

# IEEE Type C Excitation Limiter Transient Stability Models OEL / UEL / SCL

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# Based on IEEE Std 421.5™-2016



IEEE STANDARDS ASSOCIATION



## IEEE Recommended Practice for Excitation System Models for Power System Stability Studies

IEEE Power and Energy Society

Sponsored by the  
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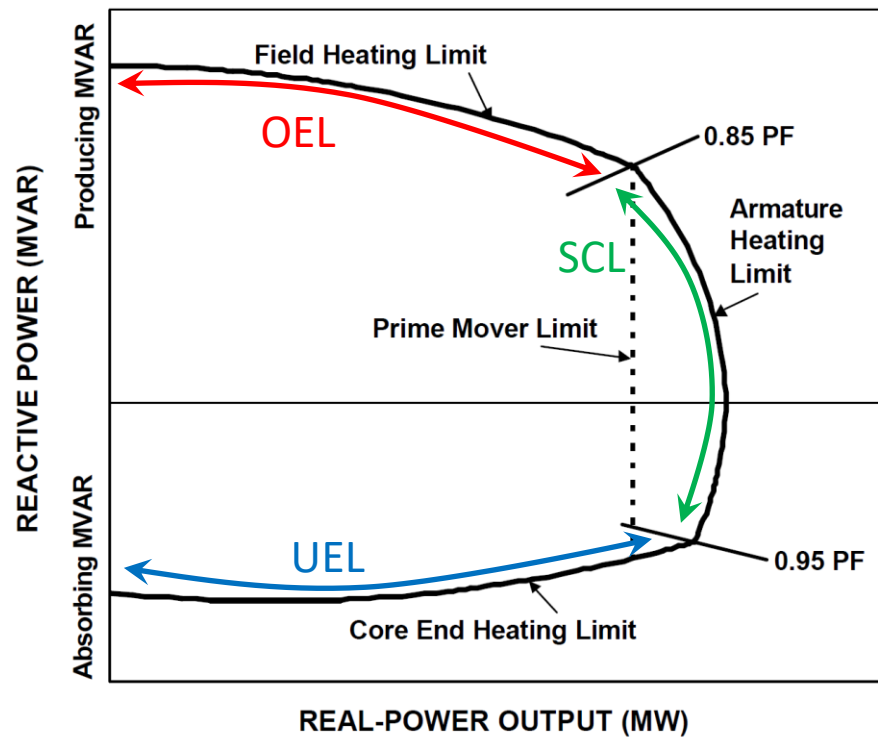
IEEE Std 421.5™-2016  
(Revision of  
IEEE Std 421.5-2005)

<https://doi.org/10.1109/IEEESTD.2016.7553421>

# Excitation Limiters



- OEL: Over Excitation Limiter
- UEL: Under Excitation Limiter
- SCL: Stator Current Limiter
- Related to a generator's steady state limits enforced by a capability curve (Mvar vs MW plot)
- **Limits are time-varying and have entire control systems enforcing each segment**



[https://en.wikipedia.org/wiki/Capability\\_curve#/media/File:Capability\\_curve\\_of\\_an\\_electrical\\_generator.png](https://en.wikipedia.org/wiki/Capability_curve#/media/File:Capability_curve_of_an_electrical_generator.png)

# Outline

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- Type C exciters have configurable OEL/UEL/SCL input location, depending on the OEL/UEL/SCL input parameter flags.
- Limiter's MAX/MIN must align with input location at the exciter.
- Understand the limiter's mode of action at the exciter.
- Will not discuss OEL, UEL and SCL models' initialization.
- Will not discuss how to tune the internals of limiters.

# IEEE Type C Exciter Models

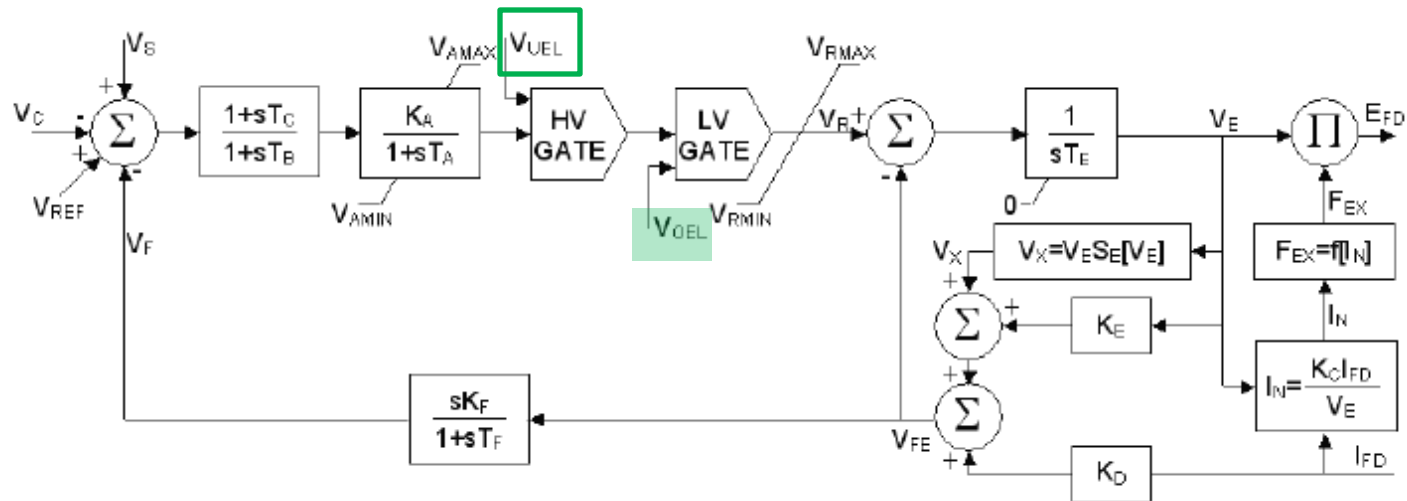


- Type DC—Direct current commutator rotating (DC1C, DC2C, DC4C)
- Type AC—Alternator supplied rectifier (AC1C, AC2C , AC3C , AC4C , AC5C , AC6C , AC7C , AC8C , AC9C , AC10C , AC11C)
- Type ST—Static excitation systems (ST1C, ST2C , ST3C , ST4C , ST5C , ST6C , ST7C , ST8C , ST9C , ST10C)
- What's different?
- **Can be configured to accept the limiter (OEL, UEL and SCL) input at one of multiple input locations.**

# Exciter AC1A



- AC1A is from IEEE Std 421.5™-2005
  - OEL input is only possible at take-over gate
  - UEL input is only possible at take-over gate
  - SCL input is absent
- Available as ESAC1A in PW, PSSE, PSLF

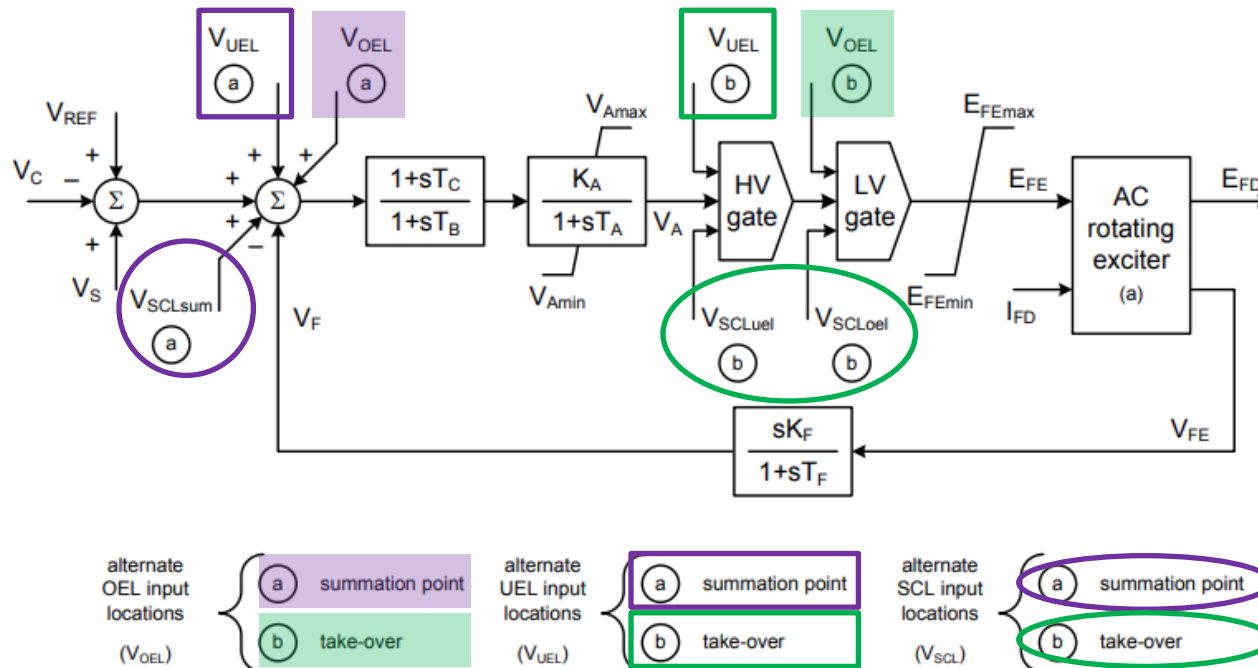


- Superseded by AC1C from IEEE Std 421.5™-2016

# Exciter AC1C



- AC1C is from IEEE Std 421.5™-2016
  - OEL input is possible at (a) summation point, or (b) take-over gate
  - UEL input is possible at (a) summation point, or (b) take-over gate
  - SCL input is possible at (a) summation point, or (b) take-over gate

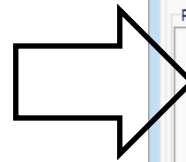


# Input Parameters

## Exciter AC1C



- Flags to indicate the configured input location for OEL / UEL / SCL
  - Input Flag = 1: Summation Point
  - Input Flag = 2: Take-over gate



Generator Information for Present

Bus Number: 40307 ID: 1 Bus Name: COWLITZ\_FALL Area Name: NORTHWEST (40) Labels ...: COWFALLS\_230\_G01 Generator MVA Base: 39.00

Status: ☐ Open ☒ Closed Energized: ☐ NO (Offline) ☒ YES (Online) Fuel Type: RenewWAT (Water) | [PW=4] [E=] Unit Type: HY (Hydro) | [PW=8] [EPC=5]

Power and Voltage Control Costs OPF Faults Owners, Area, etc. Custom Stability PFWModels, Weather

Machine Models Exciters Governors Stabilizers Other Models Terminal and State Results Step-up Trans

Insert Delete Gen MVA Base: 39.0 Show Block Diagram Create VCurve

Type: AC1C ☐ Active (only one may be active) Set to Defaults

Parameters

OEL	1	Ta	0.02000	Kd	0.38000	Eefmin	-5.43000
UEL	1	VaMax	14.50000	Ke	1.00000	Vfemax	99.00000
SCL	1	VaMin	-14.50000	E1	4.18000	Vemin	0.00000
Tr	0.00000	Te	0.80000	SE1	0.10000	Spdmt	0.00000
Tb	0.00000	Kf	0.03000	E2	3.14000		
Tc	0.00000	Tf	1.00000	SE2	0.03000		
Ka	400.00000	Kc	0.20000	Eefmax	6.03000		

OK Save Save to Aux Cancel Help Print

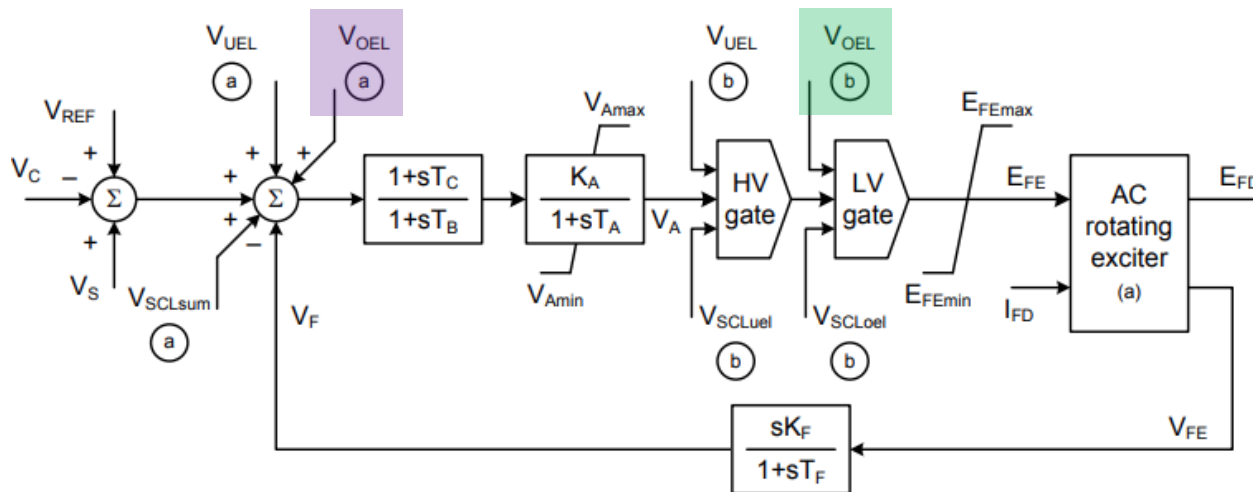


# Input Locations for OEL

## Exciter AC1C



	OEL input at <b>Summation Point</b>	OEL input at <b>Take-over Gate</b>
OEL NOT Limiting	$VOEL = 0$	$VOEL \geq VA$
OEL Limiting	$VOEL < 0$	$VOEL < VA$
Exciter Signal	$V_{REF} - V_C + VOEL$	$MIN(VA, VOEL)$



alternate  
OEL input  
locations  
( $VOEL$ )

- (a) summation point
- (b) take-over

alternate  
UEL input  
locations  
( $V_{UEL}$ )

- (a) summation point
- (b) take-over

alternate  
SCL input  
locations  
( $V_{SCL}$ )

- (a) summation point
- (b) take-over

# IEEE Type C Limiter Models

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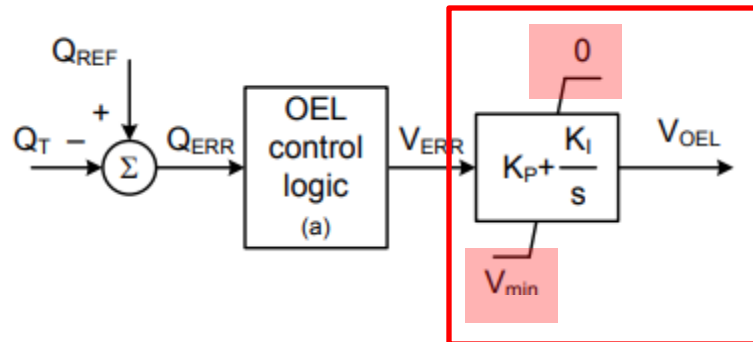


- Over Excitation Limiters  
OEL2C, OEL3C, OEL4C, OEL5C
- Under Excitation Limiters  
UEL2C
- Stator Current Limiters  
SCL1C, SCL2C

# Over Excitation Limiter OEL4C



- Exciter model OEL input flag must be configured appropriately!
- OEL4C **can only be included at a summation point** at the exciter model
- Note: Hardcoded upper limit on PI-block and  $V_{min} < 0$ .  
→ VOEL is always  $\leq 0$ .

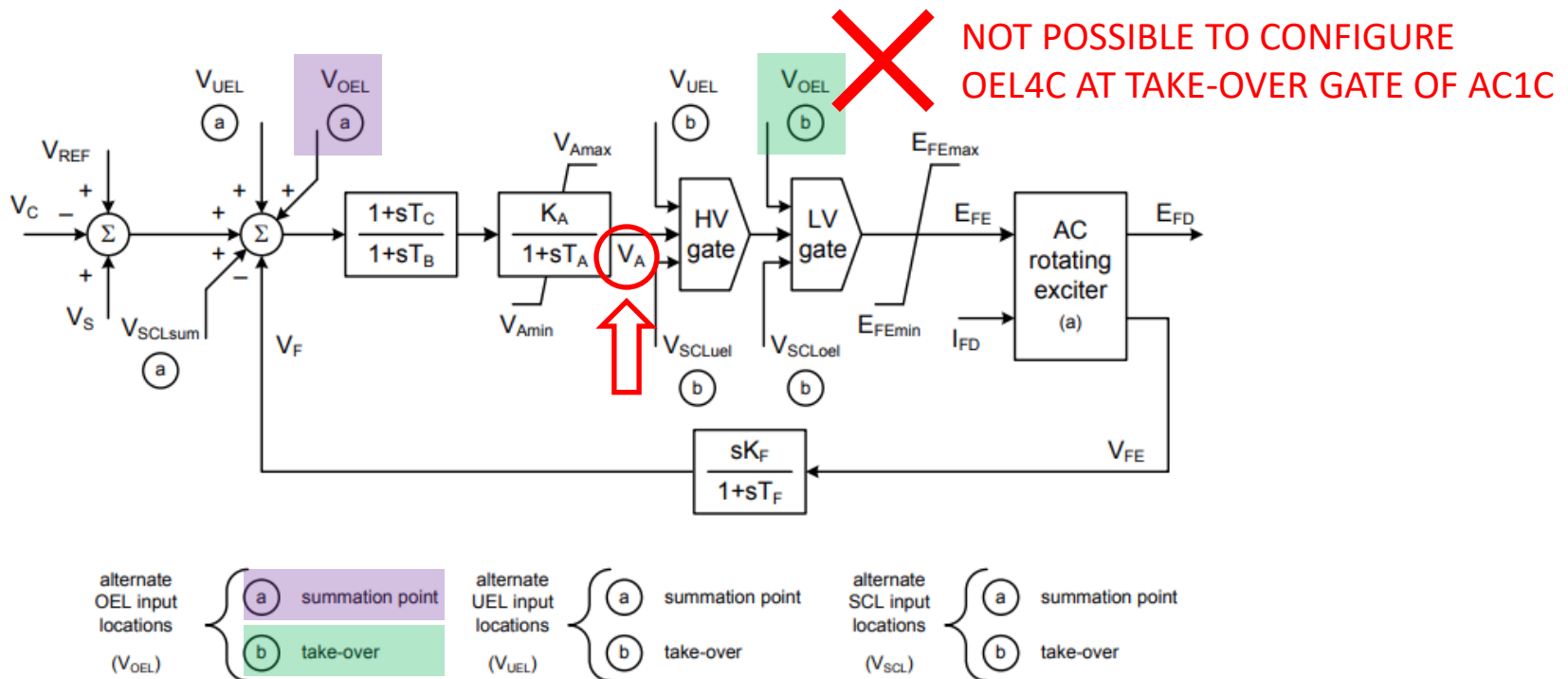


- OR Exciter model has OEL input only at summation point

# Exciter-Limiter Pair: AC1C + OEL4C



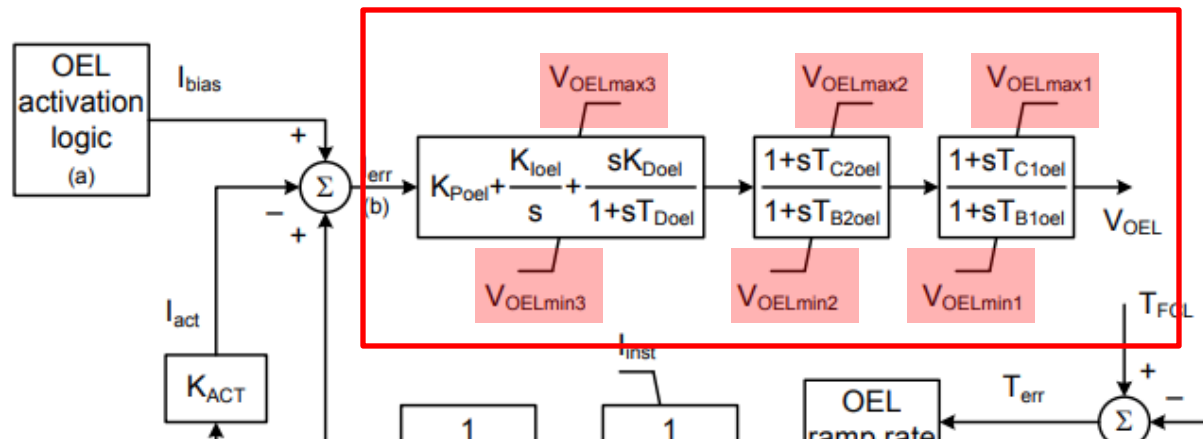
	OEL input at <b>Summation Point</b>	OEL input at <b>Take-over Gate</b>
Assuming normal condition for OEL4C initialization, $VOEL = 0$	$V_{REF}-V_C$ value is not affected  OK	Initial VA value is a positive <b>LV gate curtails this!!!!</b> <b>NOT VALID</b>



# Over Excitation Limiter OEL2C





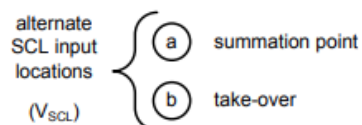
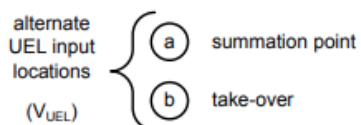
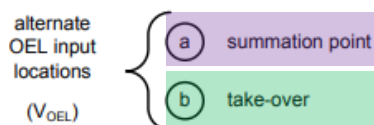
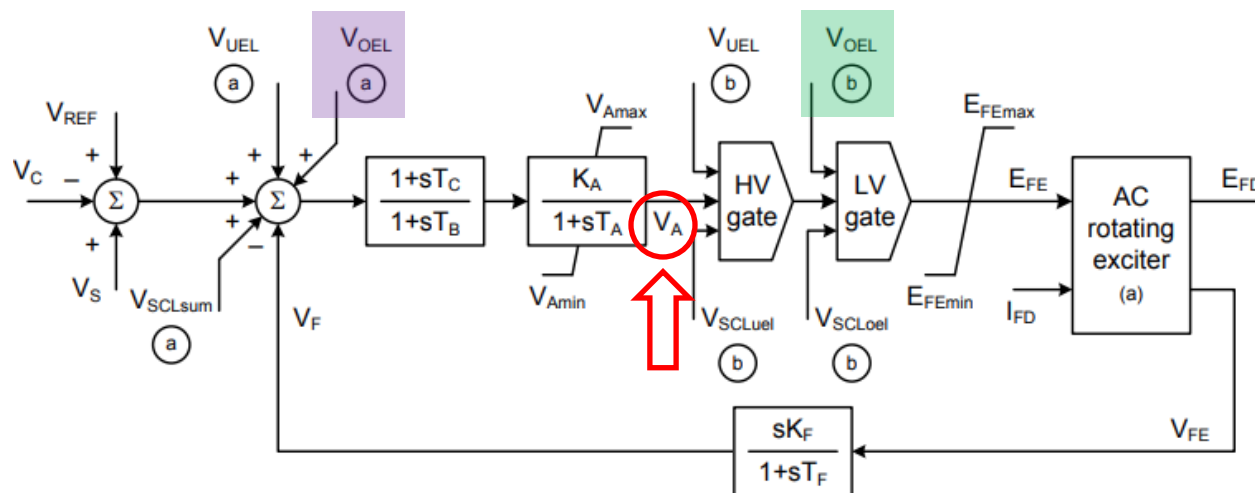
- VOEL output from OEL2C can be an input at **either** (a) summation point, **or** (b) take-over gate
- **Exciter OEL Input Flag** needs to be set correctly.
- OEL2C parameters **VOELmax1/2/3** and **VOELmin1/2/3** must be coordinated with the specific exciter model instance.
- OEL2C **internals (logic, lookup, etc)**, and the **power flow state** also need to be coordinated with true constraints of the excitation system.



# Limiter-Exciter Pair: OEL2C + AC1C






	OEL input at <b>Summation Point</b>	OEL input at <b>Take-over Gate</b>
Assuming normal condition for OEL2C initialization, $VOEL = VOEL_{max1}$	To ensure that $V_{ref}-V_c$ value is not affected, $VOEL_{max1}$ must be 0 $VOEL_{min1}$ must be $< 0$ 	Initial VA value is a positive For VA to not get curtailed, $VOEL_{max1}$ must be $\geq V_A$ $VOEL_{min1}$ must be $< VOEL_{max1}$ 



# Limiter-Exciter Pair Compatibility

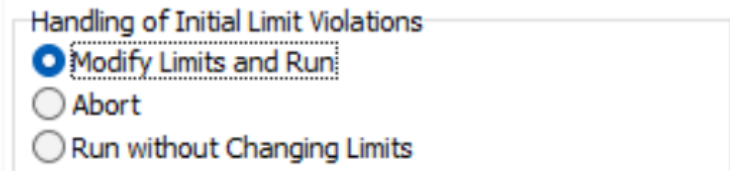


	Exciter is configured for Limiter input at <b>Summation Point</b>	Exciter is configured for Limiter input at <b>Take-over Gate</b>
Limiter can only feed into summation point  (OEL4C, SCL1C)	Limiter OK	Limiter NOT VALID  
Limiter can feed into either summation point or take-over gate depending on output limits  (OEL2C, OEL3C, OEL5C, UEL2C, SCL2C)	<p>OELMAX must be = 0 OELMIN must be &lt; 0</p> <p>UELMAX must be &gt; 0 UELMIN must be = 0</p> 	<p>OELMAX must be <math>\geq</math> exciter "VA" OELMIN must be &lt; OELMAX</p> <p>OELMAX must be &gt; OELMIN UELMIN must be <math>\leq</math> exciter "VA"</p> 

# PowerWorld Specific Implementation Details



- Type C Limiters can be used with Type C Exciters, and also older Exciters
- PowerWorld Transient Stability Tool has several checks
  - Validation and Autocorrection (BEFORE initialization):
    - (i) Ensures limiter is suitable for exciter, and
    - (ii) Ensures limiter MAX/MIN limits are consistent if exciter is configured to receive input signal at summation point.
  - Initial Limit Modification (DURING initialization, selected by default):
    - (i) If the limiter initializes "normally", then OELMAX and UELMIN are modified
    - (ii) OELMIN and UELMAX are NOT modified
  - Detailed messages are added in the log






# Case Information Displays



- All limiters have internally maintained string field called "**Output Used**". This is used for Validation and Autocorrection.
  - Summation Point: Active Exciter is receiving signal
  - Takeover Gate: Active Exciter is receiving signal
  - No Input: Active Exciter does not have any input location for this signal
  - Not Used: Active Exciter is configured to ignore this signal
  - Not Suitable: Active Exciter is not suitable for this type of signal
  - Not Configured: Active Exciter is not configured for this type of signal
  - No Exciter: Active Exciter is absent



Gen Other Model	Number of Bus	ID	Name_Nominal kV of Bus	Area Name of Gen	Type	MVA Base	Device Status	Model Class	Output Used ▲	Tup	Tuq	Tuv	Vbias	K1	K2	Kt
PLAYINREF	46				UEL2C	707.8	Active	Under Excitation Limiter	No Exciter	0	0	0	1	2	2	
REPC_A (794)	47				UEL2C	11.457	Active	Under Excitation Limiter	No Exciter	0.07	0.07	0.014	1	2	2	
REPC_B (171)	48				UEL2C	11.457	Active	Under Excitation Limiter	No Exciter	0.07	0.07	0.014	1	2	2	
REPC_B100	49				UEL2C	81.33	Active	Under Excitation Limiter	Not Used	0.5	0.017	0.017	1	2	2	
REPCA1	50				UEL2C	4	Active	Under Excitation Limiter	Not Used	5	5	1	1	2	2	
REPCTA1	51				UEL2C	81.33	Active	Under Excitation Limiter	Not Used	0.5	0.017	0.017	1	2	2	
VAR1	52				UEL2C	222	Active	Under Excitation Limiter	Summation Point	5	0	5	1	2	2	
VAR2	53				UEL2C	222	Active	Under Excitation Limiter	Summation Point	5	0	5	1	2	2	
Pref Controller	54				UEL2C	133.333	Active	Under Excitation Limiter	Summation Point	5	0	5	1	2	2	
LCFB1 (75)	55				UEL2C	33.333	Active	Under Excitation Limiter	Summation Point	5	0	5	1	2	2	