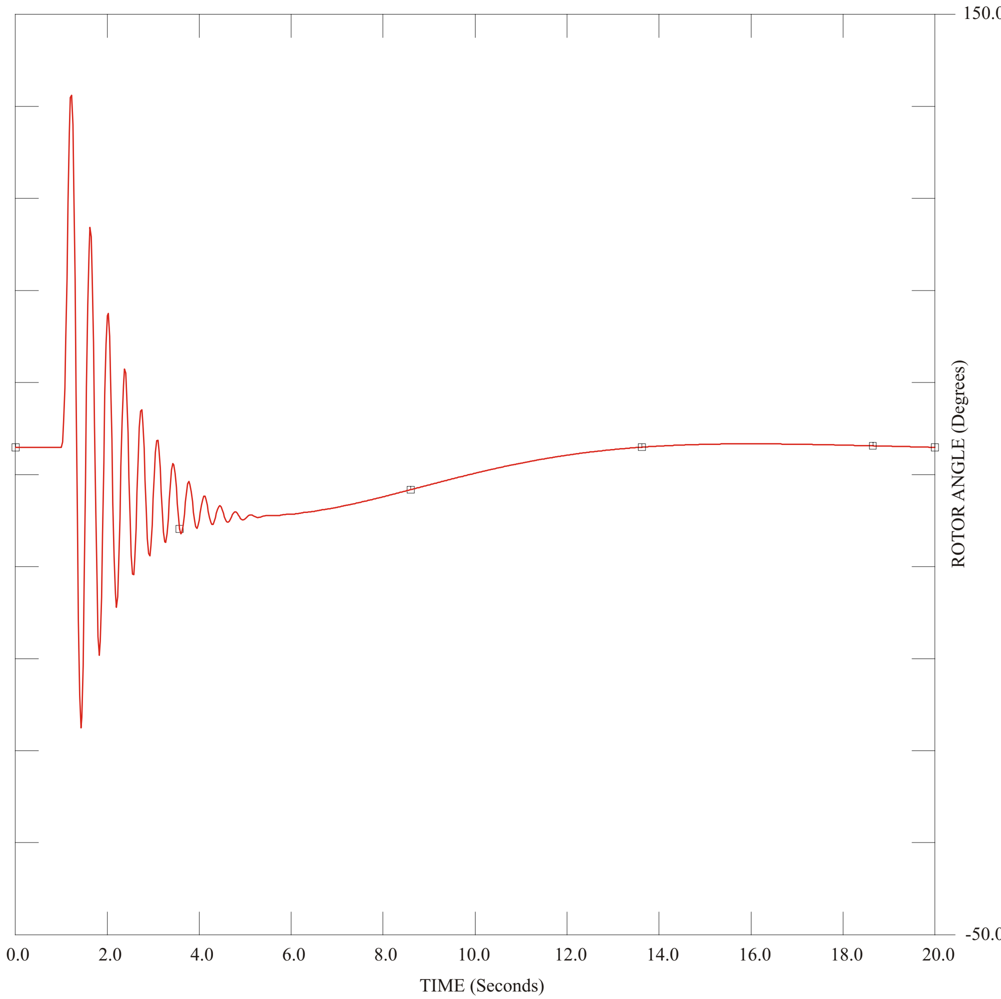
GTAA Project:

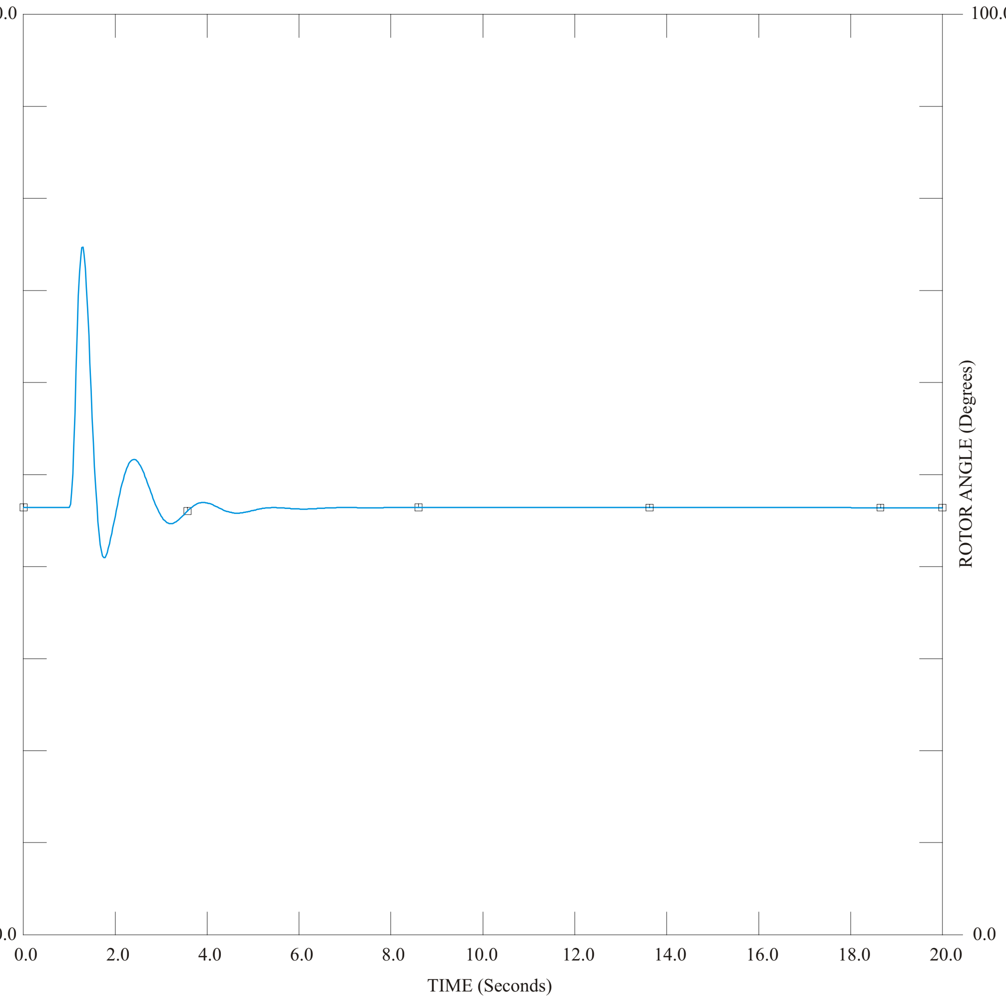
Output of the PSSs on the Gas-turbine Generating units in response to a three-phase fault on circuit V72R at Claireville TS

Output of the PSS on the Steam-turbine Generating unit in response to a three-phase fault on circuit V74R at Claireville TS

DIAGRAM 15

28th July 2005





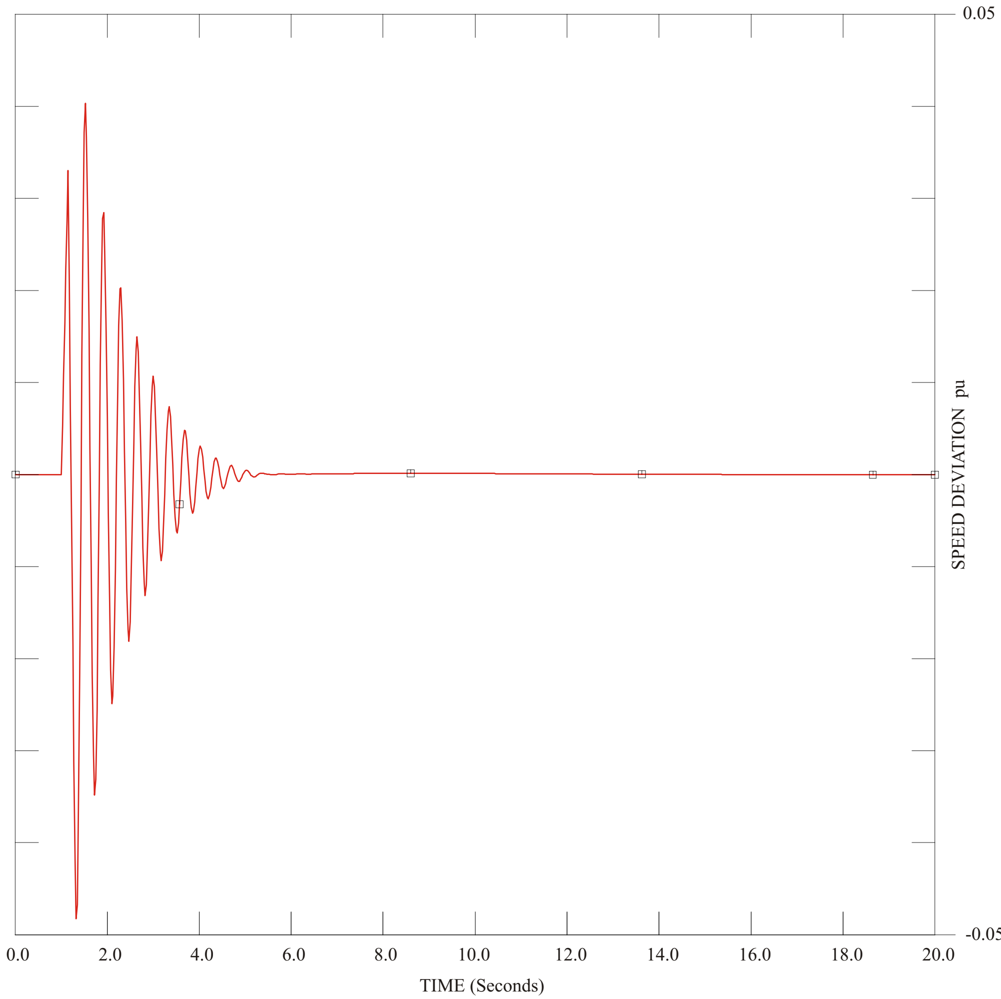
GTAA Project:

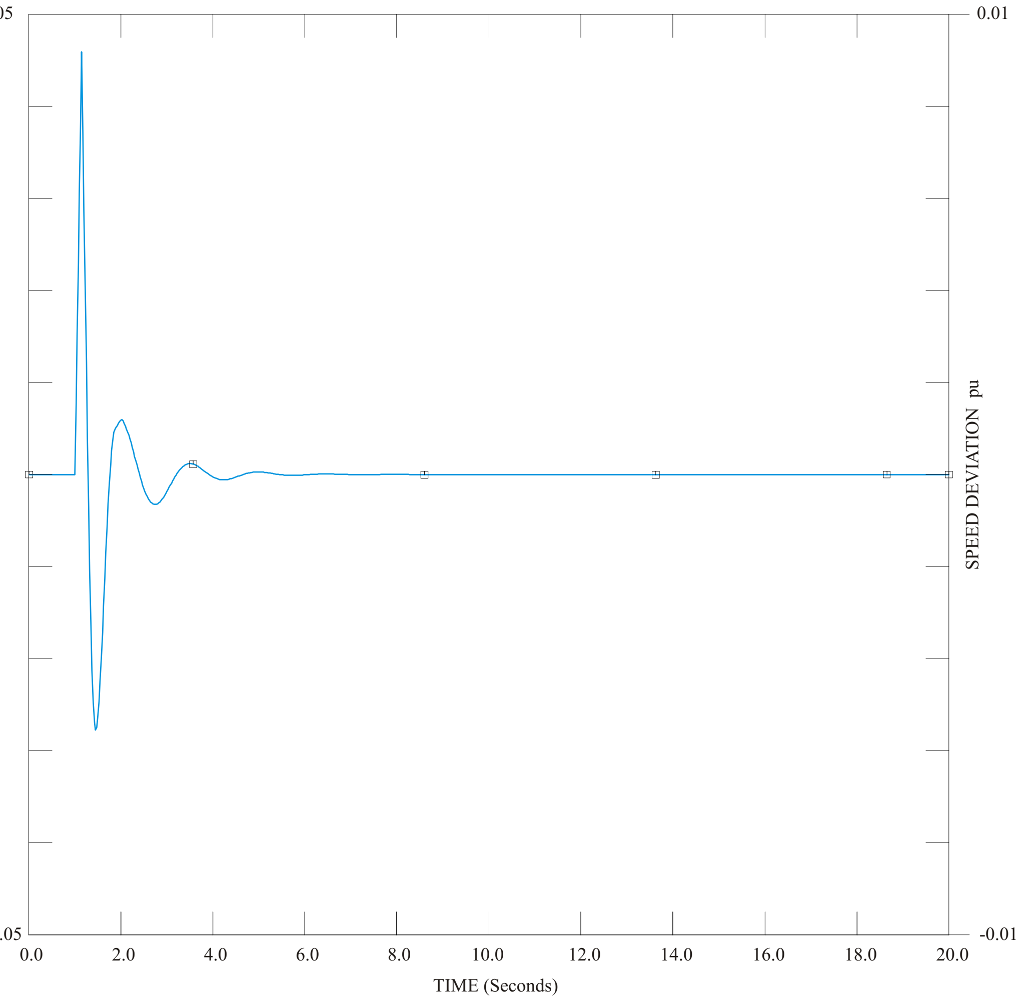
Rotor Angle response of the Gas-turbine Generating units to a three-phase fault on circuit V72R at Claireville TS

Rotor Angle response of the Steam-turbine Generating unit to a three-phase fault on circuit V74R at Claireville TS

DIAGRAM 16

28th July 2005





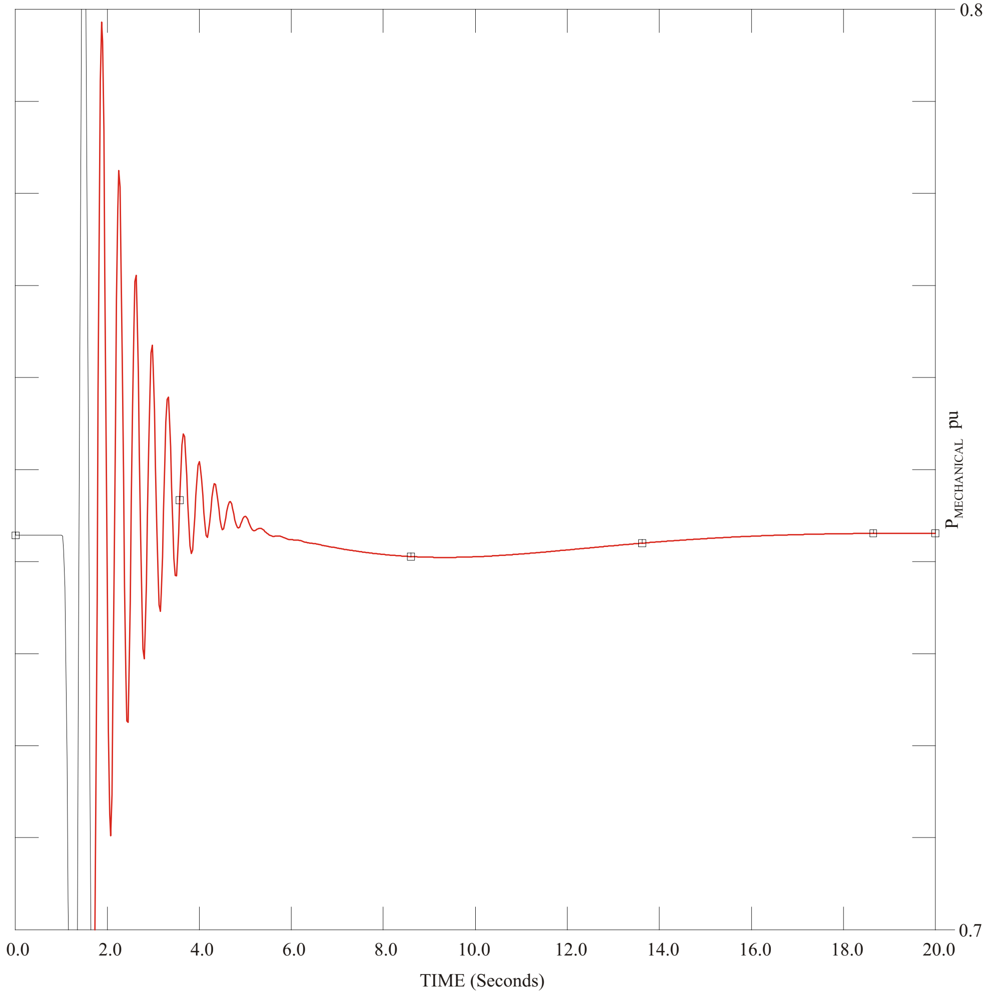
GTAA Project:

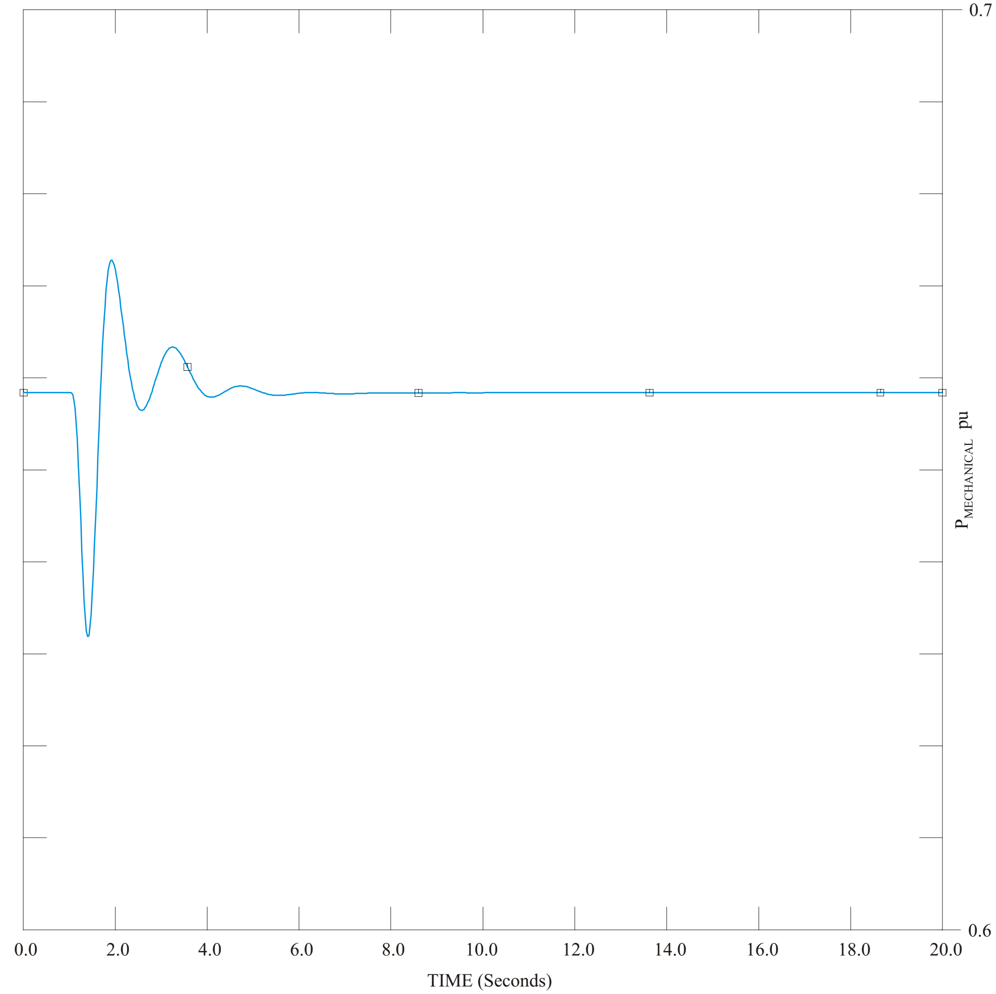
Change in the speed of the Gas-turbine Generating units in response to a three-phase fault on circuit V72R at Claireville TS

Change in the speed of the Steam-turbine Generating unit in response to a three-phase fault on circuit V74R at Claireville TS

DIAGRAM 17

28th July 2005





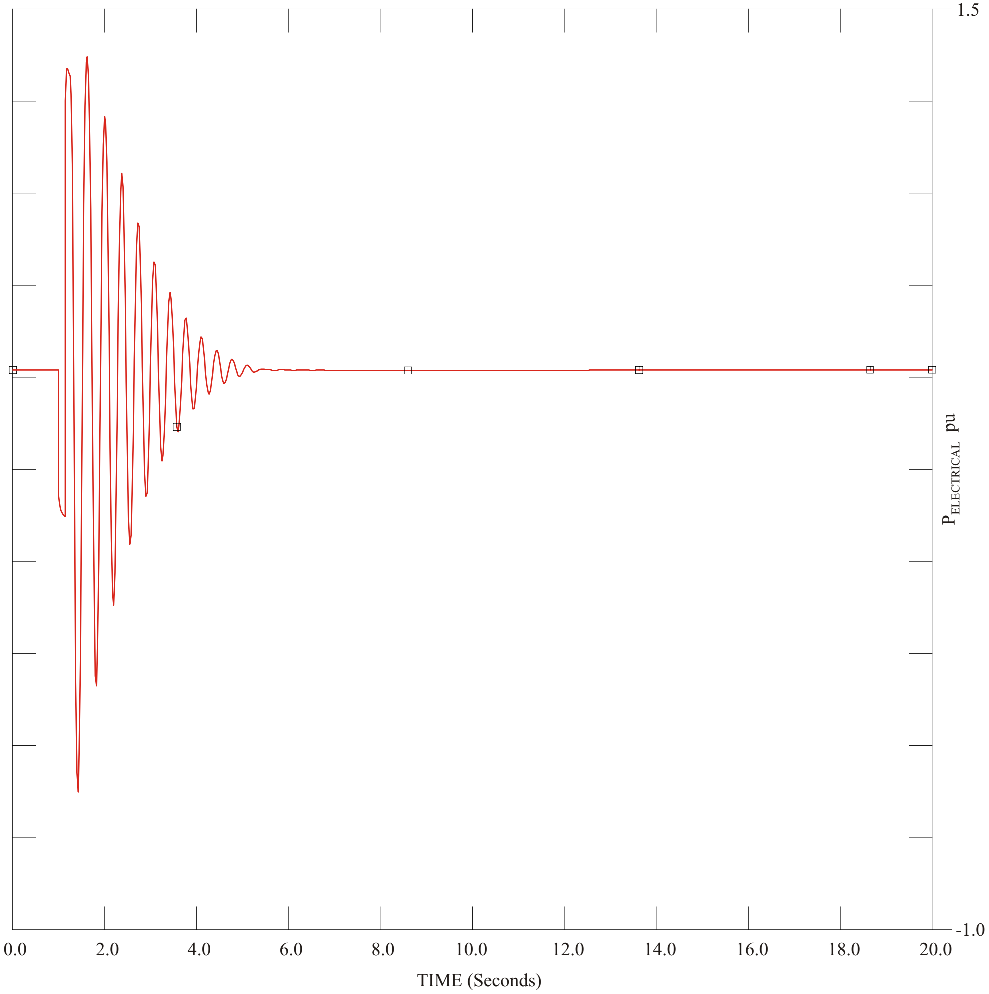
GTAA Project:

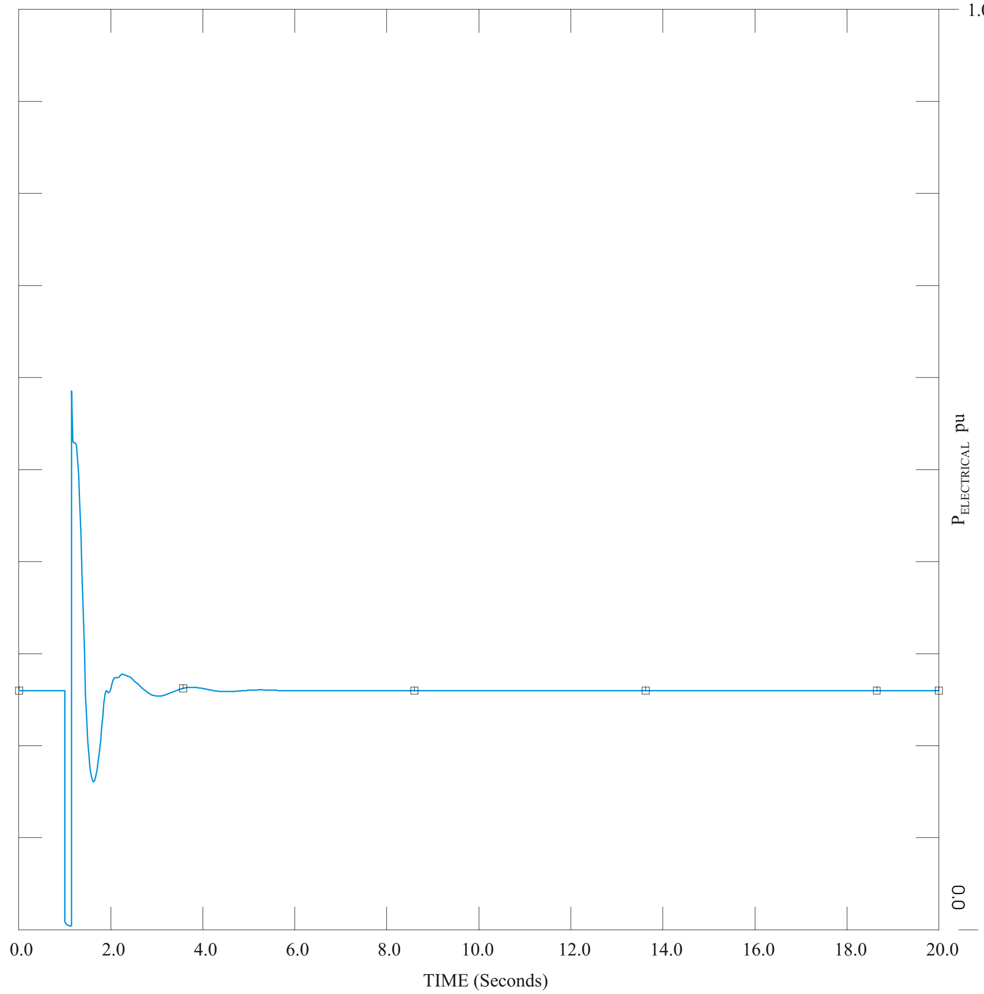
$P_{MECHANICAL}$ of the Gas-turbine Generating units in response to a three-phase fault on circuit V72R at Claireville TS

$P_{MECHANICAL}$ of the Steam-turbine Generating unit in response to a three-phase fault on circuit V74R at Claireville TS

DIAGRAM 18

28th July 2005





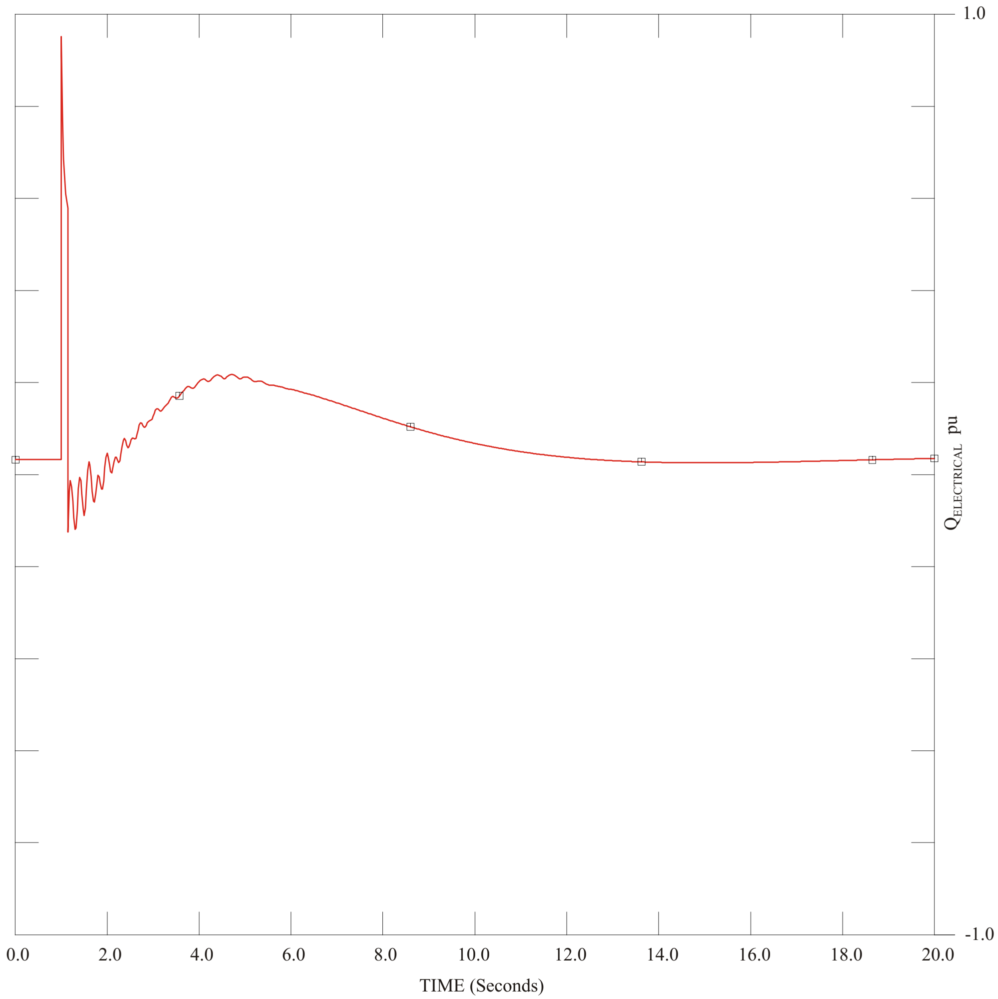
GTAA Project:

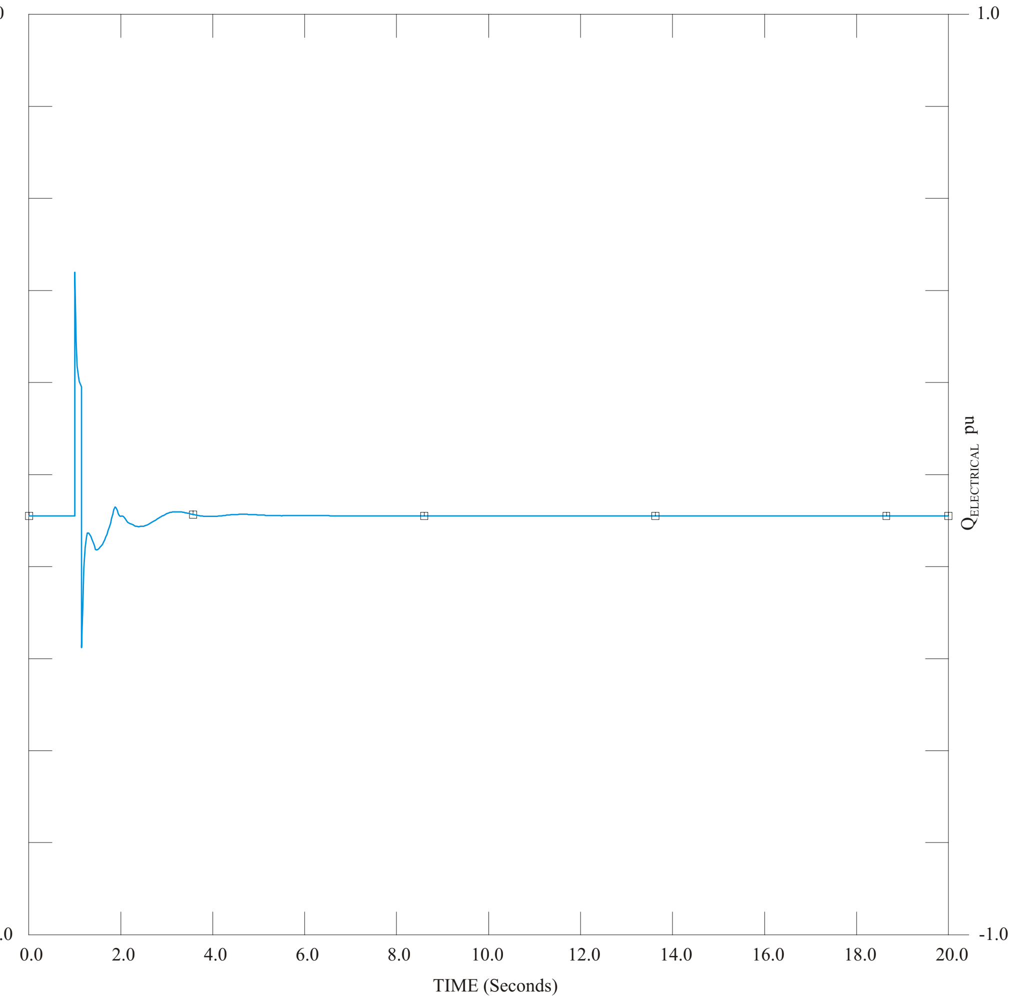
$P_{ELECTRICAL}$ of the Gas-turbine Generating units in response to a three-phase fault on circuit V72R at Claireville TS

$P_{ELECTRICAL}$ of the Steam-turbine Generating unit in response to a three-phase fault on circuit V74R at Claireville TS

DIAGRAM 19

28th July 2005





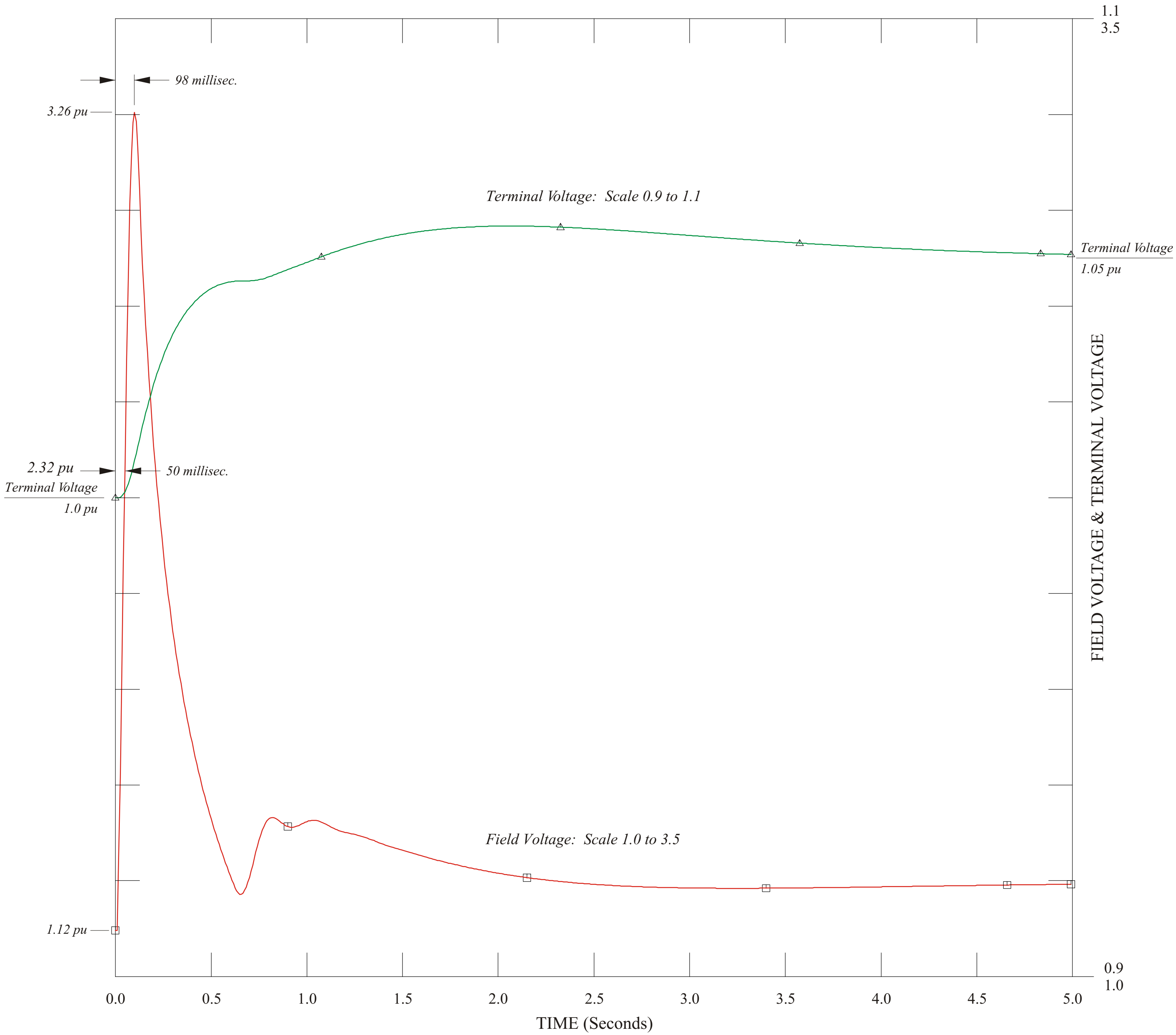
GTAA Project:

Reactive Power Output of the Gas-turbine Generating units in response to a three-phase fault on circuit V72R at Claireville TS

Reactive Power Output of the Steam-turbine Generating unit in response to a three-phase fault on circuit V74R at Claireville TS

DIAGRAM 20

28th July 2005



GTAA Project: Open-Circuit Step-Response of the Gas-turbine Generating units

[to a 5% increase in the generator terminal voltage]

DIAGRAM 21

29th July 2005

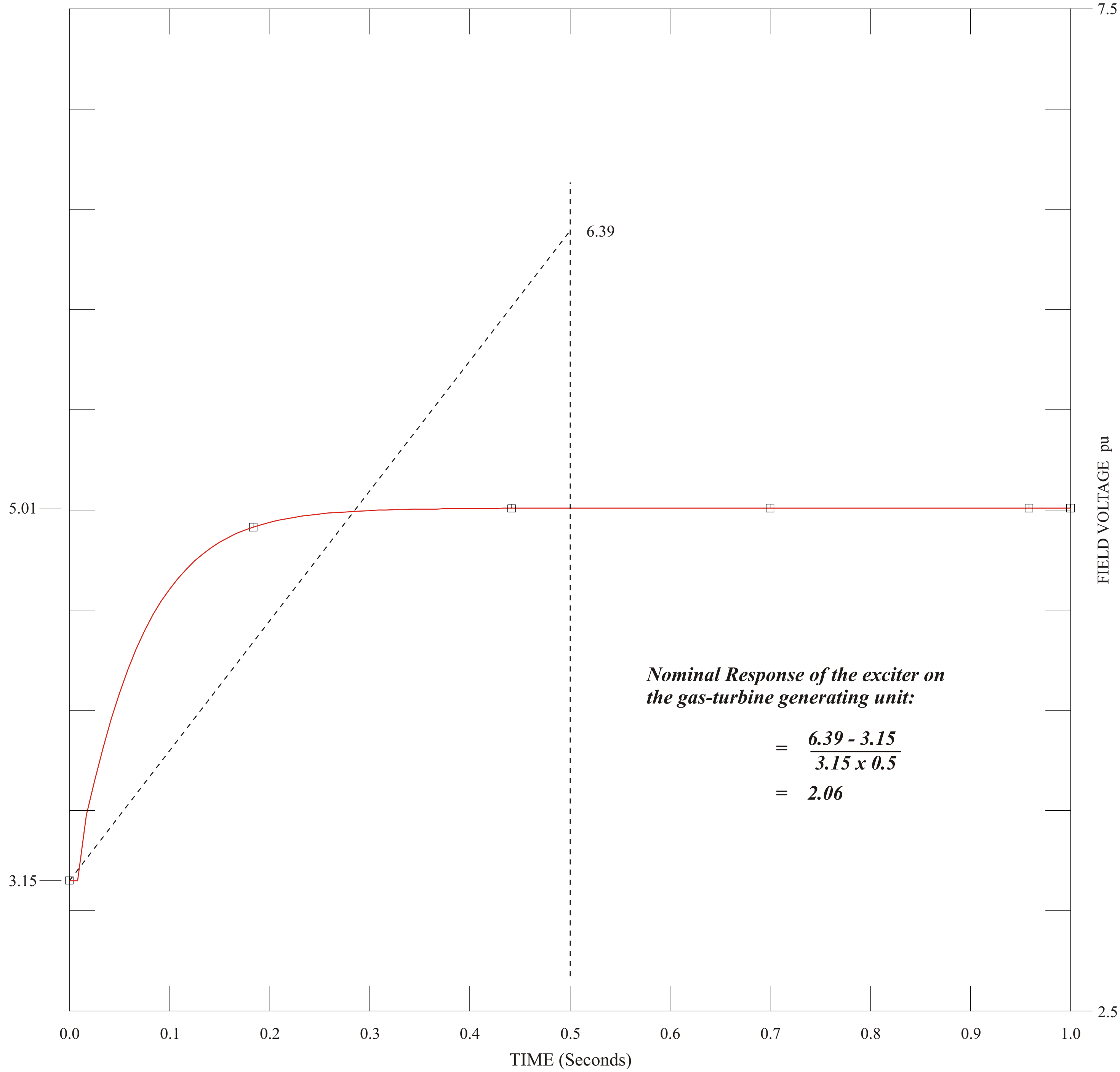
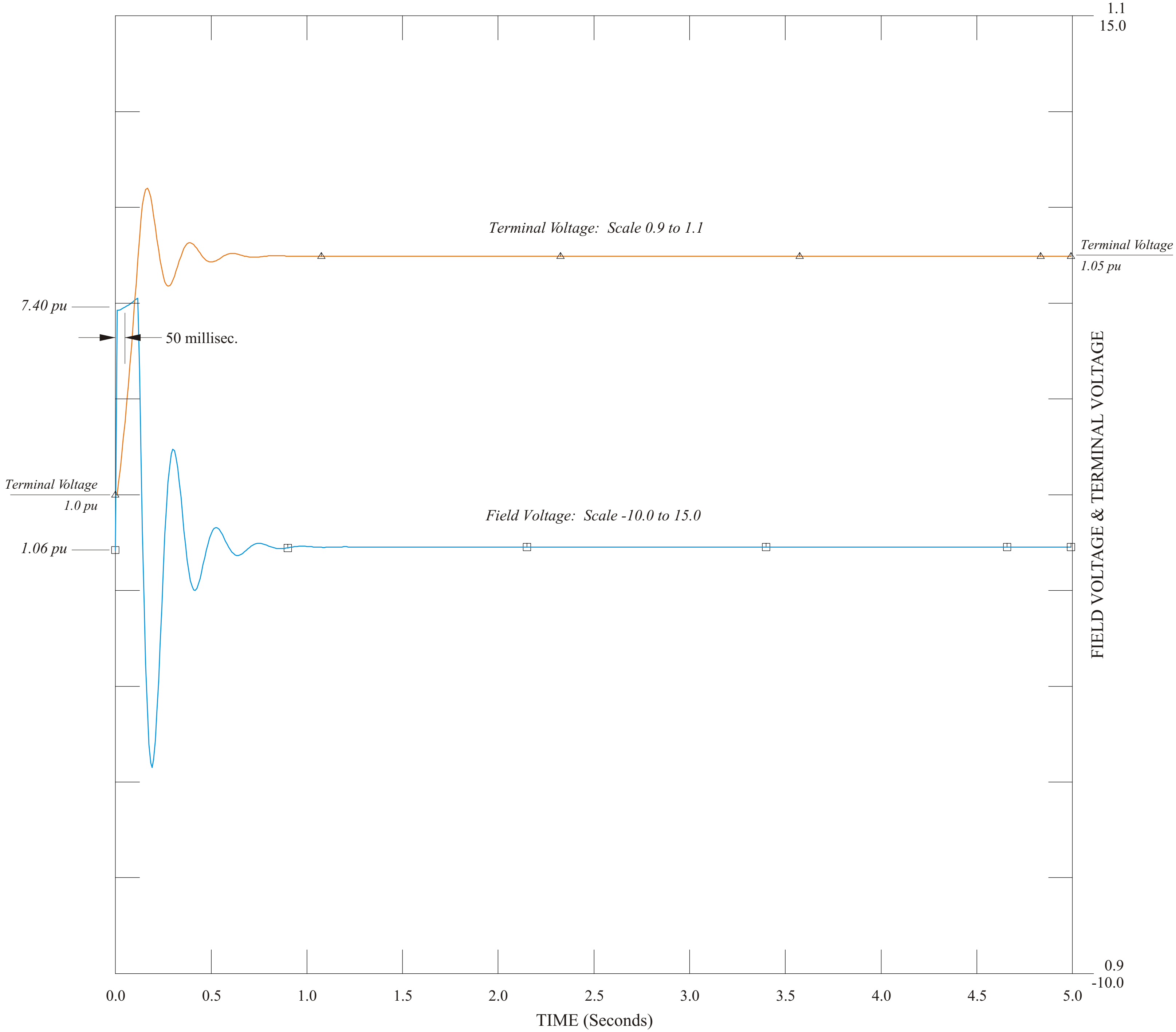


DIAGRAM 22

GTAA Project: Response Ratio Test for the Gas-turbine Generating units

29th July 2005



GTAA Project: Open-Circuit Step-Response of the Steam-turbine Generating unit

[to a 5% increase in the generator terminal voltage]

DIAGRAM 23

29th July 2005

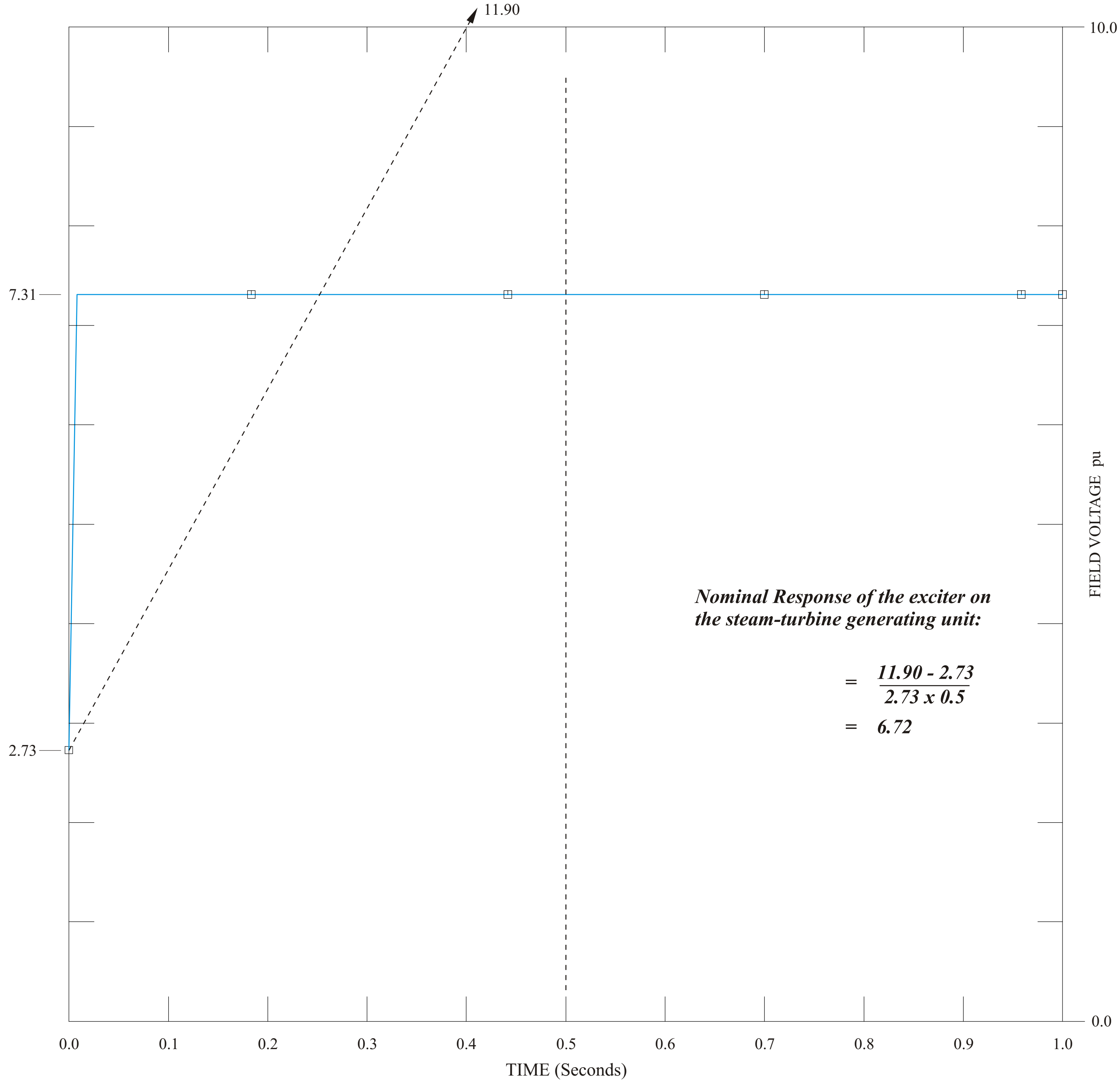
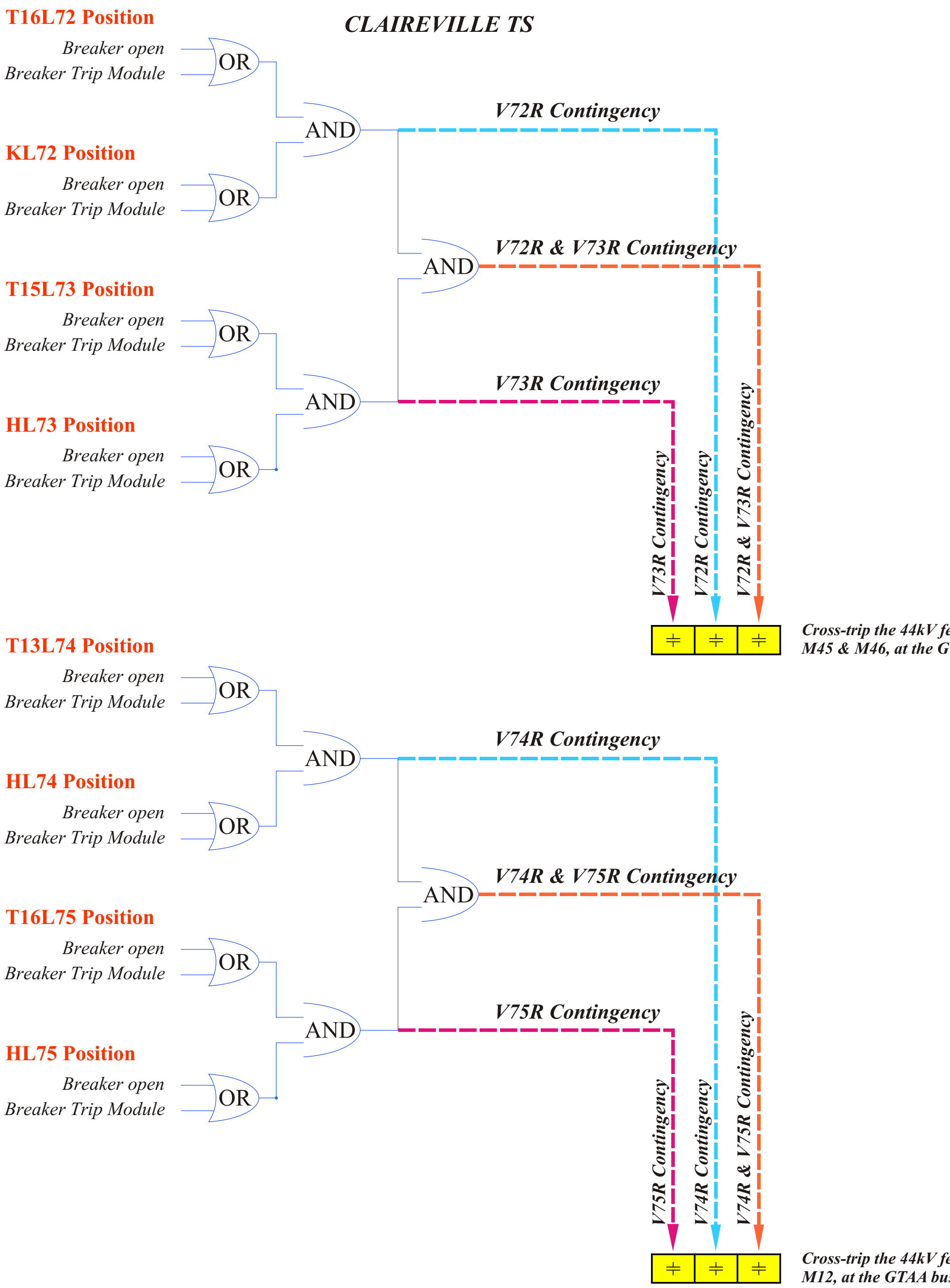
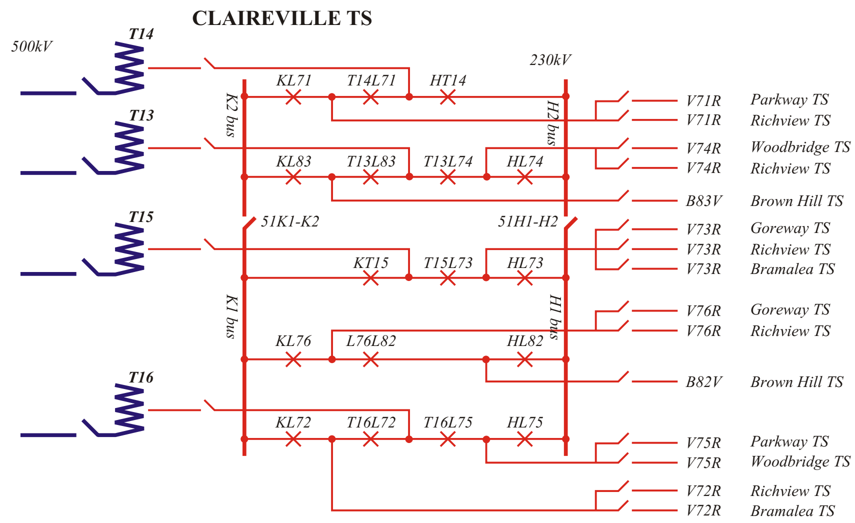


DIAGRAM 24

29th July 2005

GTAA Project: Response Ratio Test for the Steam-turbine Generating unit





Latching Relay (or equivalent) to be armed via SCADA

Under normal-operating conditions, with all elements in-service, the scheme would only be armed for the respective double-circuit contingency conditions.

Under outage conditions involving either a 230kV circuit OR its associated step-down transformer (at Bramalea TS or at Woodbridge TS) the scheme would be armed for a single-circuit contingency involving the companion circuit.

DIAGRAM 25

1st June 005