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

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Based on IEEE Std 421.5™-2016

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**
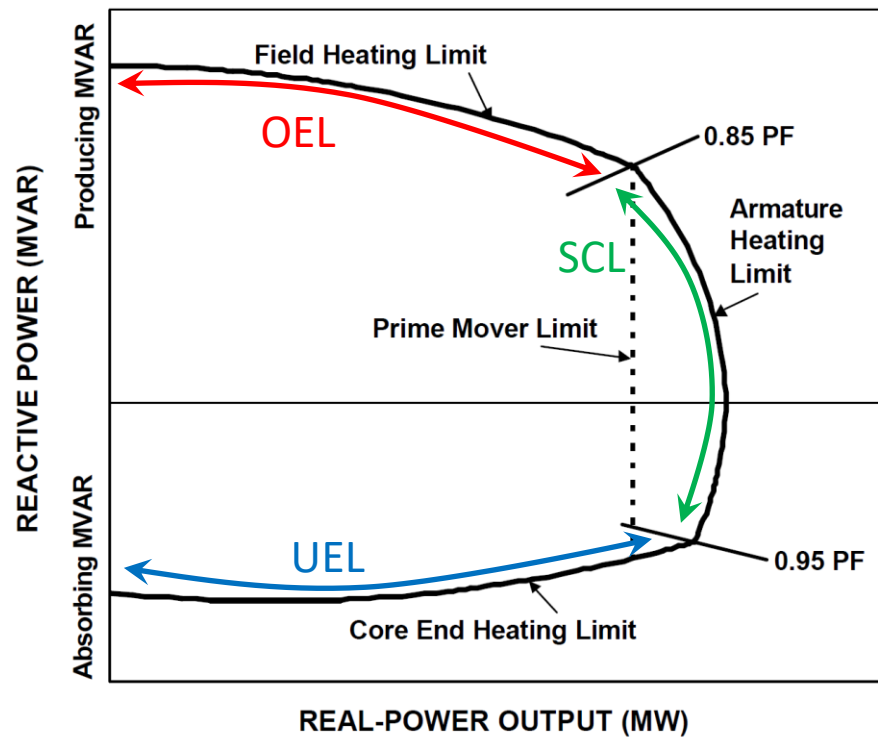
https://en.wikipedia.org/wiki/Capability_curve#/media/File:Capability_curve_of_an_electrical_generator.png

Outline

- 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
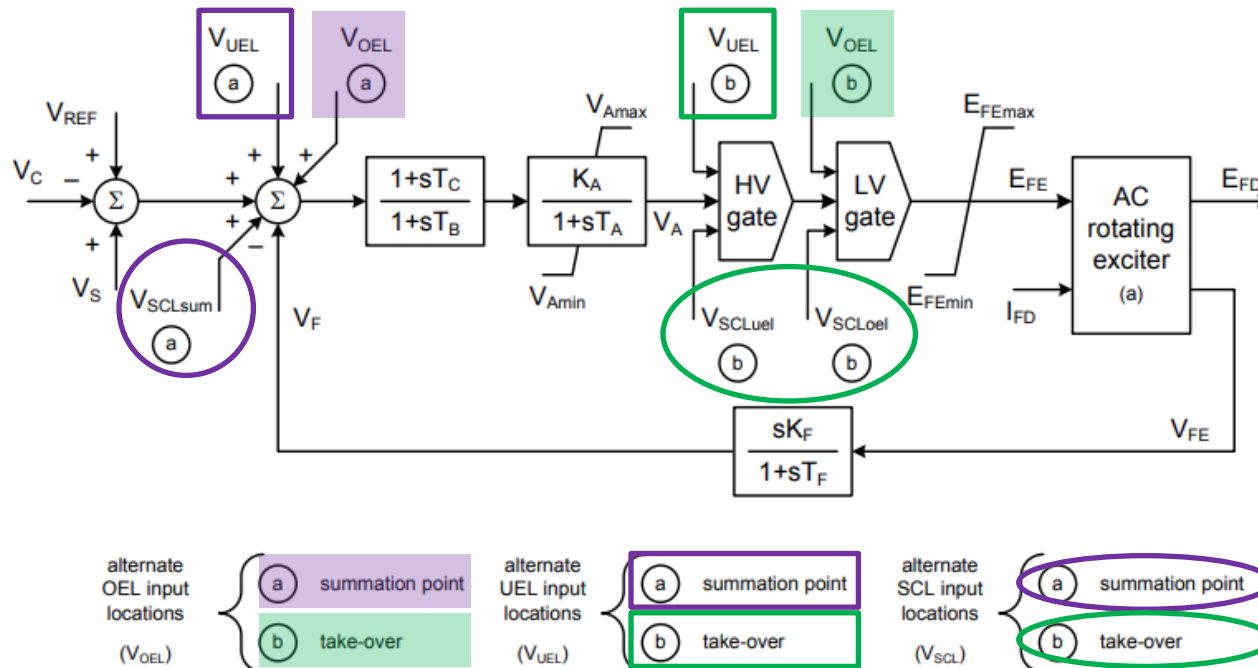
- Available as ESAC1A in PW, PSSE, PSLF
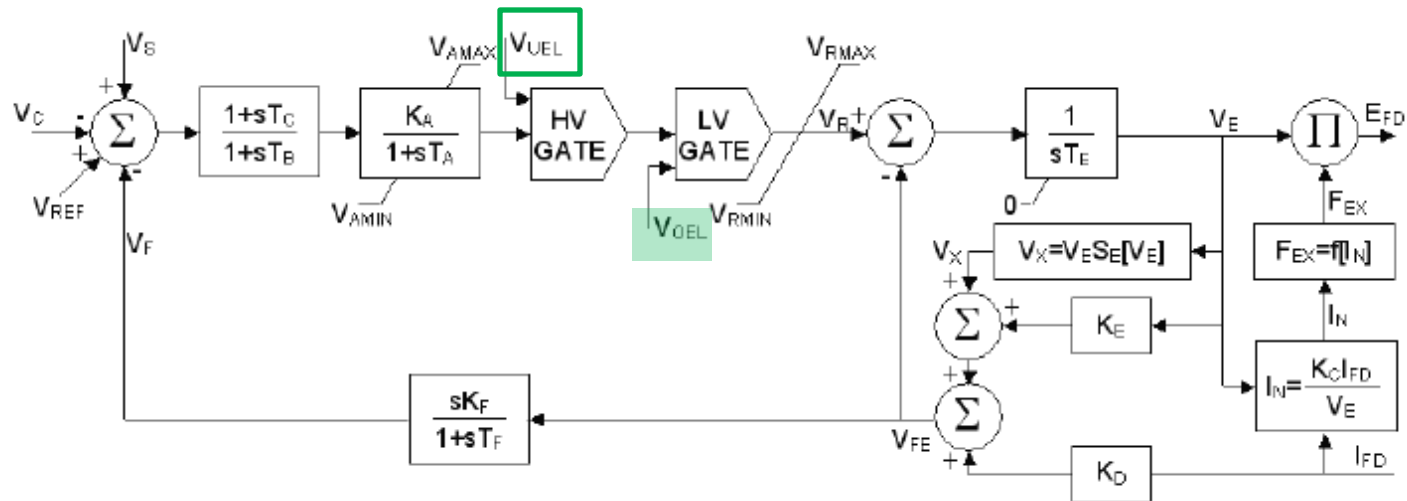
- Superseded by AC1C from IEEE Std 421.5™-2016

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
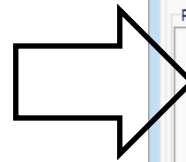
Input Parameters
Exciter AC1C

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

Input Locations for OEL
Exciter AC1C

	OEL input at **Summation Point**	OEL input at **Take-over Gate**
OEL NOT Limiting	VOEL = 0	VOEL ≥ VA
OEL Limiting	VOEL < 0	VOEL < VA
Exciter Signal	VREF − VC + VOEL	MIN(VA, VOEL)
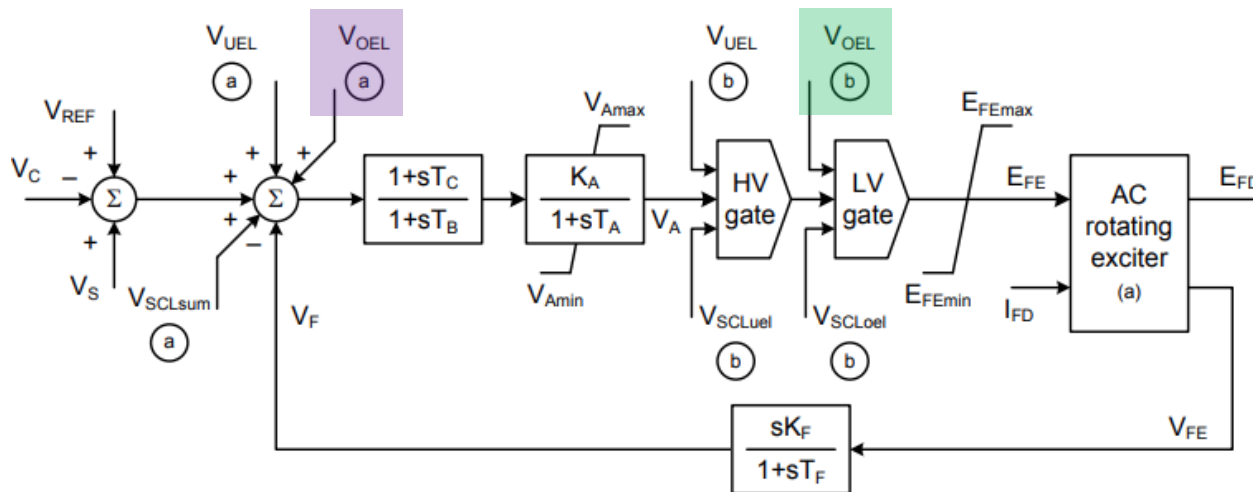
# IEEE Type C Limiter Models

- 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 Vmin < 0.
    - ➔VOEL is always ≤ 0.
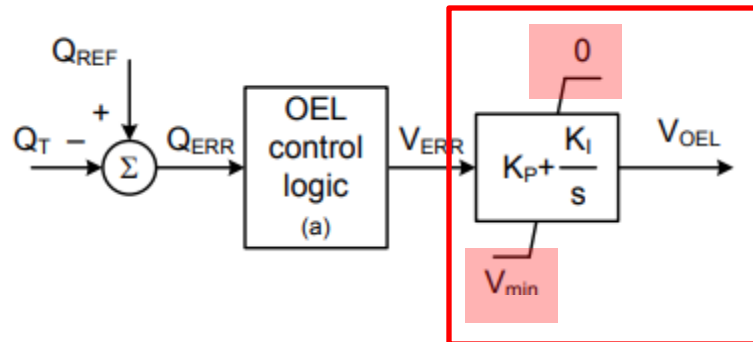
- OR Exciter model has OEL input only at summation point

Exciter-Limiter Pair: AC1C + OEL4C

	OEL input at **Summation Point**	OEL input at **Take-over Gate**
Assuming normal condition for OEL4C initialization, VOEL = 0	VREF-VC value is not affected OK	Initial VA value is a positive **LV gate curtails this!!!!!** **NOT VALID**

NOT POSSIBLE TO CONFIGURE OEL4C AT TAKE-OVER GATE OF AC1C
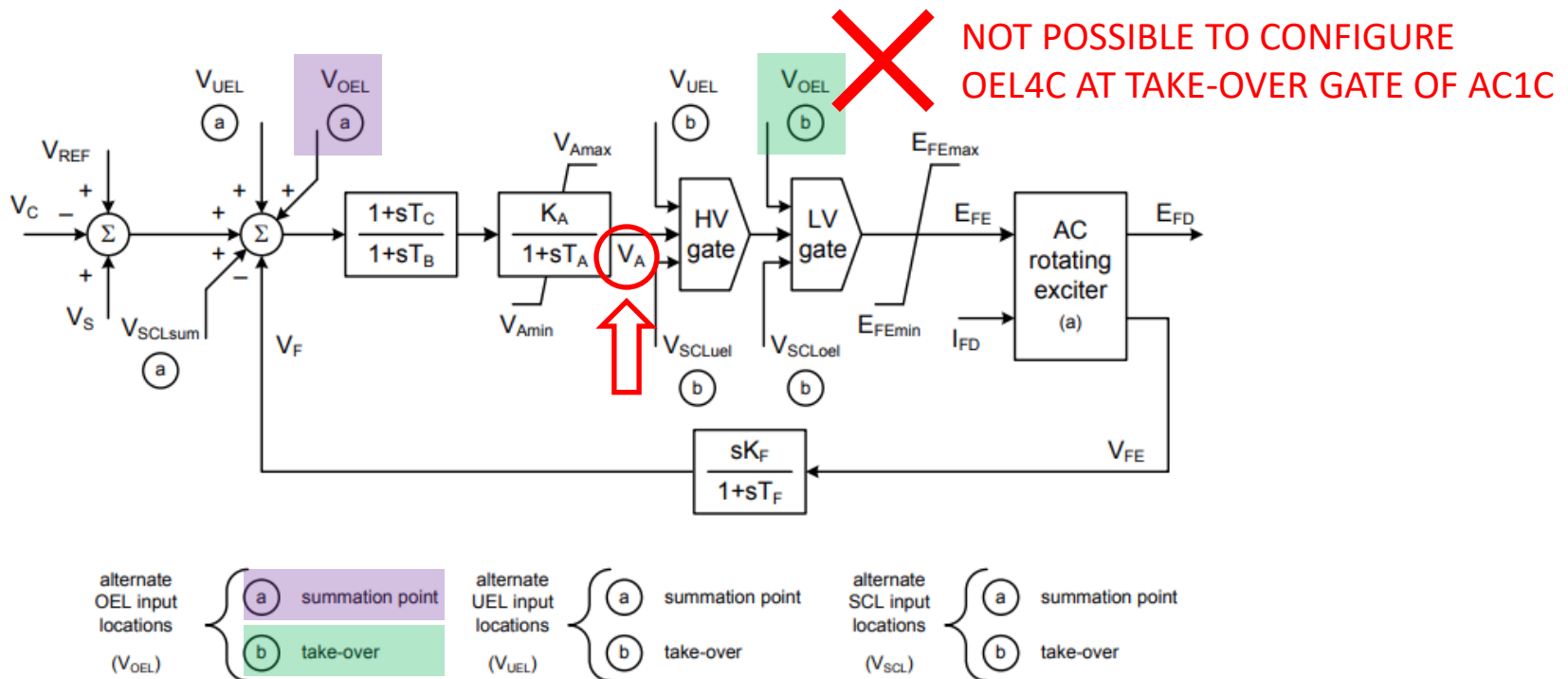
Over Excitation Limiter OEL2C

- 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.
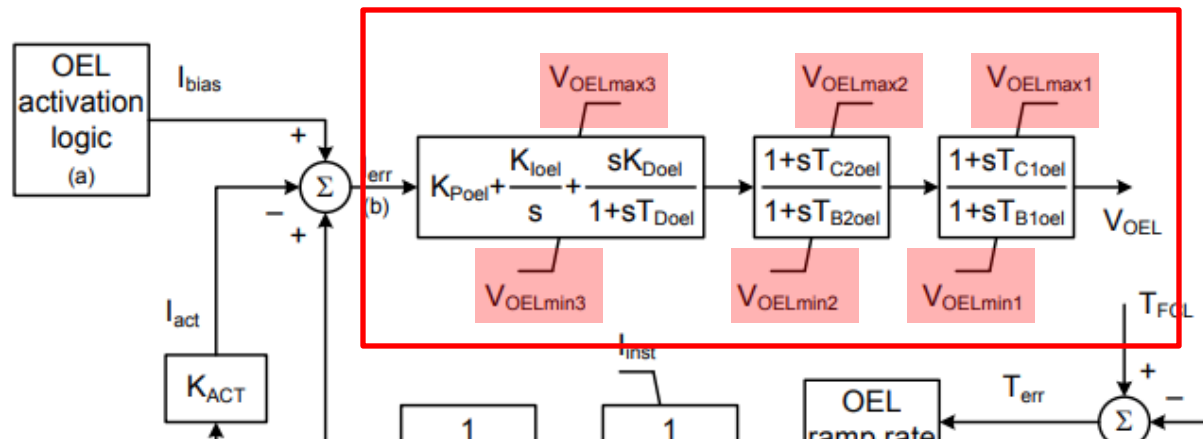
Limiter-Exciter Pair: OEL2C + AC1C

	OEL input at **Summation Point**	OEL input at **Take-over Gate**
Assuming normal condition for OEL2C initialization, VOEL = VOELmax1	To ensure that Vref-Vc value is not affected, VOELmax1 must be 0 VOELmin1 must be < 0 ⚠️	Initial VA value is a positive For VA to not get curtailed, VOELmax1 must be ≥ VA VOELmin1 must be < VOELmax1 ⚠️
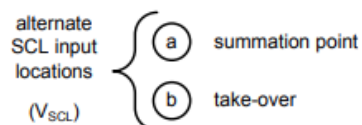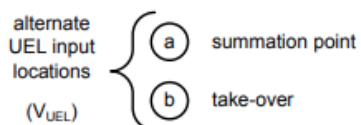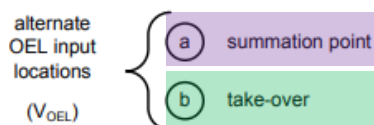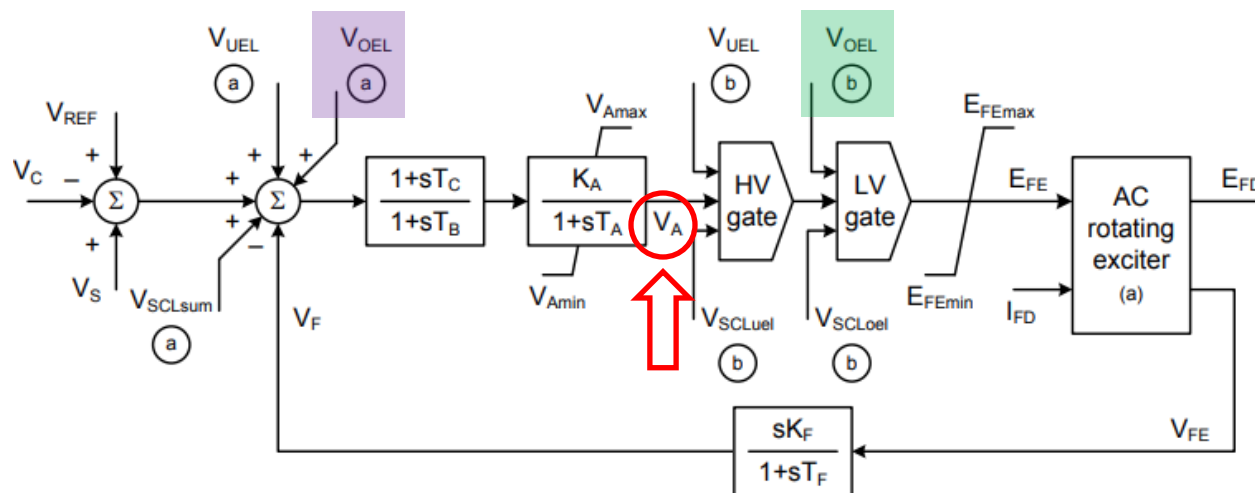
Limiter-Exciter Pair Compatibility

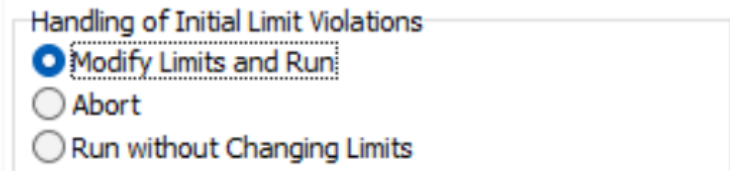|	Exciter is configured for Limiter input at **Summation Point**	Exciter is configured for Limiter input at **Take-over Gate**
Limiter can only feed into summation point (OEL4C, SCL1C)	Limiter OK	Limiter NOT VALID ✖
Limiter can feed into either summation point or take-over gate depending on output limits (OEL2C, OEL3C, OEL5C, UEL2C, SCL2C)	OELMAX must be = 0 OELMIN must be < 0 UELMAX must be > 0 UELMIN must be = 0 ⚠	OELMAX must be ≥ exciter "VA" OELMIN must be < OELMAX OELMAX must be > OELMIN UELMIN must be ≤ exciter "VA" ⚠

PowerWorld Specific Implementation Details

- Type C Limiters can be used with Type C Exciters, <u>and also older Exciters</u>

- PowerWorld Transient Stability Tool has several checks
  - Validation and Autocorrection (<u>BEFORE initialization</u>):
    (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 (<u>DURING initialization</u>, selected by default):
    (i) If the limiter initializes "normally", then OELMAX and UELMIN are modified
    (ii) OELMIN and UELMAX are NOT modified

    Handling of Initial Limit Violations
    ● Modify Limits and Run
    ○ Abort
    ○ Run without Changing Limits

  - 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