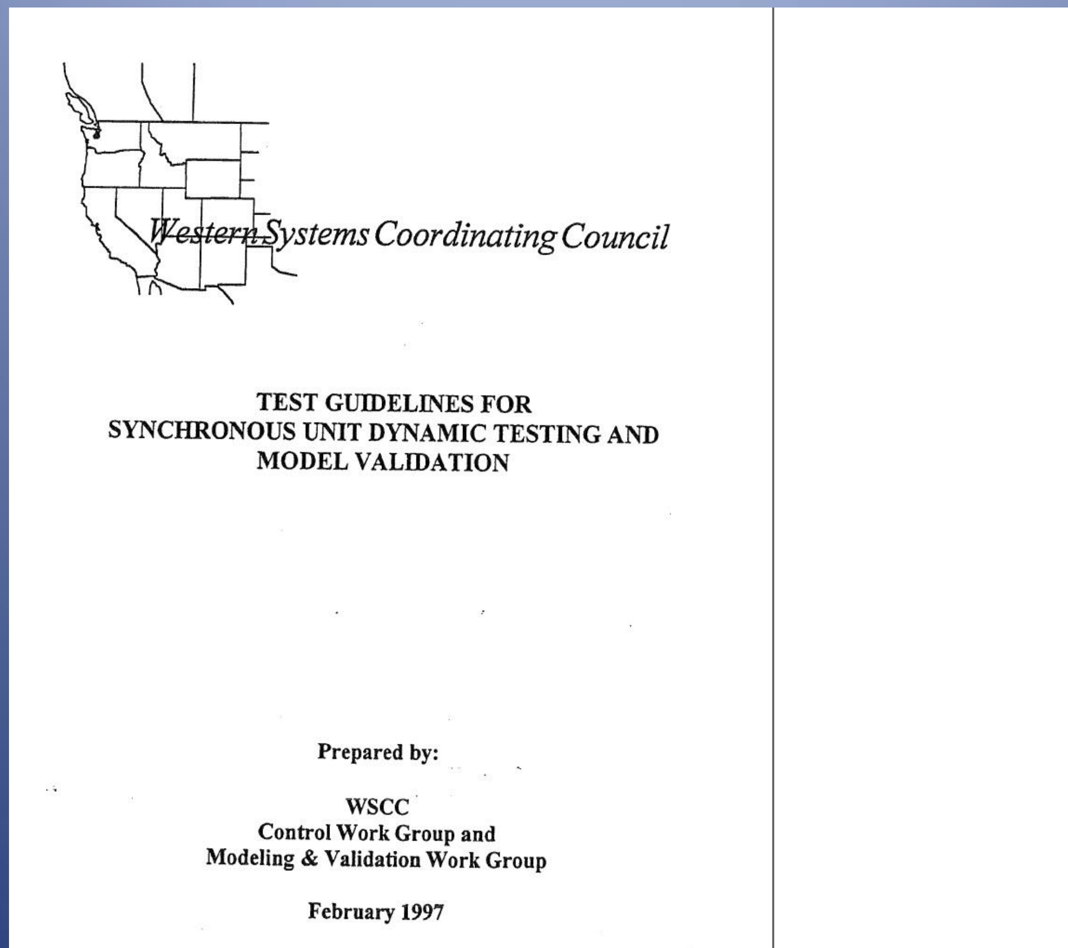
NW Hydro Operator’s Forum
-WECC TESTING-

What’s it all about?

Rod Gunther
PacifiCorp Energy
Hydro Resources

Good Reading Resource



Western Systems Coordinating Council

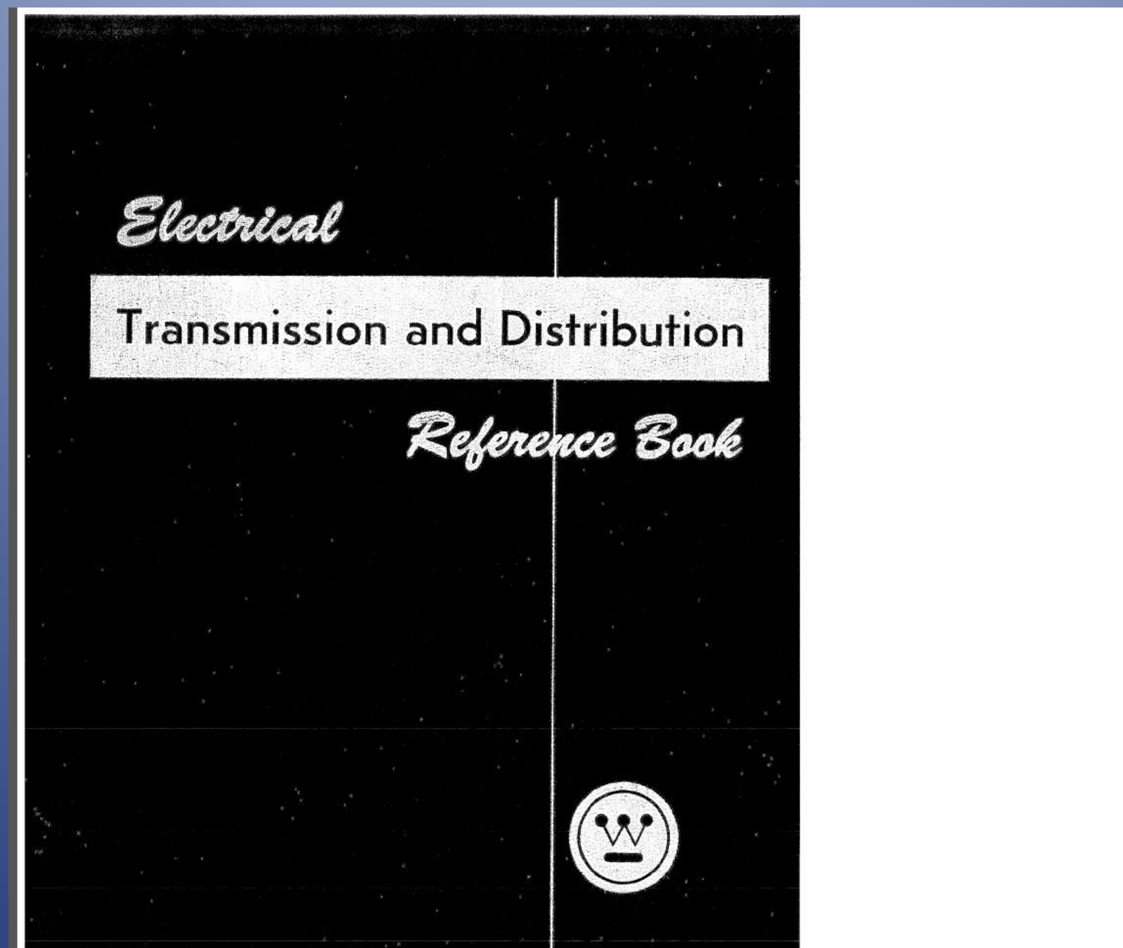
TEST GUIDELINES FOR SYNCHRONOUS UNIT DYNAMIC TESTING AND MODEL VALIDATION

Prepared by:

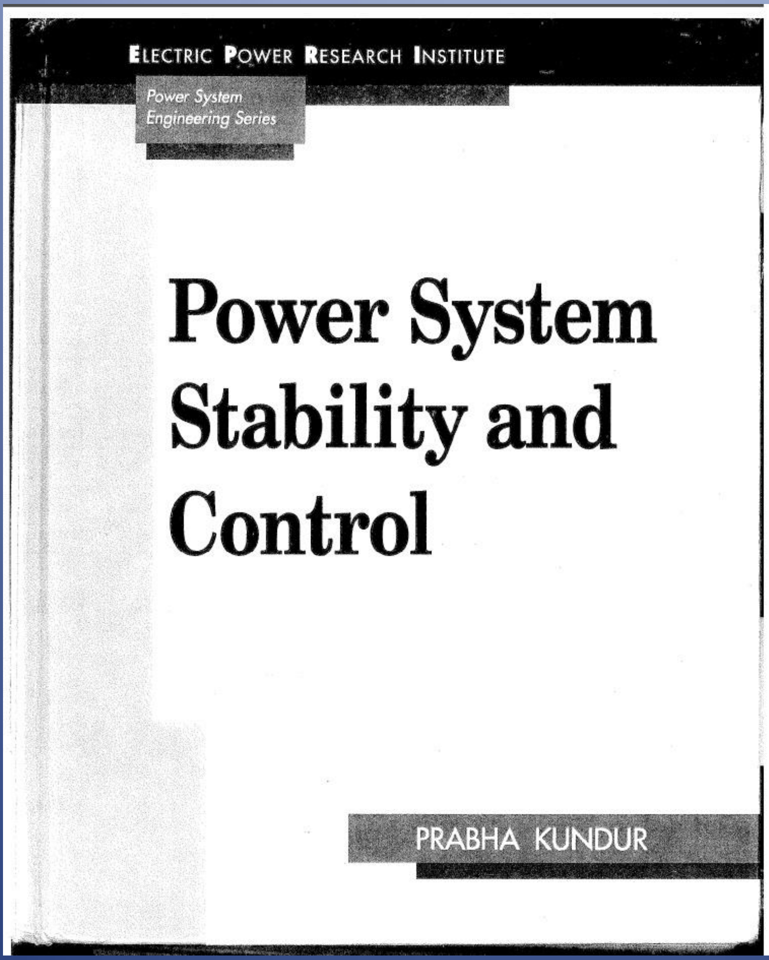
WSCC
Control Work Group and
Modeling & Validation Work Group

February 1997

Reference


Electrical
Transmission and Distribution
Reference Book

Great Reading for the Engineer



Great Book

Electromagnetic
and
Electromechanical
Machines

Leander W. Matsch

Professor of Electrical Engineering
University of Arizona

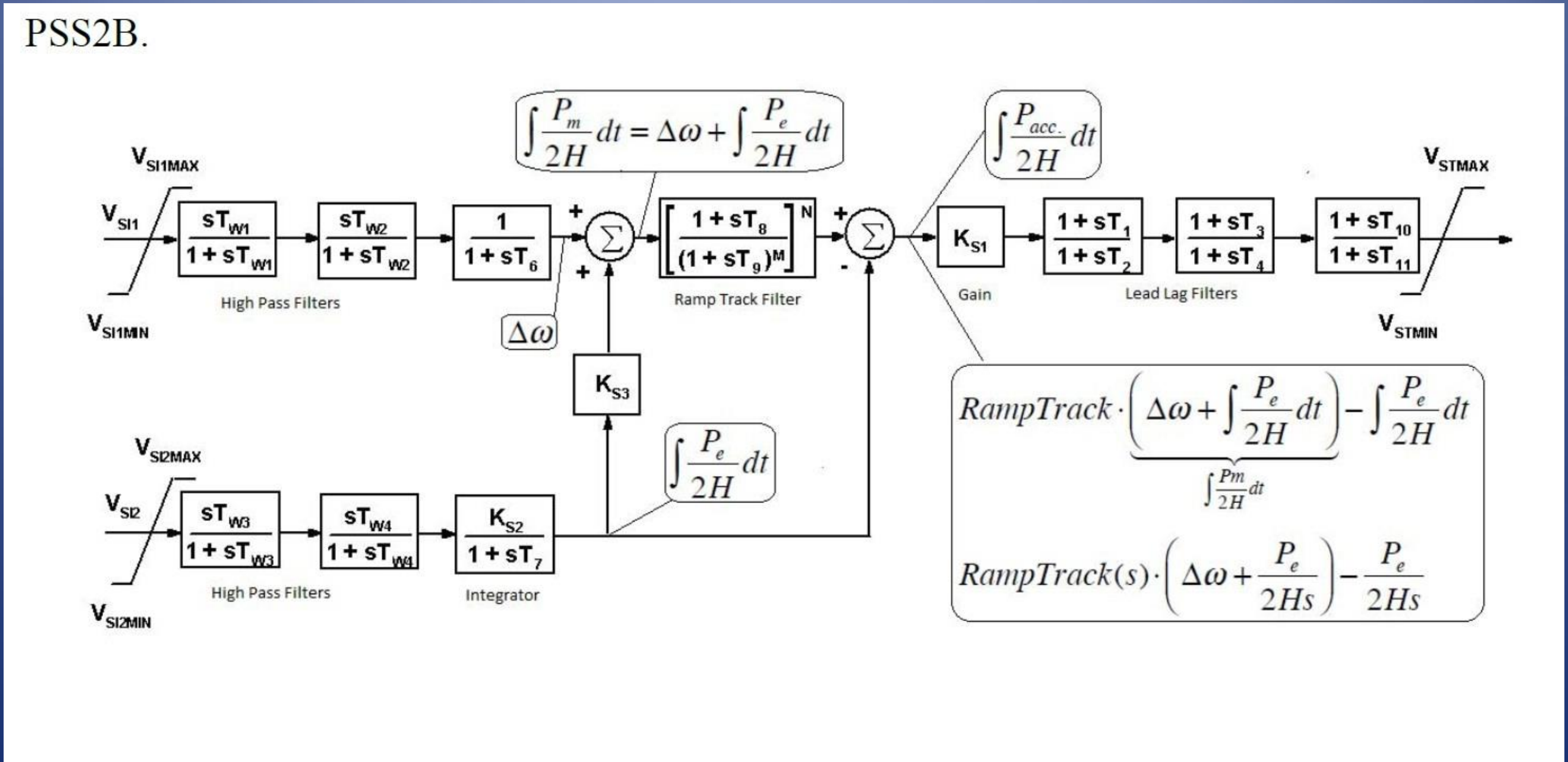
PacifiCorp Energy

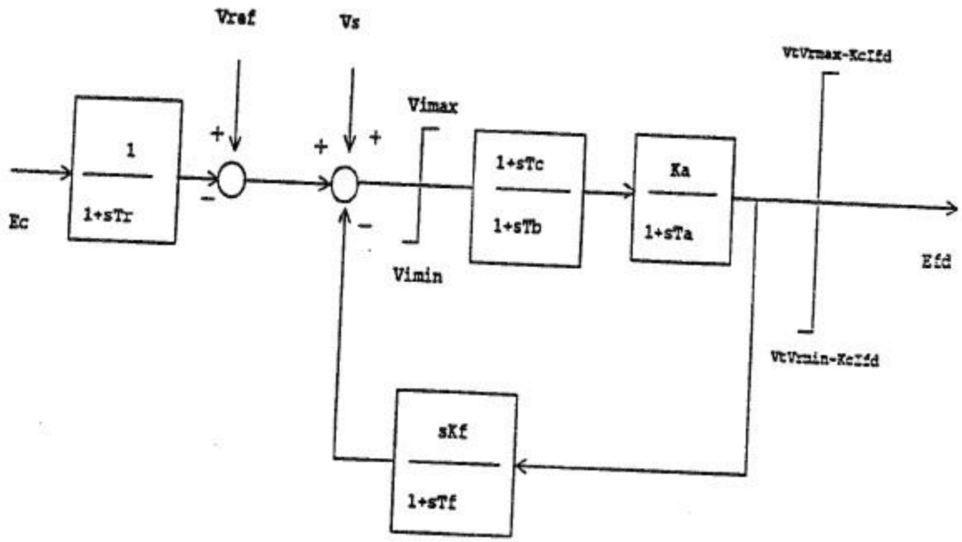
- Has been testing and modelling since the 1990
- Whole industry has been on a learning curve.
- What to test, how to test, how to report?
- We started with OEMs
- Then on to consultants
- We are doing much of the testing and modelling ourselves (Hydro).

PacifiCorp

- We have created models of our equipment based upon standard IEEE transfer functions.
- The data, in PSSE format is turned over to our transmission planning group for review and verification and then they submit this data to the WECC.

Stabilizer Transfer Function





tr	Filter time constant, sec
vimax	Maximum error, pu
vimin	Minimum error, pu
tc	Lead time constant, sec
tb	Lag time constant, sec
ka	Gain
ta	Time constant, sec
vrmax	Maximum controller output
vrmin	Minimum controller output
kc	Excitation system regulation factor, pu
kf	Rate feedback gain
tf	Rate feedback time constant, sec

exst1 IEEE type ST1 excitation system

gentpj

Tpdo	7
Tppdo	0.035
Tpqo	0
Tppqo	0.035
H	3
D	0
Ld	1
Lq	0.75
Lpd	0.32
Lpq	0.75
Lppd	0.23
Lppq	0.23
Ll	0.15
S1	0.15
S12	0.45
Ra	0.003
Rcomp	0
Xcomp	-0.05
Kis	0.07

esst4b

Tr	0.0167
Kpr	35
Kir	10
Ta	0
Vrmax	1
Vrmin	-0.87
Kpm	1
Kim	0
Vmmax	99
Vmmin	-99
Kg	0
Kp	2
Angp	0
Ki	0
Kc	0.08
Xl	0
Vbmax	6
Vgmax	999

pss2a

J1	1
K1	0
J2	3
K2	0
Tw1	7.5
Tw2	7.5
Tw3	7.5
Tw4	0
T6	0
T7	7.5
Ks2	1.27
Ks3	1
Ks4	1
T8	1
T9	0.2
n	1
m	5
Ks1	7
T1	0.1
T2	0.0167
T3	0.1
T4	0.0167
Vstmax	0.1
Vstmin	-0.1
a	1
Ta	0.1
Tb	0.0167

hyg3

Pmax	1
Pmin	0
Cflag	1
Rgate	0
Relec	0.05
Td	0.02
Tf	0.02
Tp	0.1
Velop	0.1
Velcl	-0.1
K1	0.01
K2	1.5
Ki	0.75
Kg	2
Tt	0.2
db1	0
eps	0
db2	0
Tw	1
At	1
Dturb	0.5
qnl	0
H0	1
Gv1	0.07
Pgv1	0
Gv2	0.23
Pgv2	0.2
Gv3	0.57
Pgv3	0.8
Gv4	0.66
Pgv4	0.9
Gv5	0.8
Pgv5	0.98
Gv6	1
Pgv6	1

oel1

Ifdset	2.5
Ifdmax	3.3
Tpicku	20
Runbac	0
Tmax	999
Tset	999
Ifcont	2.5
Vfdflag	0

Inside the Soda exciter, and how to simulate its operation on a computer

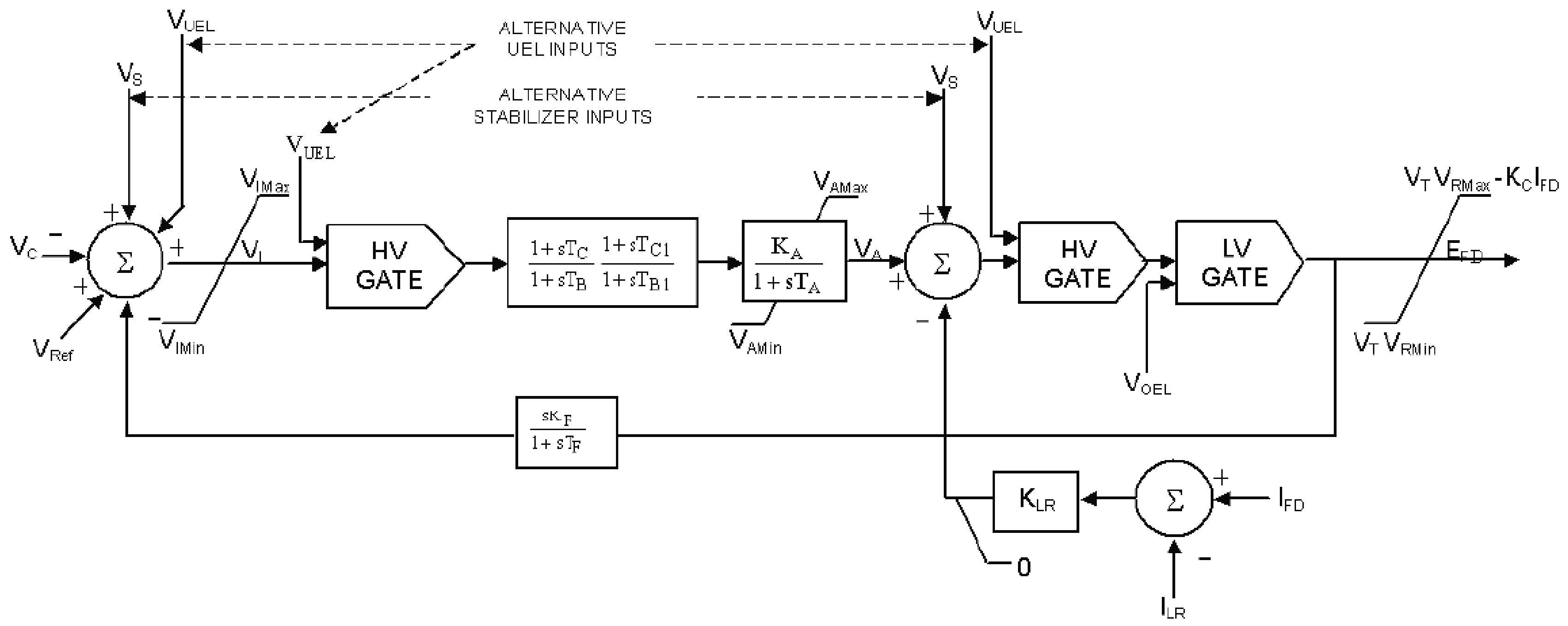
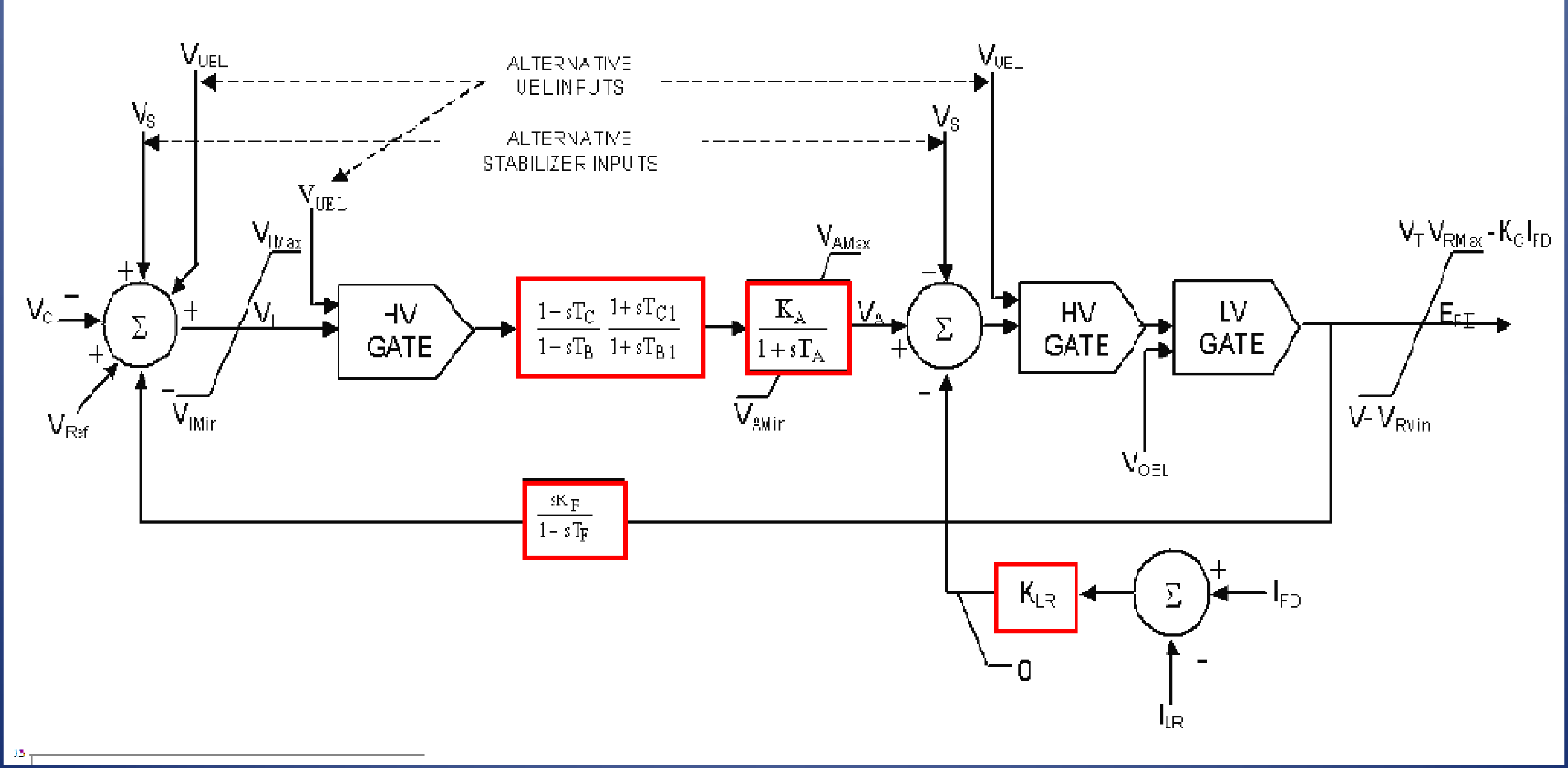
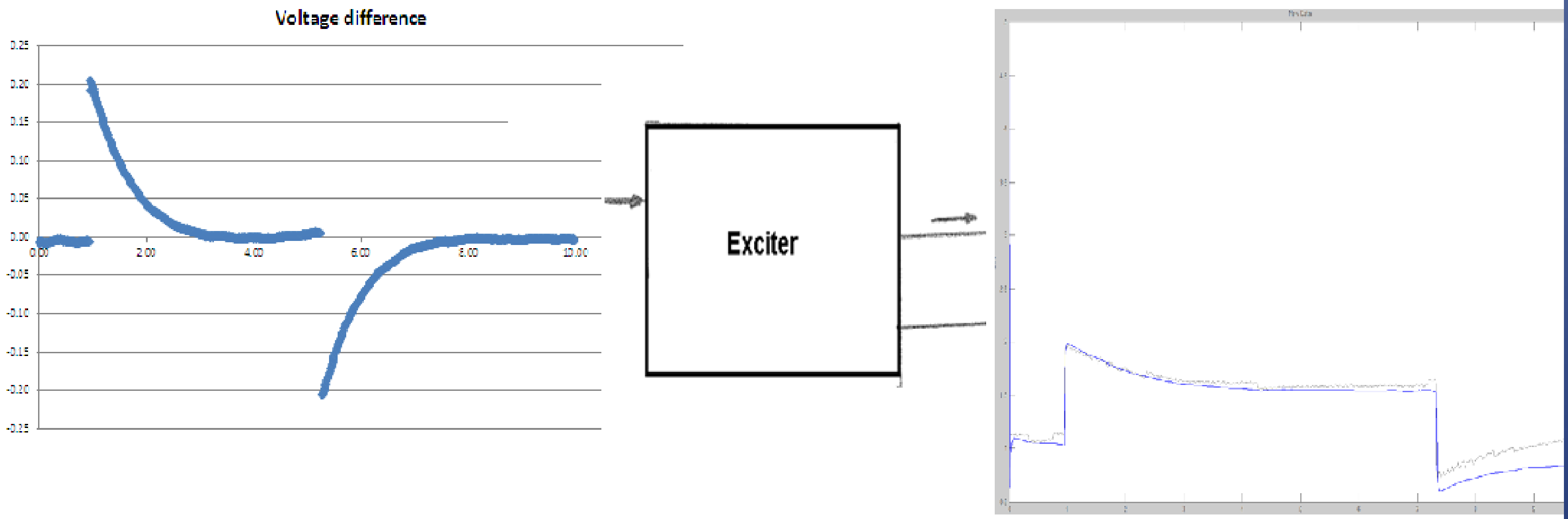


Figure 7-1—Type ST1A—Potential-source, controlled-rectifier exciter

Adjust parameters in red in order to have the input result in the desired output



A Successful simulation of our simulated output interpreting the measured input to provide a similar output. Gray output is field data, and blue is simulated



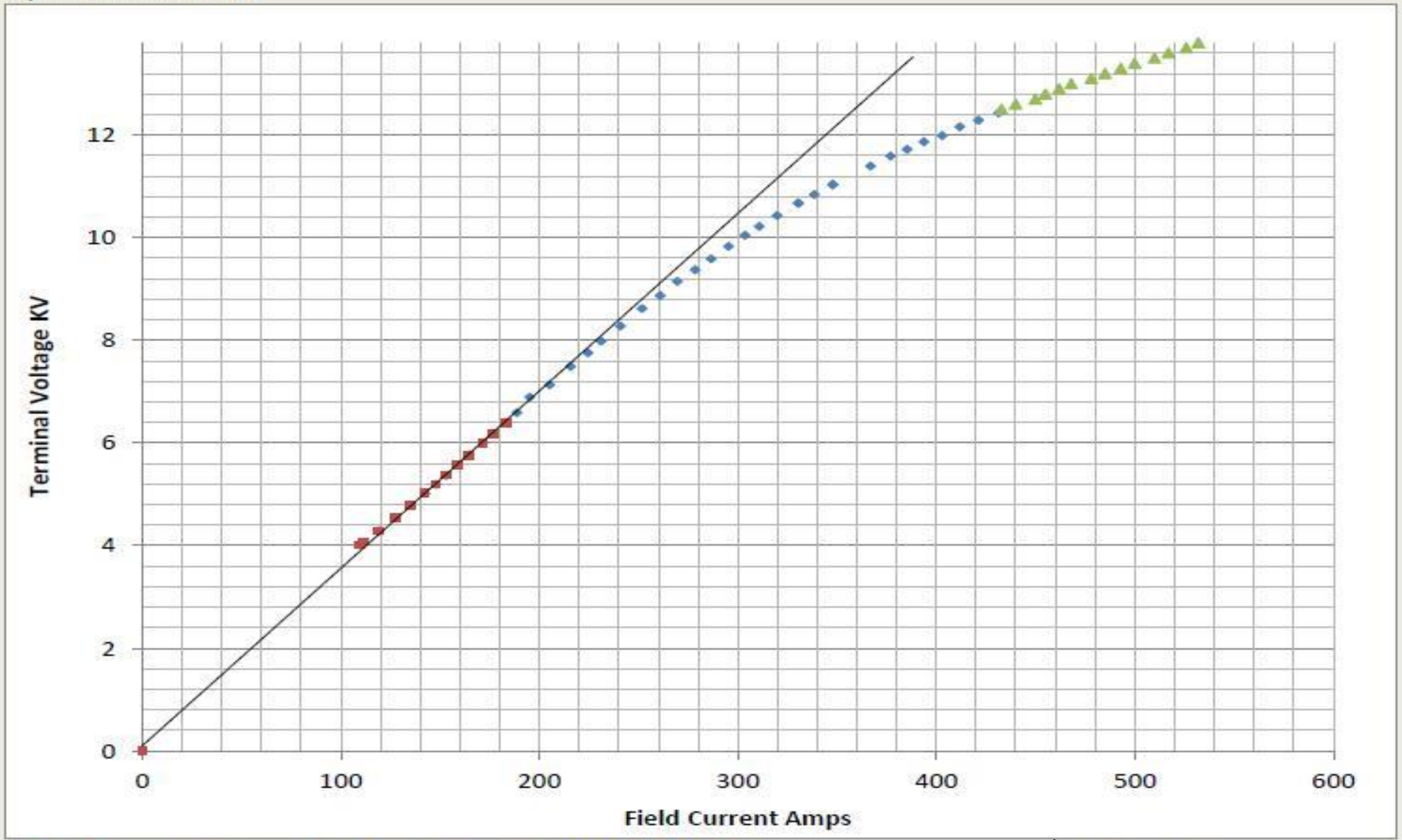
Testing to prove models.

We use a number of field tests to verify our models:

1. Saturation test
2. Inertia test
3. Current interruption test
4. Steady state tests
5. ‘Bump’ tests

Saturation Test

Open Circuit Values



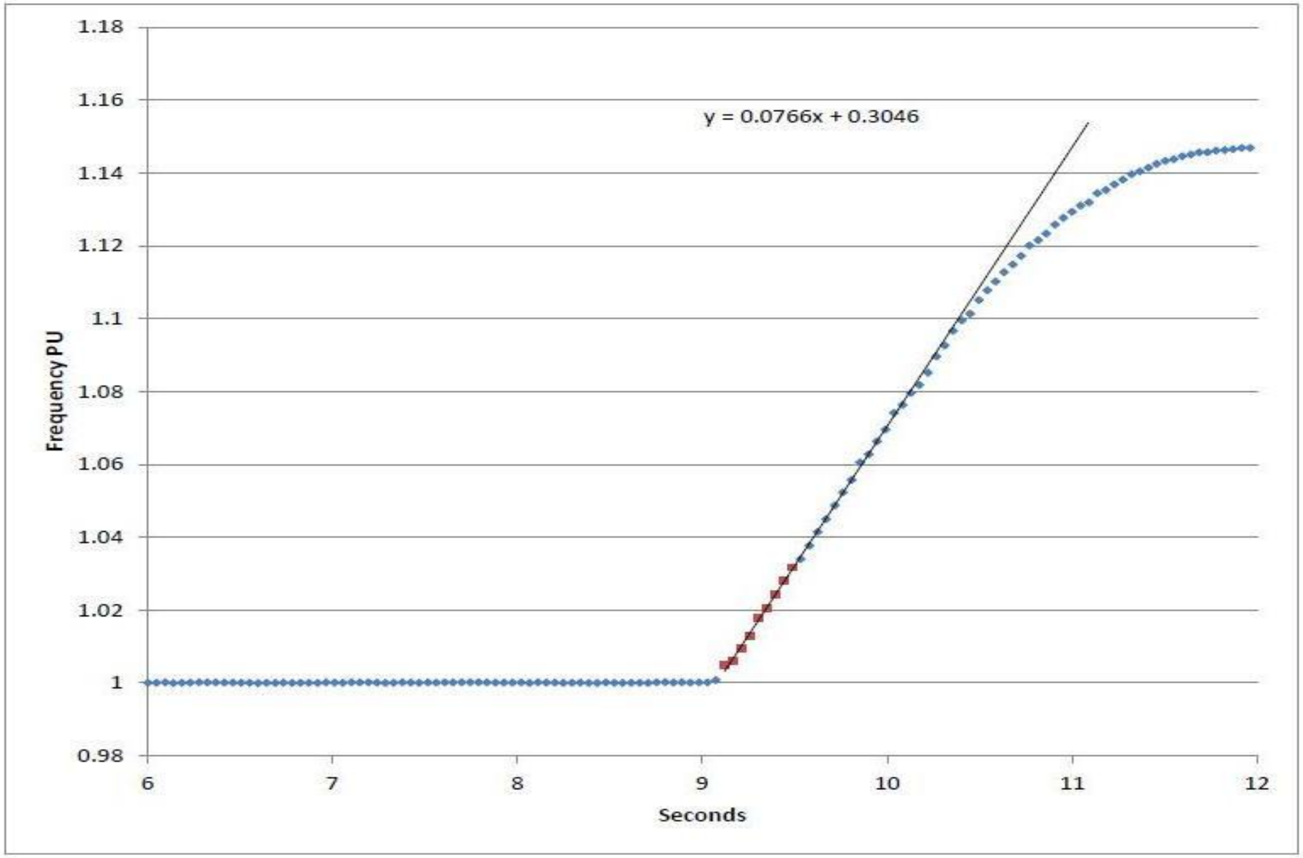
Calculated unsaturated field current @ 1 PU terminal volts	322 Amps
Measured saturated field amps @ 1 PU terminal volts	372 Amps
Calculated unsaturated field current @ 1.2 PU terminal volts	399 Amps
Calculated saturated field current @ 1.2 PU terminal volts	532 Amps
Saturation factor @ 1 PU terminal volts (SE1.0)	0.12
Saturation factor @ 1.2 PU terminal volts (SE1.2)	0.33
Resistance normalized to 75°C	0.16 Ω
Calculated Field Voltage corresponding to 1 PU unsaturated field current	53.3V

Inertia test

Load Rejection test

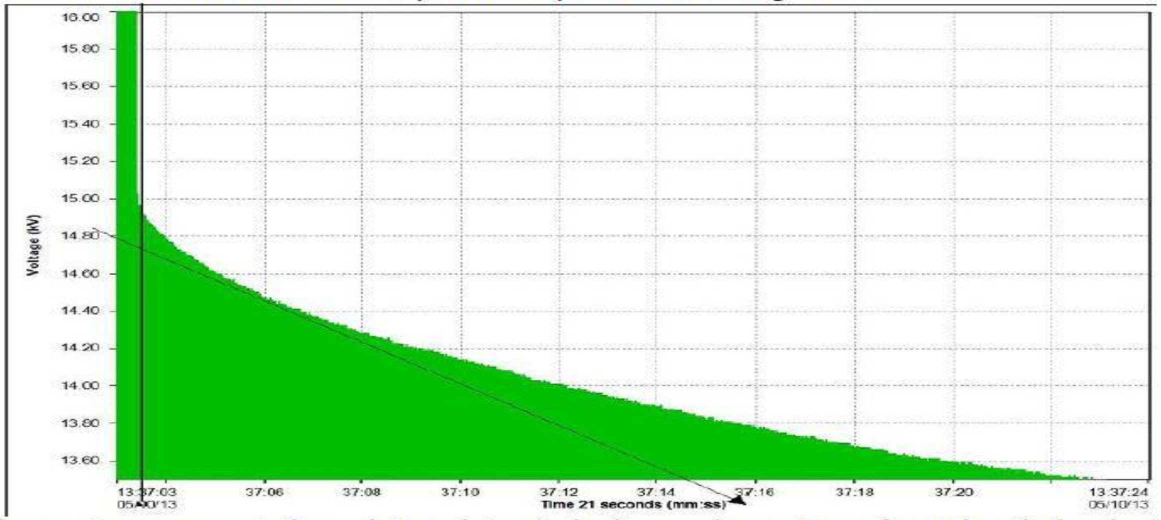
A load rejection by sudden removal of generator from the grid via generator breaker is performed to determine the machine's turbine-generator combined inertia of the unit. The machine was set to 15 MW, and at unity power factor. The generator breaker was opened and the unit was allowed to overspeed. The resulting trend shows the acceleration of the machine, which is used to calculate the inertia.

$$\text{Inertia PU} = \frac{InitialMW/MVA\ base}{2*(\frac{Hz\ PU}{seconds})}$$

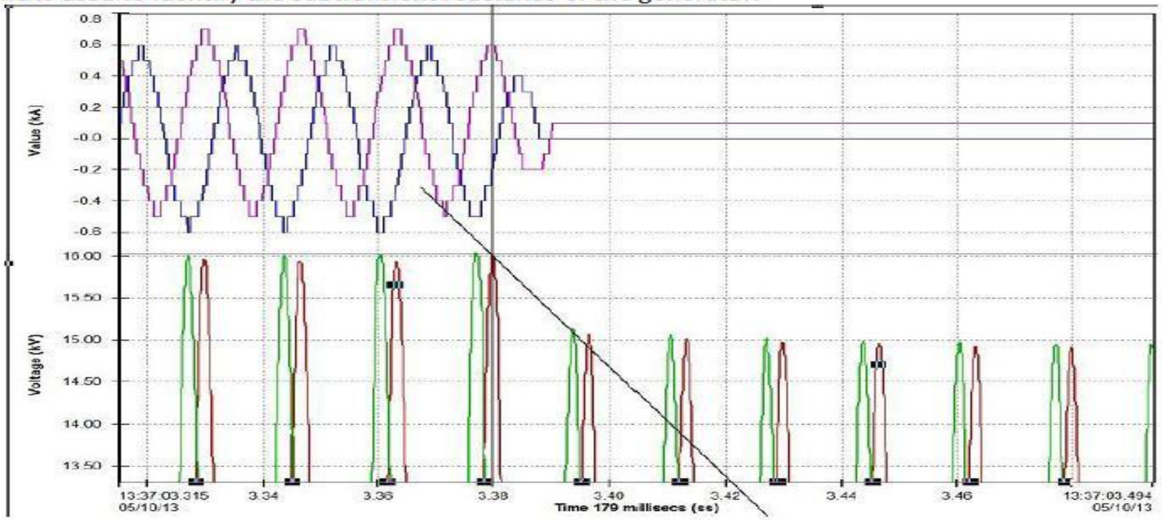


Current Interruption

This waveform capture represents the positive half of peak-peak terminal voltage waveform during current interruption, which is used to determine the transient and synchronous parameters of the generator.



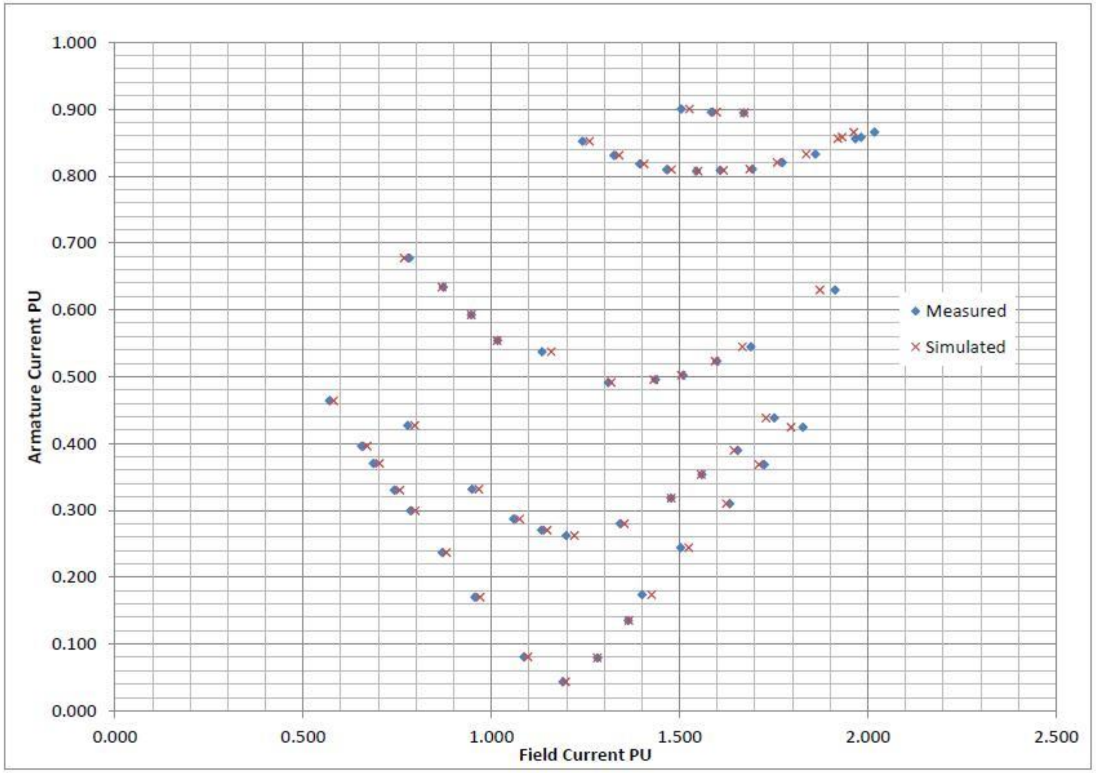
This waveform capture represents the peak to peak terminal voltage and current waveform when the breaker is initially opened, and is used to identify the subtransient reactance of the generator.



Vee Curves from Steady State

Vee-Curve analysis

Generator vee-curves were constructed using data collected at 5 different MW values. At each MW setting, the generator was first placed at the minimum allowable MVAR value, and values for MW, MVAR, Field amps and Terminal volts were recorded as the machine was adjusted up in increments of 3 MVAR to the maximum allowable MVAR value.



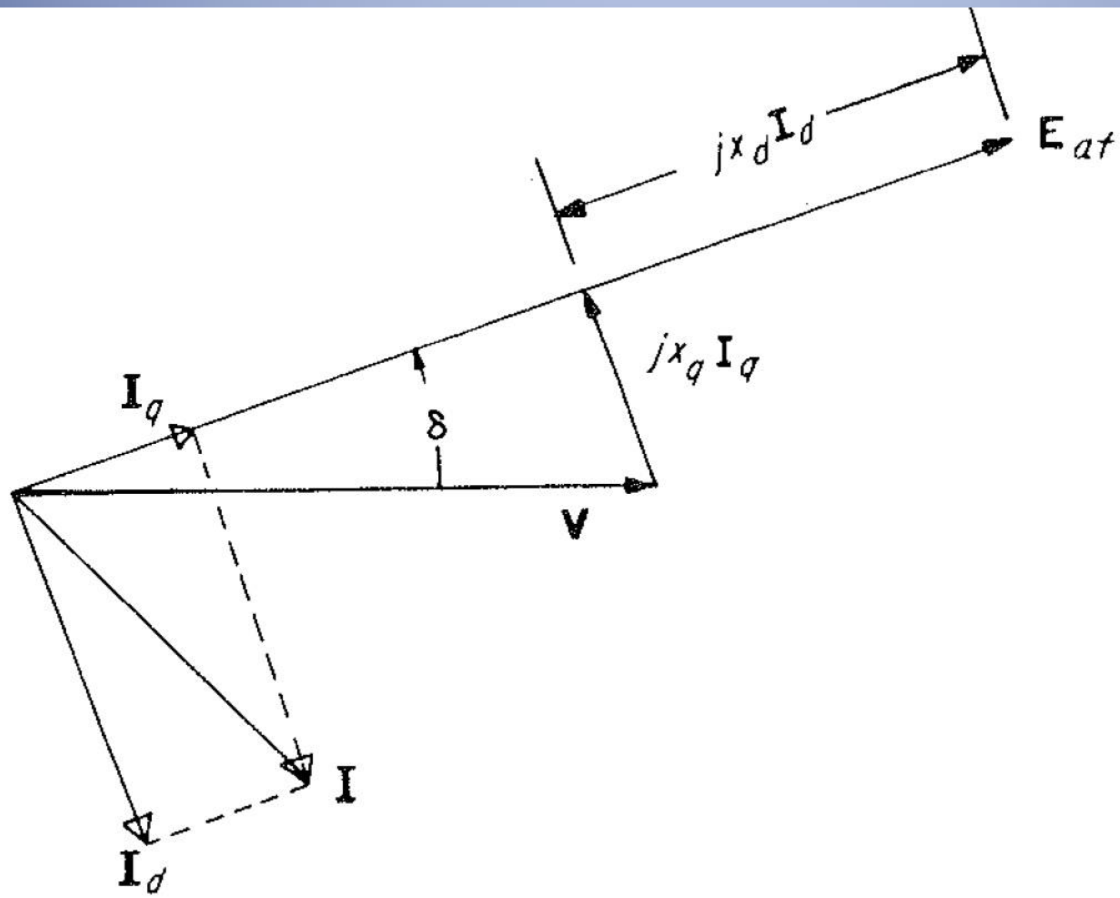
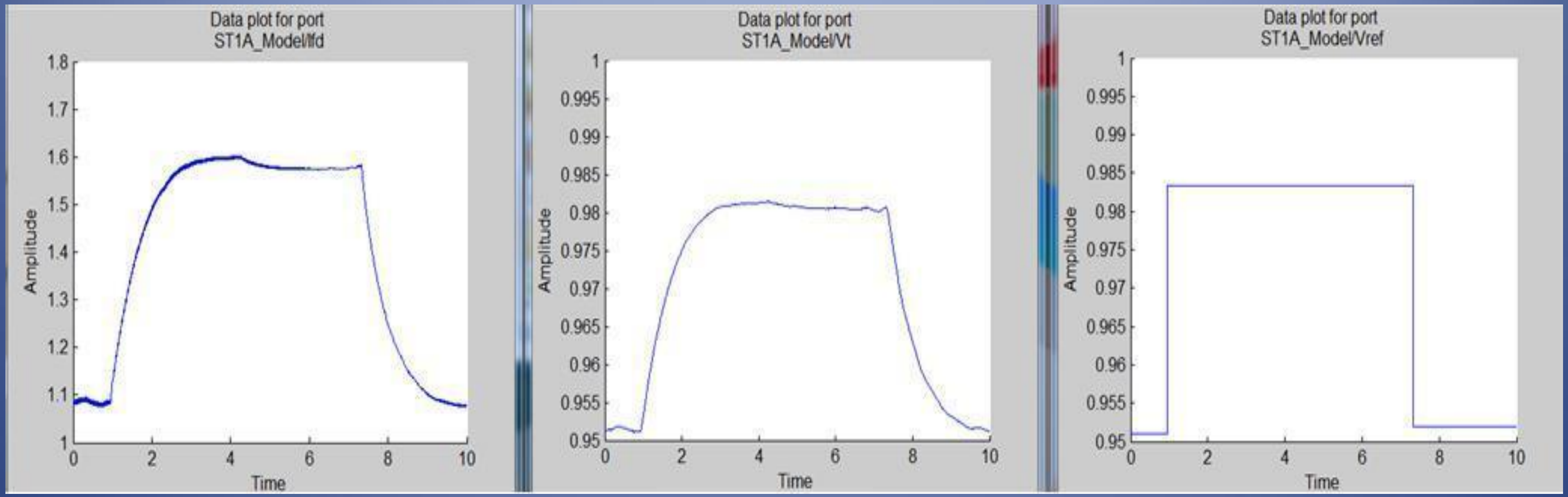


Fig. 5-55. Phasor diagram for salient-pole generator, neglecting r_a.

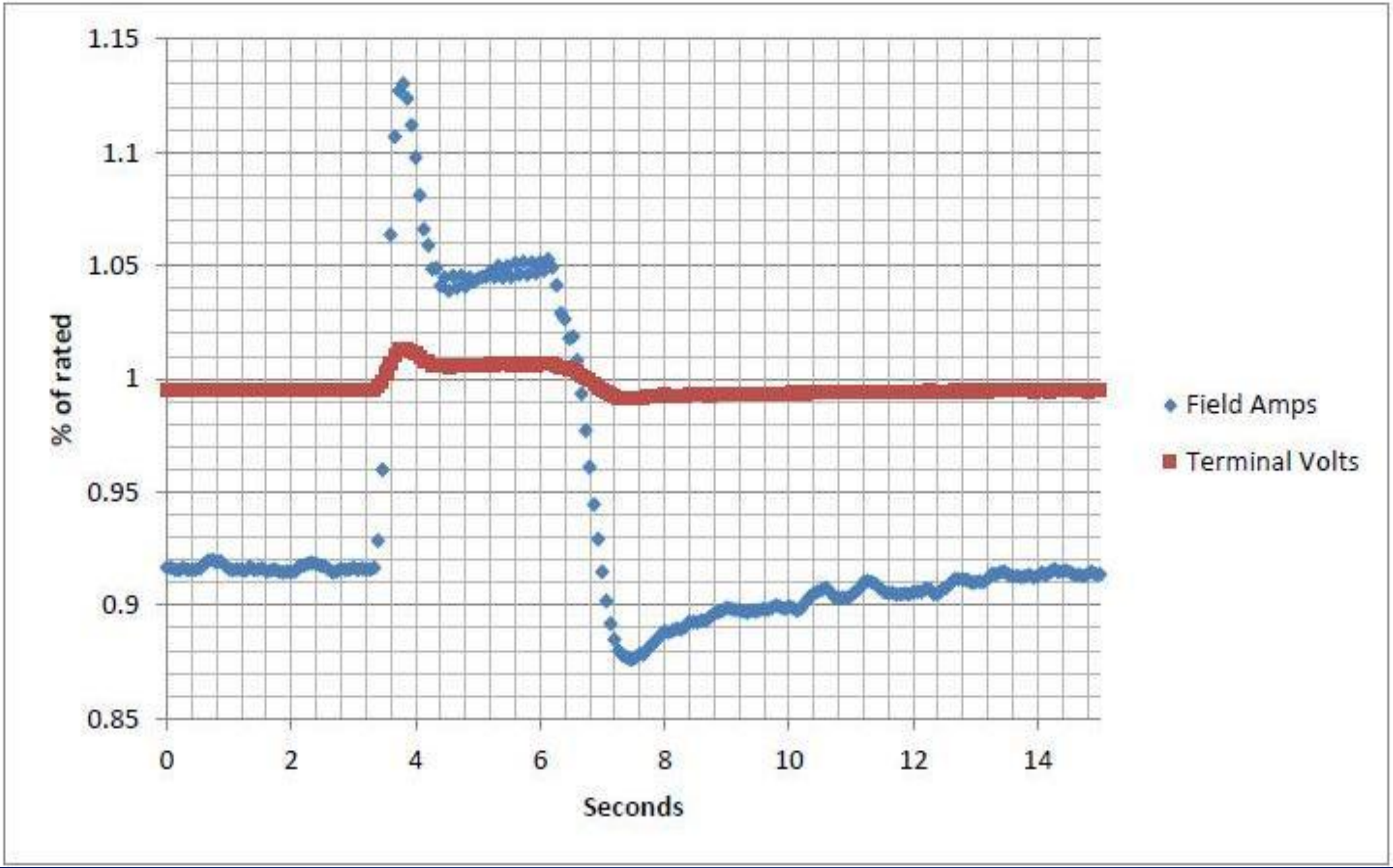
Bump Tests



Data plot for port
ST1A_Model/Ifd
Amplitude
Time
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0
2
4
6
8
10
Data plot for port
ST1A_Model/Vt
Amplitude
Time
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0.96
0.955
0.95
Data plot for port
ST1A_Model/Vref
Amplitude
Time

Bump Tests

The following Caption shows response of OEL when a 10% step response was attempted.



Test Equipment

- Consider:
  - 1. resolution
  - 2. data storage and retrieval
  - 3. safety
  - 4. ease of operation