To: D. Davies, WECC
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From: J. Undrill
Date: 27 November 2011
Re: Evaluation of conversion of excitation system models in the WECC data base

1. General

A series of simulations was made with an original WECC dynamics data file and with dynamics data files in which essentially all old ex-series excitation system models have been replaced by the newer IEEE 421.5 es-series models. The conversions were made with the newly developed program **3ic** and a library of Model Conversion Data Files. The program and MCDF library accompany this memorandum. No changes were made to the dynamics data file after conversion, but a few changes were made in the original dynamics data file before conversion to handle issues with the original data. These changes are noted below.

The simulations were made with 'switch deck files' provided by WECC for:

trip of two Palo Verde units
a fault near the Malin 500kV bus
a fault near the Lugo 500kV bus

The 'before and after' results were compared for a selection of generators that showed significant changes in excitation in the three simulations. The attached table summarizes the results of the comparison. The notation 'OK' indicates that the before and after trajectories of field voltage are substantially identical.

2. Changes made in input dynamics data file

2.0 Data issues

The conversion of WECC excitation system models, as contained in dynamics data file 12hs31s.dyd has revealed a number of instances where the parameter values presently in use are open to question. This memo notes the instances that have been found and describes corrections/adjustments that have been made in the course of converting older, ex-series, excitation models into the new IEEE es-series models.

2.1 Bus 58290 BALZ 1&2

The value of vimin in the exac8b model of unit "3 " at this bus is zero. This value renders the exac8b model completely inactive. When exac8b is replaced by the esac8b model the excitation system becomes active because esac8b does not include the limit on the input signal. The response of BALZ is therefore different in simulations with the two models.

Vimin was changed to 0.1 in the working file 12hs31j.dyd.

Figures 1 and 2 show the difference produced at Balz by correcting Vimin. Figure 1 was made with the exac8b model and original data (red, blue) and with the new esac8b model as produced by 3ic. There is no agreement because the original modeling allowed no change in the field voltage (red) of one of the two generators. Figure 2 shows the field voltage trajectories produced by the original exac8b modeling with Vimin corrected, and with the new modeling. The agreement between the original modeling and that produced by 3ic is now near-perfect.

2.2 Bus 26030 HAYNES5G

Simulations made with the exst4b model of the original file show a high frequency oscillation that is only marginally damped stable. Simulations made with the replacement esst1 model show the same high frequency oscillation but in this case it is marginally unstable. The implementations of the simulation in exst4b and esst4b are slightly different and this explains the difference in the stability of the high frequency oscillation.

Checking the HAYNES5G modeling for that machine, using 4ia and cc.p, shows good behavior with both exst4b and esst4b. It is apparent, therefore, that the unstable high frequency oscillation seen in full system simulations is associated with local conditions other than the excitation system.

Turning off the pss2a power system stabilizer models on HAYNES5G results in matching results with the two excitation system models in full-WECC cases.

The pss2a models were turned off in the working file 12hs31j.dyd.

Figure 3 shows the behavior of HAYNGESG5:

- (lower) as modeled in the original data file with the exst4b model and stabilizers on on the HP and LP generators
- (mid) as modeled by the esst4b models produced by 3ic with stabilizers on on both generators
- (upper) as modeled by the esst4b models produced by 3ic with stabilizers off on both generators

2.3 Bus 41213 HILLS CR

The value of the rate feedback element time constant, Tf, is zero in the original data file. The exdc1 and esdc1a models give different responses in the full-WECC simulations if the time constant of the rate feedback element is zero. This difference showed up in early comparisons.

The MCDF for exdc1-esdc1a has been changed to enforce Tf1>=0.05 to rectify this problem.

2.5 Buses 50642, 50773, 50307 WHN 4G, SPN 4G, JHT G2

The exdc4 model has no correct equivalent in the "new" IEEE model series. The esdc3a model is not a correct representation of the excitation systems that exdc4 is intended to represent. As a result, machines with exdc4 excitation systems behave differently in simulations made with the es-series models. In many cases

the esdc3a model will show unstable response and will not settle to a post-event equilibrium.

There are 73 instances of exdc4 in the original data file. These were converted in the comparison exercises reported here. Because the excitation systems described by exdc4 remain in service only on small machines the differences in their behavior have no significant effect on the system or on the behavior of larger machines.

The exdc4 models should be left unconverted.

2.6 Bus 15914 KYRENE 4

The value of the rate feedback gain, Kf, is 0.0 in the original data file. Because the forward gain of the voltage regulator (Ka) is 400 and the forward-path lead-lag block is unused, the transient gain of the system is excessive and check simulations made with both exac1 and esac1a in the b.p program show unacceptable response.

The exac1-esac1a MCDF has been updated to ensure that Kf>=0.02 if the forward lead-lag element does not provide a reduction in transient gain.

Figure 4 shows the open circuit behavior of the machine with the original exac1 model and data (blue) and with the esac1a modeling produced by 3ia with the correction of the rate feedback gain, Kf.

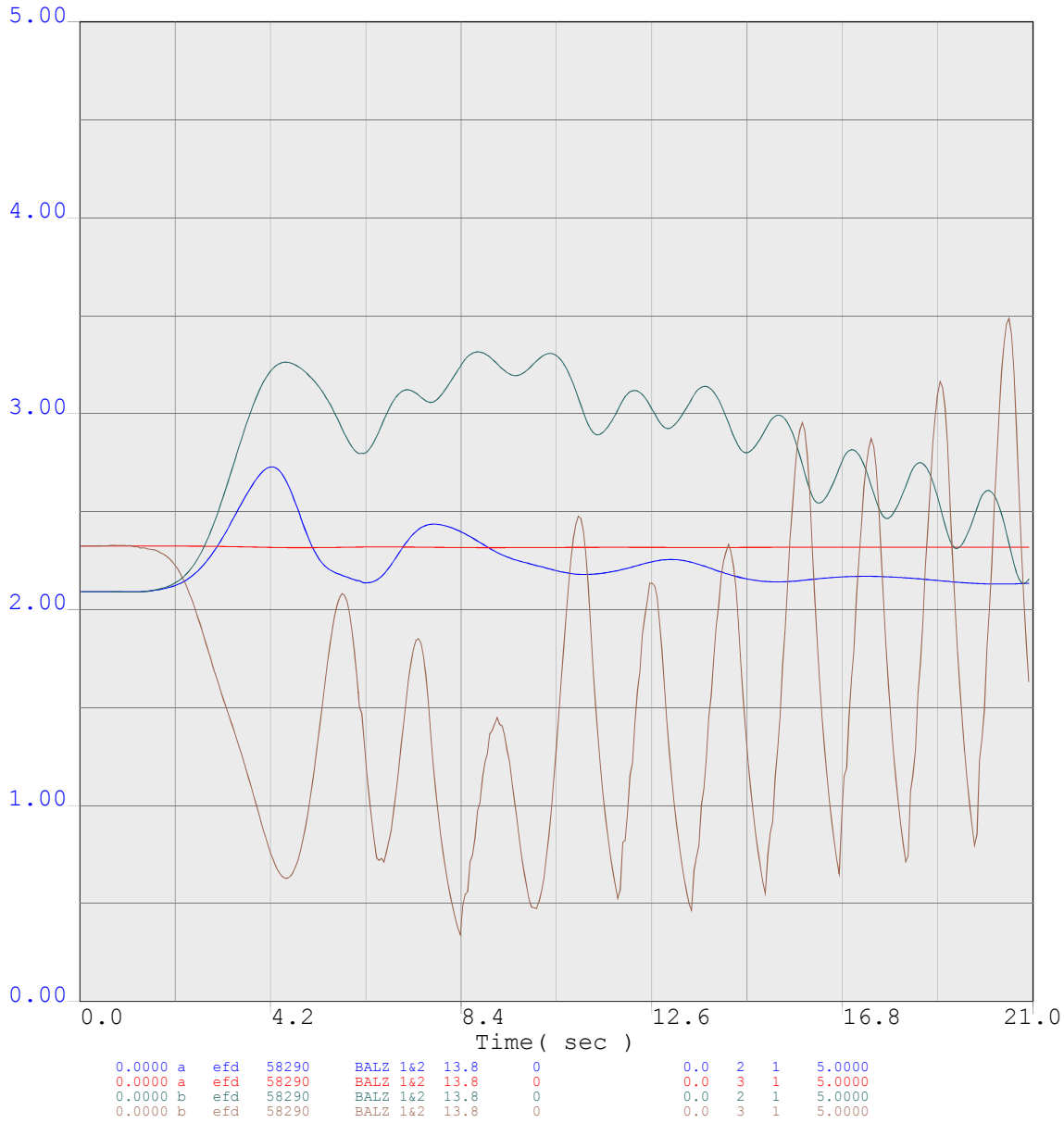
2.7 Bus 16504 SUNDTCT

The original dyd file contains records for two generators at bus 16504 with the bus name appearing as "SUNDTCT". The generator records are accompanied by exac8b excitation system records. Elsewhere in the same file there are oel1 records associated with bus 16504 but with the bus name "IRVNTCT". The intent of the original data file is inclear.

The 3ia conversion program issues genrou, esac8b, and oel1 records for the generator at bus 16504. The test simulations that do not call for a high value of field current show identical results from the original exac8b and new esac8b modeling. In test 5 in which the bb.p program simulates response to a fault the original and new modeling show distinctly different trajectories of field voltage because the original model (ex) responds to the oel1 and the new model (es) does not. The differing results from test 5 and identical results from test 3 are shown in figure 5.

2.8 Buses 29061, 29290 WHITEWTR, GARNET

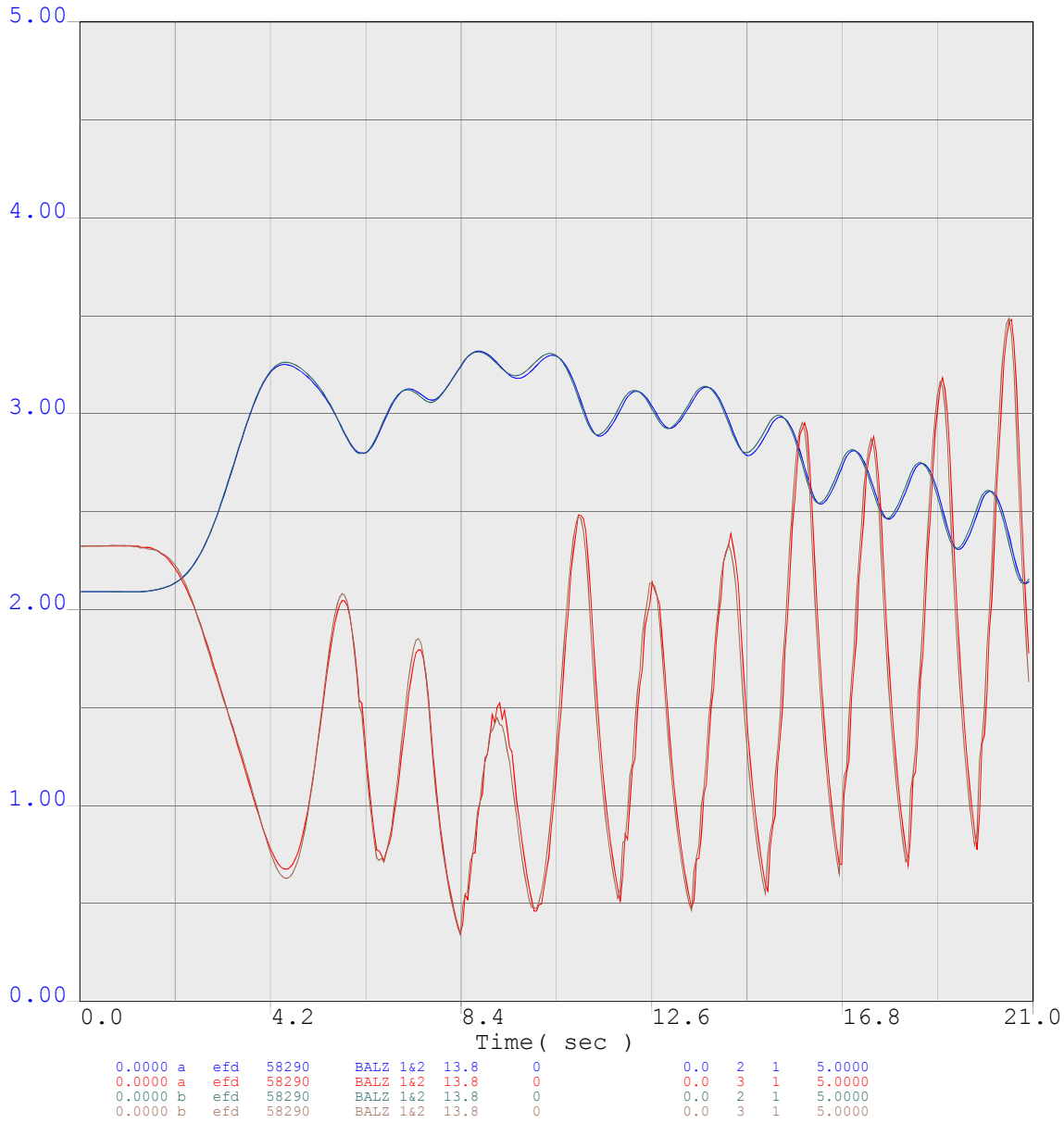
The generators at these buses pull out of synchronism towards the end of 30 second simulations. The rexs excitation system is not a conversion; the original data file contains rexs records.



2012 HS3SA1 STAB STUDY DOUBLE PALO VERDE UNIT LOSS / 2PVTEST
12HS3-S BASE CASE
Current file selected from 2 different files

Figure 1 BALZ 1 and 2 (without correction of vimax)

AVR step response - on line
Blue - ieeet1 unit 2 - responsive - vimax > 0
Red - exac8b unit 3 - no response - vimax = 0
Green - esdc1 unit 2 - responsive - vimax > 0
Brown - esac8b unit 3 - responsive - vimax > 0



2012 HS3SA1 STAB STUDY DOUBLE PALO VERDE UNIT LOSS / 2PVTEST
12HS3-S BASE CASE
Current file selected from 2 different files

Figure 2 BALZ 1 and 2 (with correction of vimax)
AVR step response - on line
Blue - ieeet1 unit 2 - responsive - vimax > 0
Red - exac8b unit 3 - response - vimax > 0
Green - esdc1 unit 2 - responsive - vimax > 0
Brown - esac8b unit 3 - responsive - vimax > 0

a:orig2pvtest.chf
b:new2pvtest.chf

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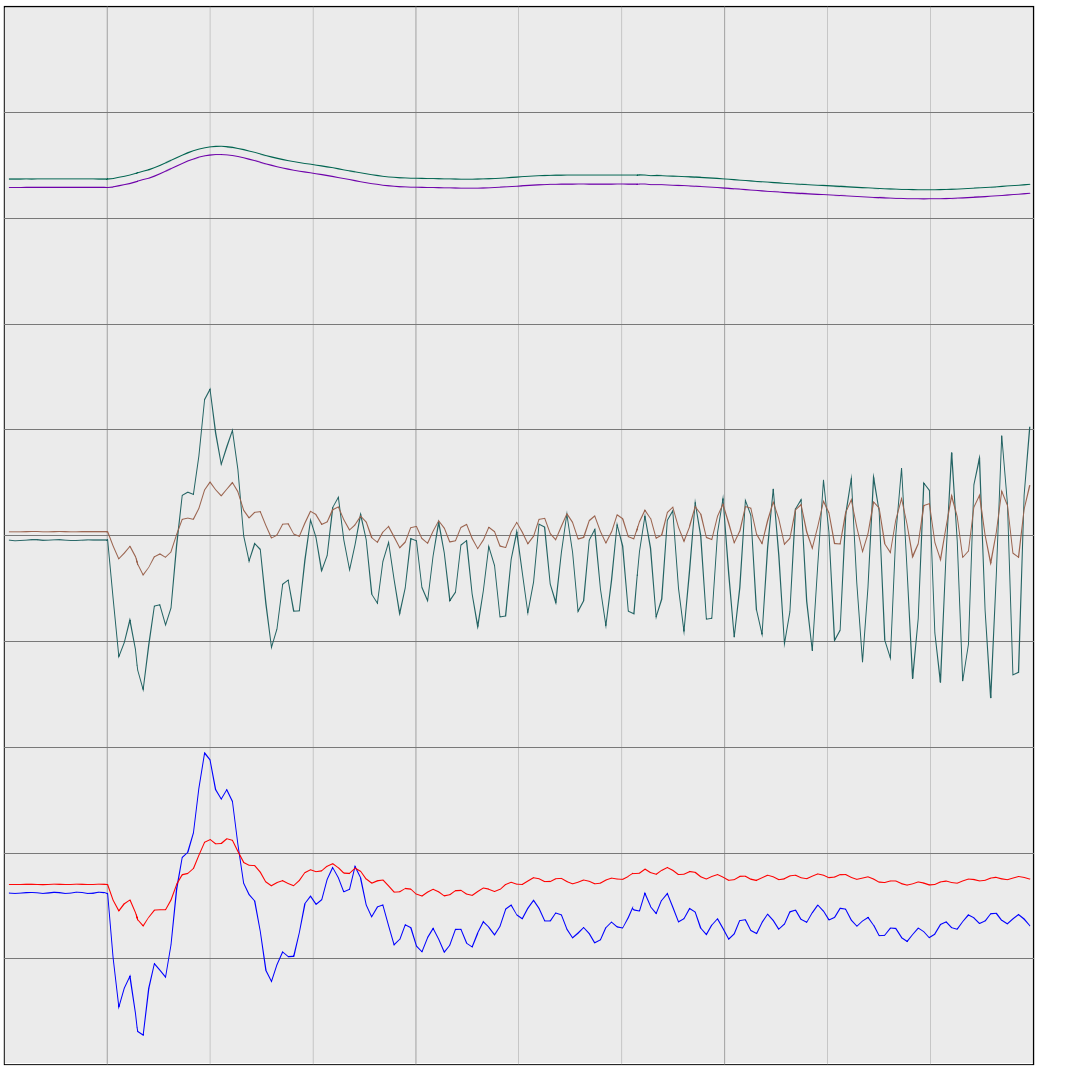
Sun Nov 27 17:10:53 2011



2012 HS3SA1 STAB STUDY DOUBLE PALO VERDE UNIT LOSS / 2PVTEST
12HS3-S BASE CASE
Current file selected from 4 different files

Figure 3 Behavior of HaynesG5
AVR step response - on line
Lower Original exst4b with PSS on
Middle Replaced esst4b with PSS on
Upper Original and Replaced respond
differently (but are identical)

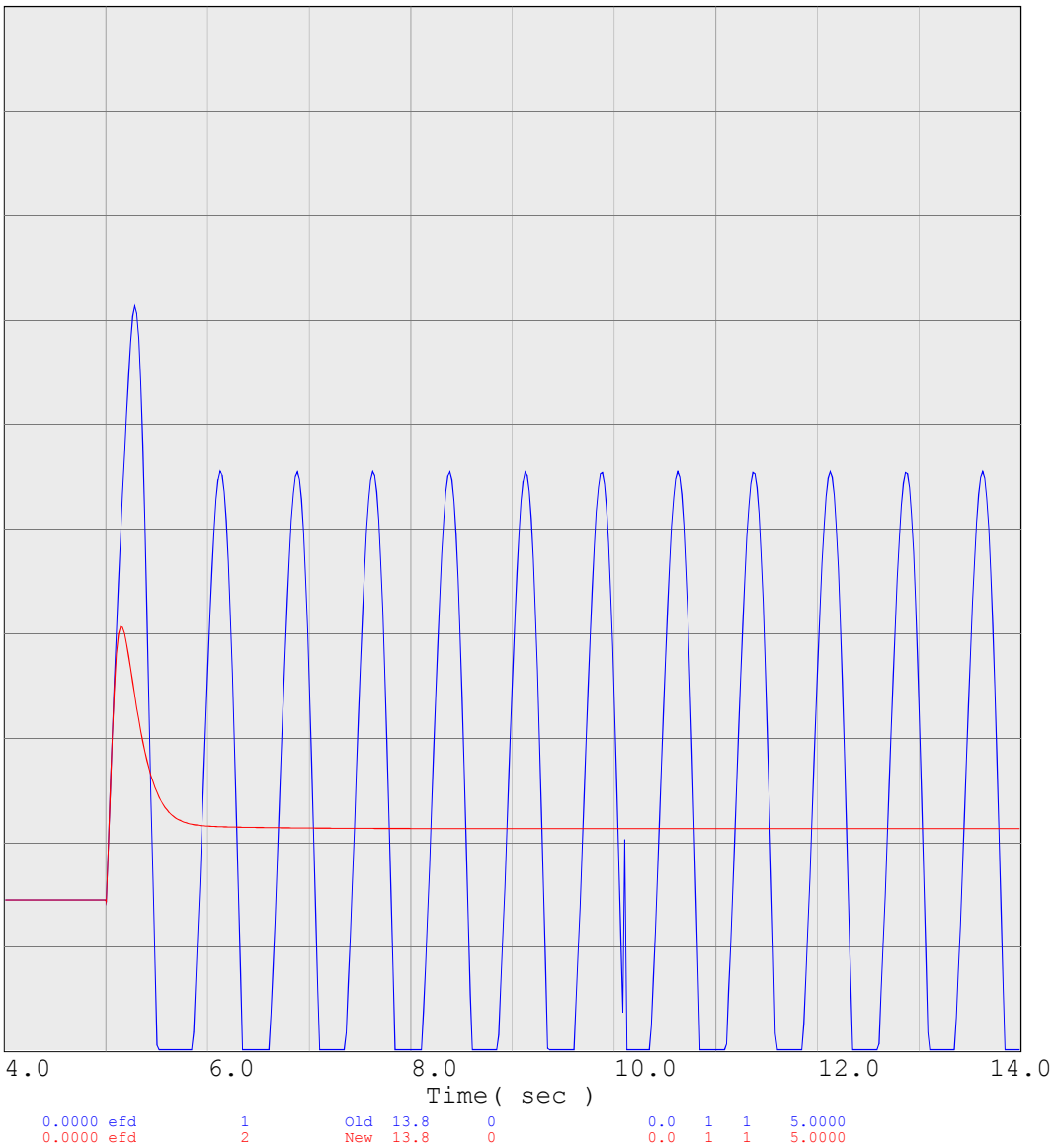
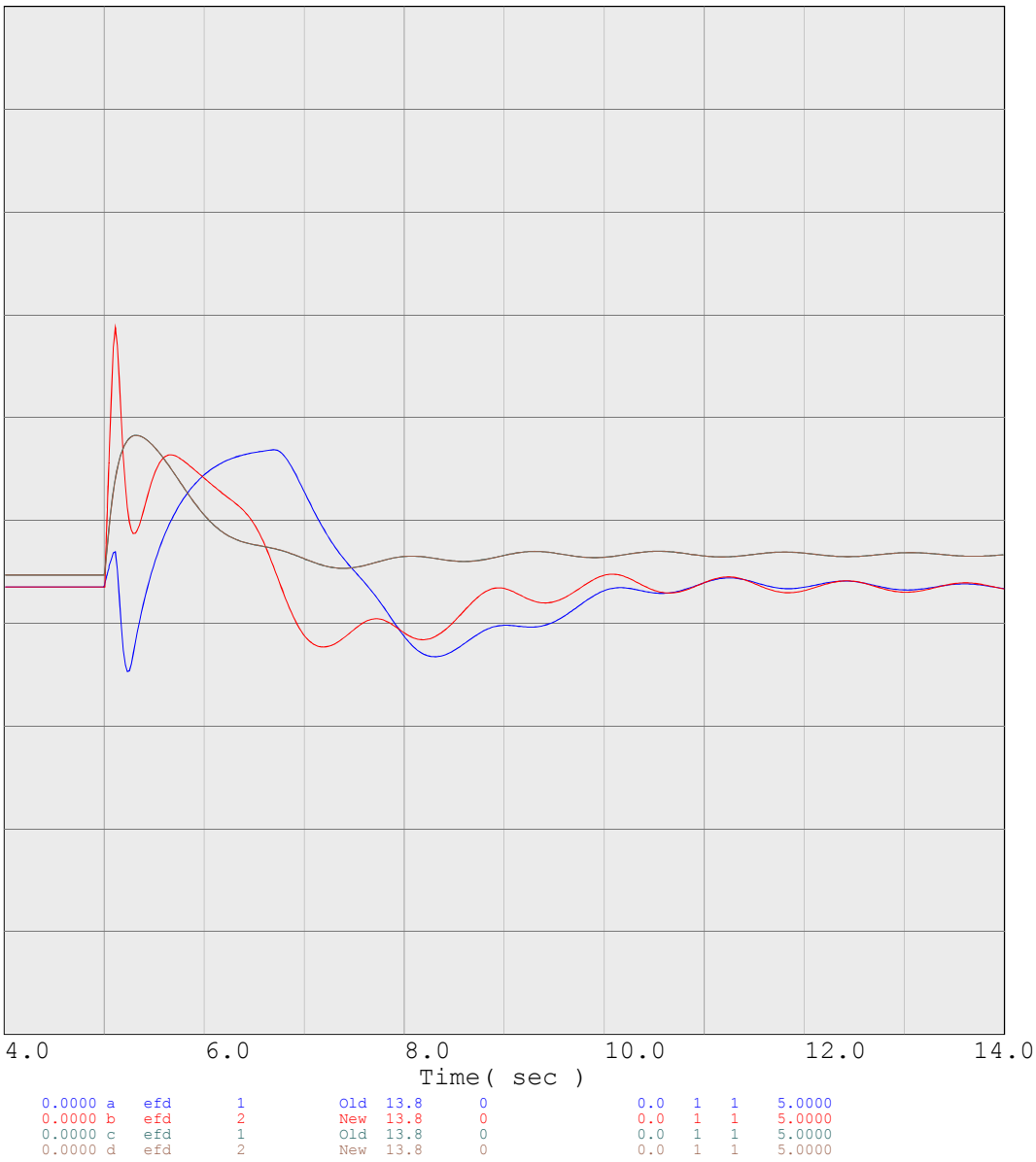


Figure 4 Kyrene 4
Open circuit response

Blue - original exac1 with Kf=0
Red - replaced esac1a with Kf-0.02



Current file selected from 4 different files

Figure 5 Response of SUNDTCT

Blue - original exac1 - fault behavior - responds to oel1
Red - replaced esac1b - fault behavior - no response to oel1
Green - original exac1 - response to AVR step
Brown - reolaced esac1b - response to AVR step

Bus	Name	Model	Lugo	Malin	2PVTest		
Corrections since 10 Nov							
26030	HAYNES5G	exst4b			Unstable	Orig and new both unstable when pss2a is active	In 12hs31j
36405	MOSSLND6	exst1			OK	Changed ta in exst1 to comply with model rules	In 12hs31j
58290	BALZ	exac8b			OK	Error in orig data - vimax=0	In 12hs31j
41213	HILLS CR	exdc1			OK	Corrected MCDF to handle tf=0	
10318	SJUAN_G1	exac3		OK	OK		
10321	SJUAN G3			OK			
12094	PYRAMD			OK			
14913	FCNGEN3	esdc4b	OK	OK	OK	esdc4b in original file	
14914	FCNGEN4	exac4	OK	OK			
14931	PALOVRD1	exst3a	OK	OK	OK	unit 1 stayed on line	
14932	PALOVRD2	exst3a			OK	unit 2 tripped to initiate event	
14965	YUCCAGEN	rexs	OK	OK	OK	rexs in original file	
14974	RED-CT1	exst4b	OK	OK	OK		
15914	KYRENE4	exac1	OK	OK	OK	Kf=0 in original file	
15918	KYRENE7S	exac2	OK	OK			
16504	SUNDTCT	exac8b	OK	OK	OK	OEL1 operated on exac8b but not on esac8b - improper VAR sharing	
19028	HOVRA			OK			
19714	MILAGRO	exst1		OK	OK		
22233	ENCINA			OK			
24129	S.ONOFR2	rexs	OK			Rexs in original file	
24317	MAMOTH1G	exst4b	OK	OK	OK		
24815	GARNET	rexs		OK		Out of synchronism at 26 sec No model on unit QF	
25604	DVLCYN1G	exdc2a		OK			
26030	HAYNES5G	exst4b	OK	OK	OK	pss2a on H and L units turned off to avoid high frequency oscillation	
29041	IEEC G1	exst4b	OK	OK	OK		
29061	WHITEWTE	rexs		OK		Unit out of synchronism at 26 sec	
29290	CABAZON	rexs		OK		Unit out of synchronism at 26 sec	
29305	ETWPKGEN	rexs		OK			
31414	GEYSER12	exst3		OK			
36405	MOSSLND6	exst1		OK	OK		
36412	DIABLO 2	exac2	OK	OK	OK		
37303	CAMPBL1	exst1		OK	OK		
40555	HUNGHR12	exdc2		OK			
40671	LONGVIEW	exst4b		OK	OK	Suspect behavior in MALIN case	
41213	HILLS CR	exdc1		OK	OK		
43017	BEAVER	exst2a		OK	OK	Suspect exst2a on unit 2	
43019	BEAVER G1	exst1		OK			
43486	ROUND B1	exst1		OK	OK		
43490	ROUND B3	exst1		OK	OK		
44072	JDA 0304	exst1		OK			
44144	CHIEF JO	exst1	OK	OK	OK		
44231	LWG 0102	exac1a		OK			
50501	GMS			OK			
50505	GMS			OK		Off line	
50637	MCA					Tripped by RAS	
50641	KLY 12C1	exdc1		OK	OK		
50642	WHN 4G	exdc4				exdc4 assumed correct - esdc3 appears to be incorrect dead band	
50773	SPN 4G	exdc4				exdc4 assumed correct - esdc3 appears to be incorrect dead band	
57274	MCKAY2	exst1		OK	OK		
58290	BALZ	exac8b			OK	Error in orig data - vimax=0	
60025	AMFLS	exst1		OK			
60246	MILNER	exst1		OK		Small difference	
65445	DJOHN			OK			
73321	OSAGE	exac6a				None in service	
79015	GRAIG	exst3		OK			