

TO: WECC MVS
FROM: Henry Jansen, Basler Electric Company
SUBJECT: Specification of the BASOEL2 Model for Summing Point Overexcitation Limiters
DATE: April 24, 2026

Introduction

This model specification document describes the need for and implementation of the BASOEL2 model for overexcitation limiters (OELs) or maximum excitation limiters (MXLs). Presently, there are few published models for simulating OELs. IEEE Std 421.5™-2016 [1] discusses a few different forms of OEL models, namely the OEL1B and the OEL2C through OEL5C. However, those models fail to simulate the behavior of an OEL that has more than two overexcitation levels. The BASOEL2 model supports the independent configuration of up to three different overexcitation levels: a high level (short-time allowed overload), a middle level (medium-time allowed overload), and a low level (continuous limit). The high and middle overexcitation levels both have their own unique fixed time delays. The BASOEL2 model is intended to be used to model a summing point style OEL implementation, not a takeover style OEL. A volts-per-Hertz limiter (V/Hz) is included as an optional feature in the BASOEL2 model.

Model Application

The BASOEL2 model is intended to be used to model a summing point OEL that works in conjunction with another regulator to prevent a generator system from being damaged due to prolonged overexcited operation. The BASOEL2 model can only be used to simulate OELs with fixed time delays that step the value of the OEL reference once a time delay has elapsed.

Theoretically, a fixed time delay OEL with multiple overexcitation levels like the BASOEL2 model could be used as a takeover style excitation limiter. The main difference between the summing point style OEL and the takeover style OEL is how the output of the OEL is used. With the summing point style OEL, the OEL's output is used to adjust the reference level of the regulator in charge of maintaining the generator system's setpoints. On the other hand, the takeover style OEL's output is used to directly control the generator system's setpoints. To do this, the takeover OEL overrides the regulator's control actions, i.e. the takeover OEL "takes over" the responsibility of controlling the generator from the main regulator while the takeover OEL is active. Due to the operational differences between the two different OEL styles, it should not be expected for the OELs to respond in the same way to the same event, even if they share the same settings.

It is not recommended to use the BASOEL2 model to simulate a takeover style OEL. Using the BASOEL2 model to only simulate summing point OELs allows for the model to be used consistently in power system planning and coordination studies. If it is desired to use the BASOEL2 model to model a takeover style OEL, one should get approval from the manufacturer of the equipment implementing the OEL in question and from the coordination planner(s) of the system.

Mathematical Model Description of the BASOEL2 Model

A block diagram of the BASOEL2 model is depicted in Figure 1 on Page 7 of this document. The block diagram depiction of the BASOEL2 model has been taken from [2] and used with permission. The *Appendix* of this document contains pseudocode for how the BASOEL2 model is implemented and functions [2]. Table 1 through Table 3 contain the various settings, inputs, and values of the BASOEL2 model in addition to their corresponding descriptions.

Block Diagram and Block Diagram Settings, Variables, and Values

Model Settings	Setting Description
OELFlag	OEL Status: Indicates whether the OEL output is disabled or enabled. A value of 0 indicates that the OEL output is disabled and a value of 1 (or a value other than 0) indicates that the OEL output is enabled.
VHzFlag	V/Hz Limiter Status: Indicates whether the V/Hz limiter output is disabled or enabled. A value of 0 indicates that the V/Hz limiter output is disabled and a value of 1 (or a value other than 0) indicates that the V/Hz limiter output is enabled.
OELIn	OEL Input: Indicates what measurement is being compared against the OEL's threshold levels for the purposes of preventing the main generator from being damaged due to being overexcited for extended periods of time. A value of 0 indicates the main generator's field voltage is being used as the comparison measurement, a value of 1 indicates that the main generator's field current is being used as the comparison measurement, and a value of 2 indicates that the exciter's field current (or a signal proportional to the exciter's field current) is being used as the comparison measurement.
TRoel	OEL Regulator Input Filter Time Constant: Indicates the value of the time constant for the low-pass filter that is applied to the OEL's input value. It is expressed in seconds.
Kp	OEL Regulator Proportional Gain: Indicates the value of the proportional gain used in the proportional-integral (PI) controller of the OEL's regulator.
Ki	OEL Regulator Integral Gain: Indicates the value of the integral gain used in the proportional-integral (PI) controller of the OEL's regulator.
OEL1	Short-Time Allowed Overload (High Level Threshold): Indicates the upper threshold of the allowed value represented by OELIn. The value represented by OELIn will not be allowed to exceed this level once the time equal to OET1 has elapsed.
OET1	Short-Time Allowed Overload Time: Indicates the amount of time the value represented by OELIn is allowed to be above the level of OEL1.
OEL2	Medium-Time Allowed Overload (Medium Level Threshold): Indicates the medium threshold of the allowed values for OELIn. The value represented by OELIn will not be allowed to exceed this level once the time equal to OET2 has elapsed.

Table 1. List of the BASOEL2 model's settings and setting descriptions.

Model Settings (cont.)	Setting Description (cont.)
OET2	Medium-Time Overload Time (High Level Time): Indicates the amount of time the value represented by OELIn is allowed to be above the level of OEL2 after the time equal to OET1 has elapsed.
OEL3	Continuous Limit (Low Level Threshold): Indicates the low threshold of the allowed values for OELIn. The value represented by OELIn will not be allowed to exceed this level once the time equal to OET3 has elapsed and will remain at this level indefinitely.
OET3	Continuous Limit Time (Medium Level Time): Indicates the amount of time the value represented by OELIn is allowed to be above the level of OEL3 after the time equal to OET2 has elapsed.
TRVHz	V/Hz Limiter Regulator Input Filter Time Constant: Indicates the value of the time constant for the low-pass filter that is applied to the V/Hz limiter's input value. It is expressed in seconds.
KVHz	V/Hz Limiter Gain: Indicates the value of the V/Hz limiter's gain.
VHzmin	V/Hz Limiter Minimum Input: Indicates the minimum allowed input into the V/Hz limiter's summing junction.
V _{REF}	Exciter Voltage Reference: Indicates the desired exciter output voltage.
IncrementTime	Simulation Time Step Increment: Indicates the amount of time between consecutive simulation time steps.

Table 1. (cont.) List of the BASOEL2 model's settings and setting descriptions.

Model Inputs	Input Description
V _{term}	Generator Terminal Voltage: Average line-to-line measurement of the output voltage of a three-phase generator. This value is expressed in per unit with a per-unit base equal to the rated terminal voltage of the generator.
Terminal Bus Frequency	Generator Terminal Frequency: Frequency of the generator's output terminal voltage and terminal current. This value is expressed in per unit with a per-unit base equal to the rated terminal frequency of the generator.
V _{REF}	Generator Terminal Voltage Reference: The desired average line-to-line terminal voltage of the generator. This value is expressed in per unit with a per-unit base equal to the rated terminal voltage of the generator.
Machine Efd	Generator Field Voltage: The measurement of the generator's field voltage. This value is expressed in per unit with a per-unit base equal to the generator's no-load rated field voltage.
Machine Ifd	Generator Field Current: The measurement of the generator's field current. This value is expressed in per unit with a per-unit base equal to the generator's no-load rated field current.
Exciter Vfe	Exciter Field Current: The measurement of the exciter's field current or a signal proportional to the exciter's field current. This value is expressed in per unit with a per-unit base equal to the exciter's no-load rated field current.

Table 2. List of the BASOEL2 model's inputs and input descriptions.

Model Values	Value Descriptions
Int	OEL PI Controller's Integral Value: Indicates the integral value corresponding to the OEL's PI controller.
F_{p_{sens}}	V/Hz Limiter's Sensed Speed: Indicates the value of the generator's measured terminal frequency after it has been filtered by the V/Hz limiter's low-pass filter.
OEL_{sens}	Sensed Value of OEL's Input: Indicates the value of the measured OEL input after it has been filtered by the OEL's low-pass filter.
OEL_{REF}	OEL Reference: Indicates the desired OEL reference level that is to be subtracted from the value of OEL _{sens} to determine the error signal that is passed to the input of the OEL's PI controller.
V_{OELout}	OEL Output: Indicates the output of the OEL.
V_{Hzout}	V/Hz Output: Indicates the output of the V/Hz limiter.
V_{OEL}	V _{OEL} is the output of the BASOEL2 model and consists of the sum of the outputs from the OEL (V _{OELout}) and the V/Hz limiter (V _{Hzout}).
OEL1Active	OEL1Active is a binary (Boolean) variable used to indicate whether or not the value of OEL1Timer is greater than or equal to OET1 or is less than or equal to 0. When OEL1Timer is greater than or equal to OET1, OEL1Active is set equal to TRUE. When OEL1Timer is less than or equal to 0, OEL1Active is set equal to FALSE.
OEL1Limit	OEL1Limit is a binary (Boolean) variable used to indicate whether or not the value of OEL _{sens} is greater than the threshold defined by the value of OEL1. If OEL1Limit has a value of TRUE, then OEL1Limit is set equal to TRUE when the value of OEL _{sens} is greater than the product of the value of OEL1 and 0.999 and is set equal to FALSE otherwise. If OEL1Limit has a value of FALSE, then OEL1Limit is set equal to TRUE when the value of OEL _{sens} is greater than the value of OEL1 and is set equal to FALSE otherwise.
OEL1Timer	OEL1Timer is a variable that keeps track of the amount of time OEL _{sens} has exceeded OEL1 and is used to determine the value of OEL1Active. When OEL1Limit is TRUE and OEL1Active is FALSE, OEL1Timer is incremented by the value of IncrementTime. When OEL1Limit is FALSE and OEL1Active is TRUE, OEL1Timer is decremented by the value of IncrementTime. When OEL1Timer is less than or equal to 0, OEL1Timer is set equal to 0 and OEL1Active is set equal to FALSE. When OEL1Timer is greater than or equal to OET1, OEL1Timer is set equal to OET1 and OEL1Active is set equal to TRUE.

Table 3. List of the BASOEL2 model's values and value descriptions.

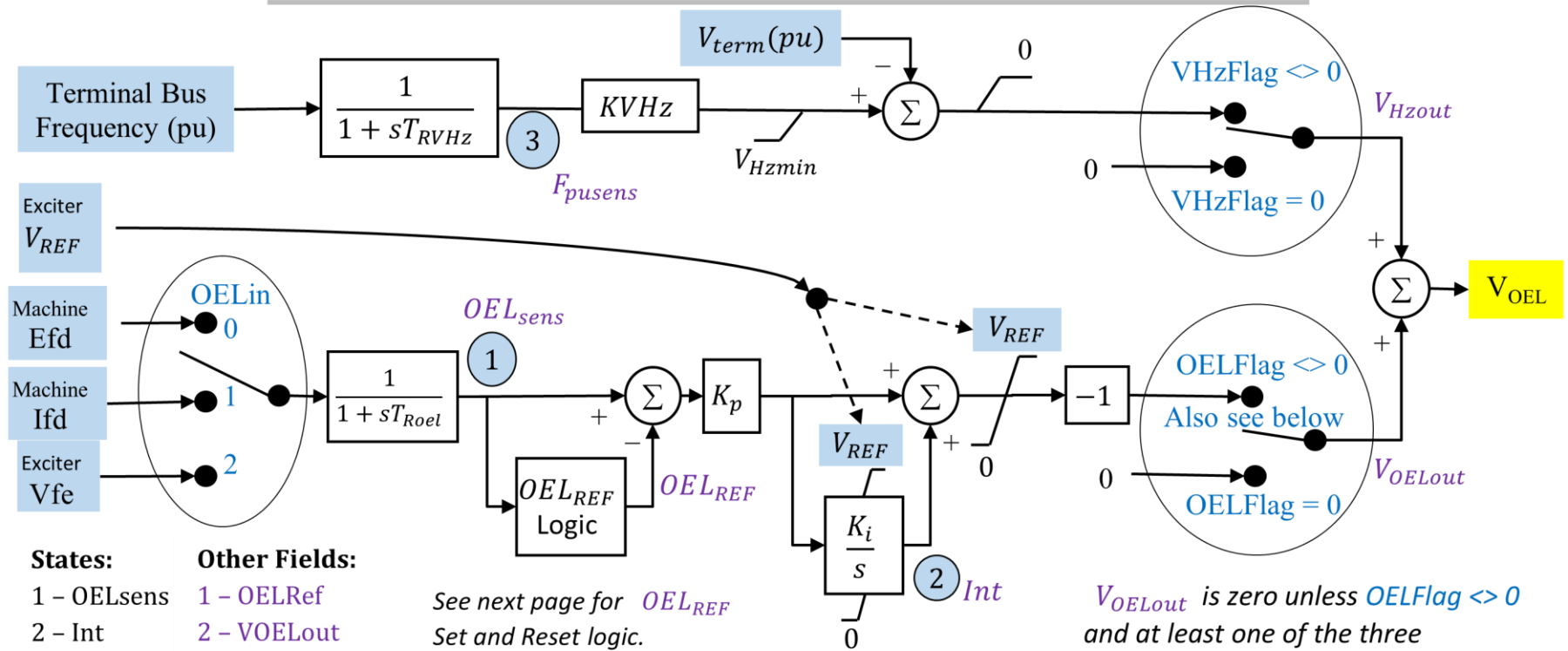
Model Values (cont.)	Value Descriptions (cont.)
OEL2Active	OEL2Active is a binary (Boolean) variable used to indicate whether or not the value of OEL2Timer is greater than or equal to the sum of OET1 and OET2 or is less than or equal to 0. When OEL2Timer is greater than or equal to the sum of OET1 and OET2, OEL2Active is set equal to TRUE. When OEL2Timer is less than or equal to 0, OEL2Active is set equal to FALSE.
OEL2Limit	<p>OEL2Limit is a binary (Boolean) variable used to indicate whether or not the value of OEL_{sens} is greater than the threshold defined by the value of OEL2.</p> <p>If OEL2Limit has a value of TRUE, then OEL2Limit is set equal to TRUE when the value of OEL_{sens} is greater than the product of the value of OEL2 and 0.999 and is set equal to FALSE otherwise. If OEL2Limit has a value of FALSE, then OEL2Limit is set equal to TRUE when the value of OEL_{sens} is greater than the value of OEL2 and is set equal to FALSE otherwise.</p>
OEL2Timer	<p>OEL2Timer is a variable that keeps track of the amount of time OEL_{sens} has exceeded OEL2 and is used to determine the value of OEL2Active. When OEL2Limit is TRUE and OEL2Active is FALSE, OEL2Timer is incremented by the value of IncrementTime. When OEL2Limit is FALSE and OEL2Active is TRUE, OEL2Timer is decremented by the value of IncrementTime.</p> <p>When OEL2Timer is less than or equal to 0, OEL2Timer is set equal to 0 and OEL2Active is set equal to FALSE. When OEL2Timer is greater than or equal to the sum of OET1 and OET2, OEL1Timer is set equal to the sum of OET1 and OET2 and OEL1Active is set equal to TRUE.</p>

Table 3. (cont.) List of the BASOEL2 model's values and value descriptions.

Model Values (cont.)	Value Descriptions (cont.)
OEL3Active	OEL3Active is a binary (Boolean) variable used to indicate whether or not the value of OEL3Timer is greater than or equal to the sum of OET1, OET2, and OET3 or is less than or equal to 0. When OEL3Timer is greater than or equal to the sum of OET1, OET2, and OET3, OEL3Active is set equal to TRUE. When OEL3Timer is less than or equal to 0, OEL3Active is set equal to FALSE.
OEL3Limit	<p>OEL3Limit is a binary (Boolean) variable used to indicate whether or not the value of OEL_{sens} is greater than the threshold defined by the value of OEL3.</p> <p>If OEL3Limit has a value of TRUE, then OEL3Limit is set equal to TRUE when the value of OEL_{sens} is greater than the product of the value of OEL3 and 0.999 and is set equal to FALSE otherwise. If OEL3Limit has a value of FALSE, then OEL3Limit is set equal to TRUE when the value of OEL_{sens} is greater than the value of OEL3 and is set equal to FALSE otherwise.</p>
OEL3Timer	<p>OEL3Timer is a variable that keeps track of the amount of time OEL_{sens} has exceeded OEL3 and is used to determine the value of OEL3Active. When OEL3Limit is TRUE and OEL3Active is FALSE, OEL3Timer is incremented by the value of IncrementTime. When OEL3Limit is FALSE and OEL3Active is TRUE, OEL3Timer is decremented by the value of IncrementTime.</p> <p>When OEL3Timer is less than or equal to 0, OEL3Timer is set equal to 0 and OEL3Active is set equal to FALSE. When OEL3Timer is greater than or equal to the sum of OET1, OET2 and OET3, OEL3Timer is set equal to the sum of OET1, OET2, and OET3 and OEL3Active is set equal to TRUE.</p>

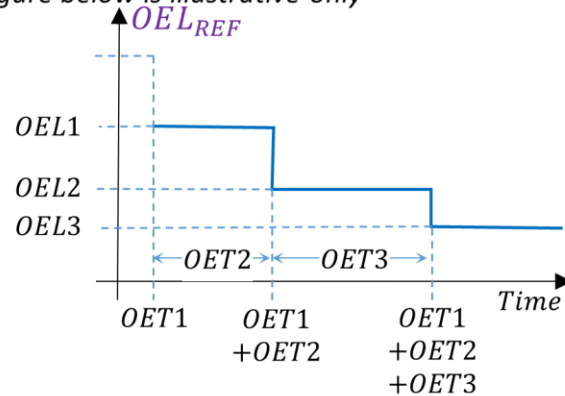
Table 3. (cont.) List of the BASOEL2 model's values and value descriptions.

Maximum Excitation Limiter Model BASOEL2



- | | |
|----------------|----------------------|
| States: | Other Fields: |
| 1 - OELsens | 1 - OELRef |
| 2 - Int | 2 - VOELout |
| 3 - Fpusens | 3 - VHzout |
| | 4 - OEL1Active |
| | 5 - OEL1Limit |
| | 6 - OEL1Timer |
| | 7 - OEL2Active |
| | 8 - OEL2Limit |
| | 9 - OEL2Timer |
| | 10 - OEL3Active |
| | 11 - OEL3Limit |
| | 12 - OEL3Timer |

See next page for OEL_{REF}
Set and Reset logic.
Figure below is illustrative only



V_{OELout} is zero unless $OELFlag <> 0$
and at least one of the three
 OEL^*/OET^*
Threshold/Timer pairs is both active
and above the respective threshold.
For details, see the pseudo-code
regarding OELref and associated timers
and internal flags on the next page

Model supported by PSSE

Figure 1. Depiction of the block diagram implementation of the BASOEL2 model from [2]. Additional pseudocode for this block diagram can be found in the Appendix.

Normal Operation of the OEL:

When the value of the filtered OEL input (OEL_{sens}) exceeds the continuous limit ($OEL3$), the OEL will activate and begin timing.

Once OEL_{sens} exceeds $OEL3$, OEL_{sens} will be allowed to remain above the short-time allowed overload ($OEL1$) threshold until a time equal to the short-time allowed overload time ($OET1$) has passed. Once the amount of time equal to $OET1$ has elapsed, the OEL will not allow the value of OEL_{sens} to exceed $OEL1$ and the OEL will take action to limit the value of OEL_{sens} to the level of $OEL1$, if required. The OEL will not take any action if OEL_{sens} is already below the threshold defined by $OEL1$ when $OET1$ elapses.

After an amount of time equal to the sum of $OET1$ and the medium-time overload time ($OET2$), the OEL will not allow the value of OEL_{sens} to exceed the medium-time allowed overload ($OEL2$) and the OEL will take action to limit the value of OEL_{sens} to the level of $OEL2$, if required. The OEL will not take any action if OEL_{sens} is already below the threshold defined by $OEL2$ when the time equal to the sum of $OET1$ and $OET2$ elapses.

After an amount of time equal to the sum of $OET1$, $OET2$, and the continuous limit time ($OET3$), the OEL will not allow the value of OEL_{sens} to exceed $OEL3$ and the OEL will take action to limit the value of OEL_{sens} to the level of $OEL3$, if required. The OEL will continue to limit the value of OEL_{sens} to the level of $OEL3$ indefinitely until an external control action is taken to decrease the value of OEL_{sens} to be less than or equal to 99.9% of $OEL3$. When OEL_{sens} is less than or equal to 99.9% of $OEL3$, the output of the OEL (V_{OELout}) will be assigned a value of 0.

Calculation of the OEL Reference (OEL_{REF}) During Normal Operation of the OEL:

During the calculation of the OEL reference (OEL_{REF}), it is initially assumed that OEL_{REF} has a value equal to $OEL1$. If the value of $OEL2Active$ is TRUE and OEL_{REF} is greater than $OEL2$, then OEL_{REF} is set equal to $OEL2$. Next, if the value of $OEL3Active$ is TRUE and OEL_{REF} is greater than $OEL3$, then OEL_{REF} is set equal to $OEL3$. This behavior is described in the pseudocode in the *Appendix* of this document.

Behavior of the OEL while the OEL is Resetting:

Once OEL_{sens} is less than or equal to 99.9% of an OEL limit (OEL1, OEL2, or OEL3) after the corresponding OEL active variable (OEL1Active, OEL2Active, and OEL3Active) is set to TRUE, the respective OEL timer (OEL1Timer, OEL2Timer, and OEL3Timer) will begin to count down. The different OEL timers will decrement by the value of the simulation's time step increment (IncrementTime). Once a timer has fully counted back to 0, the corresponding OEL active variable will be assigned a value of FALSE.

A partial reset is an event where OEL_{sens} is less than or equal to 99.9% of OEL3 and then rises above OEL3 before the OEL is fully reset. In the event of a partial reset, if OEL_{sens} was previously not allowed to exceed a particular OEL limit before the partial reset occurred, then it will still not be allowed to exceed that limit after the partial reset. A full reset is required to allow OEL_{sens} to exceed a particular OEL limit after the corresponding OEL time has elapsed. Also, if an OEL time has not fully elapsed before a partial reset occurs, then that OEL time will continue counting from where it left off once OEL_{sens} returns above OEL3. For example, if OEL_{sens} attempts to exceed OEL2 after a partial reset and the sum of the OET1 and OET2 times has already elapsed, the OEL will continue to limit OEL_{sens} to the OEL2 threshold and the OEL3Timer will continue counting from where it left off before the partial reset event occurred. This partial reset characteristic can be seen in Figure 5 the *Software Test Cases* section of this document when the generator field current attempts to exceed OEL3 after the partial reset occurs at time $t = \sim 26s$. The generator field current was still limited to OEL3 since the sum of OET1, OET2, and OET3 had already elapsed before the partial reset occurred.

The reset requirement of having OEL_{sens} be less than or equal to 99.9% of an OEL limit introduces a 0.1% hysteresis at the boundary between the OEL active and inactive states. This helps prevent numerical issues in the implementation of the BASOEL2 model's code if OEL_{sens} approaches a steady-state value near the continuous limit (OEL3). For example, without the "turn-off" hysteresis, a small amount of noise in the measurement of OEL_{sens} could cause the OEL to repeatedly switch between the active and inactive states. However, with the "turn-off" hysteresis present, once OEL_{sens} is less than or equal to 99.9% of OEL3, OEL_{sens} would be required to increase back above 100% of OEL3 before the OEL would activate again. Therefore, the "turn-off" hysteresis eliminates the issue with small amounts of noise in the measurement repeatedly triggering and deactivating the OEL. This behavior is described in the pseudocode in the *Appendix* of this document.

Validation of the BASOEL2 Model against Measured Overexcitation Limiter and Generator Behavior

Generator field current and OEL output data was gathered on a real generator for the purposes of comparing it against the behavior of the BASOEL2 model's OEL. Figure 2 depicts the test setup used to gather the baseline data for the simulation.

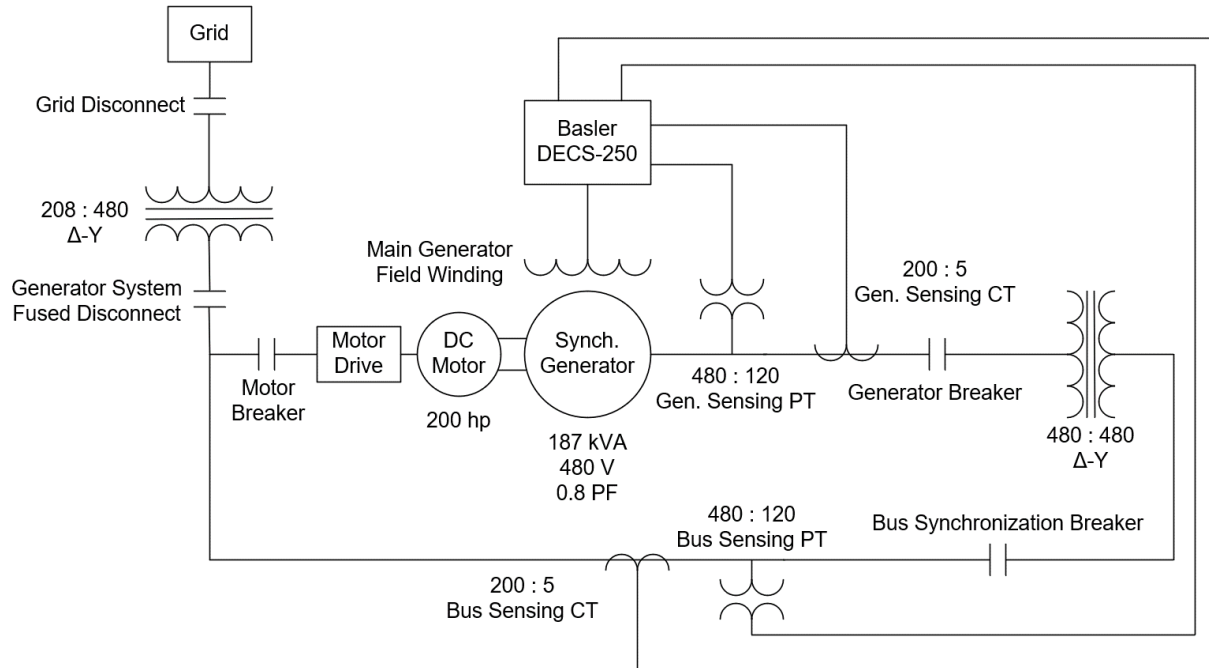


Figure 2. Depiction of the setup used to gather the data to validate the implementation of the BASOEL2 model's OEL implementation.

The OEL that was simulated by the BASOEL2 model was implemented in a Basler DECS-250 unit. The DECS-250 was also controlling the generator's terminal voltage, using an Automatic Voltage Regulator (AVR), while the unit was connected to the grid. The output of the OEL was added to the summing junction of the AVR. During the test, OEL1 was equal to 1.5 pu, OET1 was equal to 0 s, OEL2 was equal to 1.35 pu, OET2 was equal to 5 s, OEL3 was equal to 1.18 pu, and OET3 was equal to 10 s. The per-unit base for the OEL's thresholds was the generator's rated no-load field current, which was 7.4 A, and the input to the OEL was the metered generator field current, I_{FD} .

At the start of the test while the OEL was still disabled, the DECS-250 was instructed to increase the generator's output voltage to 1.16 pu so that the metered field current exceeded OEL1 by a significant amount. Then, the OEL was manually enabled and allowed to take action to limit the generator's field current based on the previously described settings. Figure 3 depicts the recorded generator field current values during the test and the corresponding generator field current values from a simulation with the BASOEL2 model. Figure 4 depicts the recorded OEL output values during the test and the corresponding OEL output values from the BASOEL2 model simulation.

With regards to the results depicted in Figure 3, the DECS-250's OEL was manually enabled at $t = 2.5$ s. Since the generator field current exceeded OEL1 (1.5 pu) and OET1 was equal to 0 s, the OEL immediately acted to limit the field current to OEL1 for the duration of OET2 (5 s). When OET2 elapsed at $t = 7.5$ s, the field current was then limited to OEL2 for the duration of OET3 (10 s). After the duration of OET3 elapsed at $t = 17.5$ s, the field current was then finally limited to OEL3 (1.18 pu).

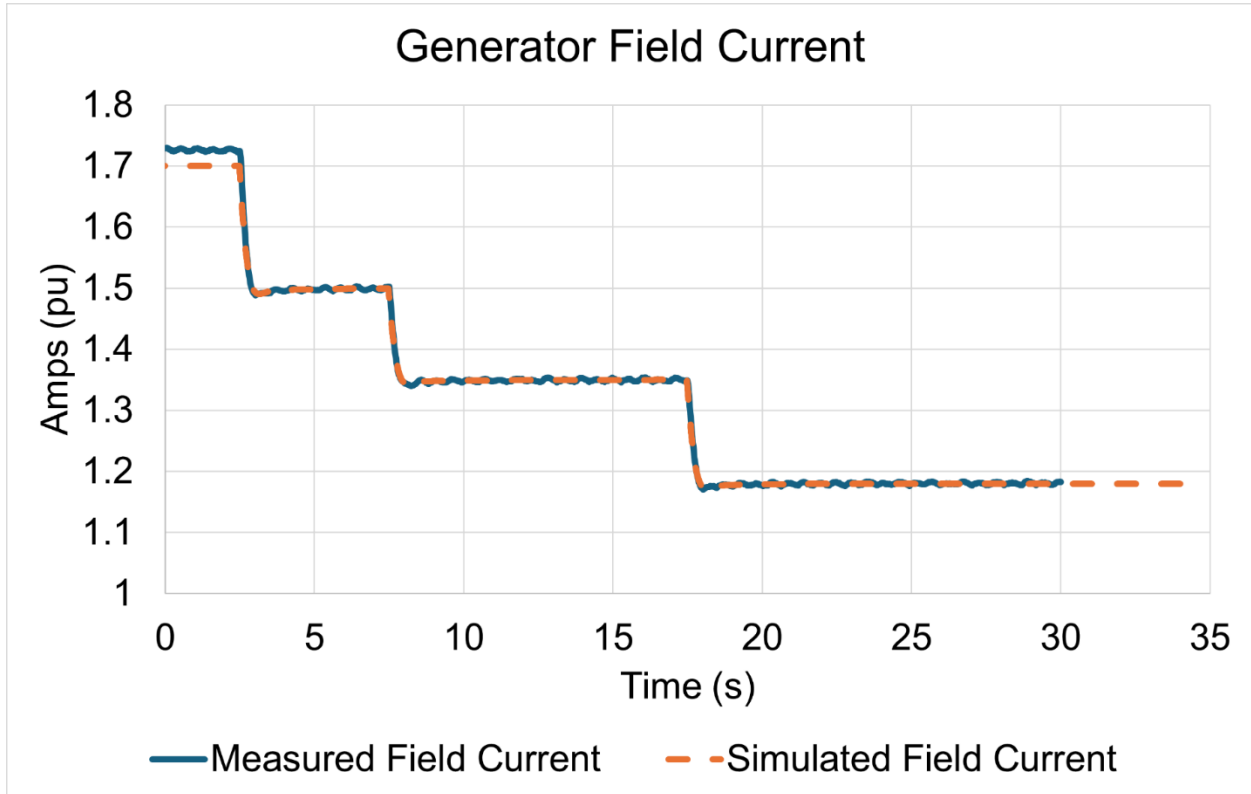


Figure 3. Depiction of the comparison between the measured and simulated field currents when the BASOEL2 model's OEL was validated.

The results depicted in Figure 4 match the timings discussed for Figure 3 and the behavior of the OEL's output matches the desired result. The desired behavior is for the OEL's output to be subtracted from the AVR's reference value at the AVR's summing junction, so that the OEL's output acts to decrease the AVR's setpoint. When the OEL's reference changes, the integral and proportional terms in the OEL's PI controller drive the output lower than its final steady-state value. This occurs because the integral and proportional terms are reacting to the newly increased error between the desired generator field current (represented by the OEL's new reference value) and the measured generator field current.

Once the generator field current is regulated down to the desired level, the OEL's output remains constant to maintain the generator field current at that level for the remaining duration of the corresponding threshold time. Since the AVR's setpoint requires a higher field current level than allowed by the OEL, the magnitude of the OEL's output increases to drive the AVR's setpoint lower to achieve the desired generator field current.

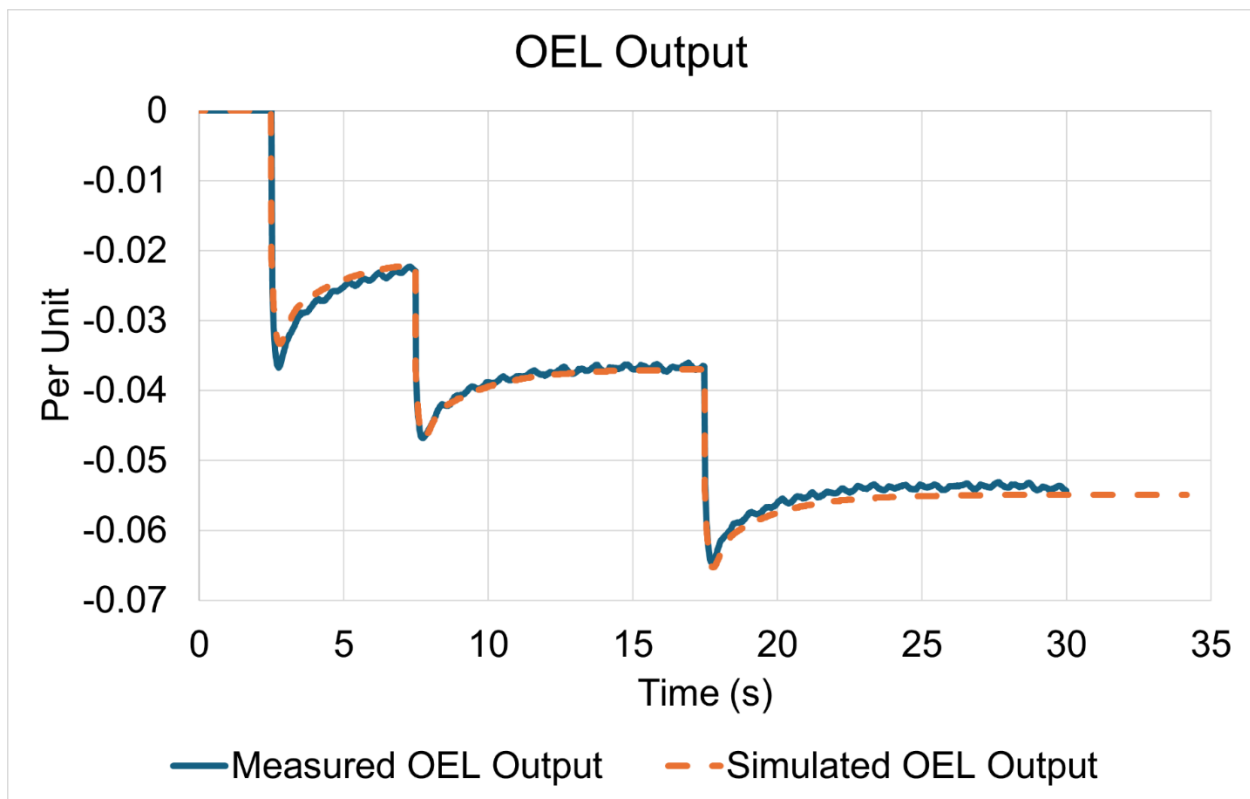


Figure 4. Depiction of the comparison between the measured and simulated OEL outputs when the BASOEL2 model's OEL was validated.

Software Test Cases

A comparison test was run to ensure that the BASOEL2 model had the same functionality between different simulation environments. The model was compared in PSSE and PowerWorld. Figure 5, Figure 6, and Figure 7 depict the results of the simulations, showing the simulated generator field current, OEL reference, and OEL output values, respectively. The BASOEL2 settings for the simulation were as follows:

- OELFlag = 1
- VHzFlag = 0
- OELIn = 1
- TRoel = 0
- Kp = 0.28
- Ki = 0,2
- OEL1 = 4.614
- OET1 = 0
- OEL2 = 3.86
- OET2 = 5
- OEL3 = 3.288
- OET3 = 2
- TRVHz = 0.01
- KVHz = 1.06
- VHzmin = 0

For the results depicted in Figure 5, the setpoint of the simulated exciter was increased to 1.10 pu at $t = \sim 4$ s. This caused the generator field current to exceed the OEL3 threshold and activate the OEL. However, the generator field current did not exceed the OEL1 or OEL2 thresholds before the time equal to the sum of OET1, OET2, and OET3 expired.

At $t = \sim 11$ s, the OEL acted to limit the generator field current to OEL3 (3.288 pu). The generator field current remained at OEL3 until the exciter setpoint dropped to 1.06 pu at $t = \sim 20$ s. At this point, the generator field current dropped below 99.9% of OEL3 and the OEL began to reset.

At $t = \sim 26$ s, the exciter setpoint increased back up to 1.10 pu. Since the OEL had not fully reset by that point, the generator field current was still limited to OEL3 until the exciter setpoint was dropped back to 1.06 at $t = \sim 36$ s.

From $t = \sim 36$ s to $t = \sim 80$ s, the OEL began resetting while it was deactivated. When the exciter setpoint was stepped back to 1.10 pu at $t = \sim 80$ s, the generator field current was allowed to exist above the continuous limit for 7 s before being limited back down to OEL3. This shows that the OEL was able to fully reset between $t = \sim 36$ s and $t = \sim 80$ s.

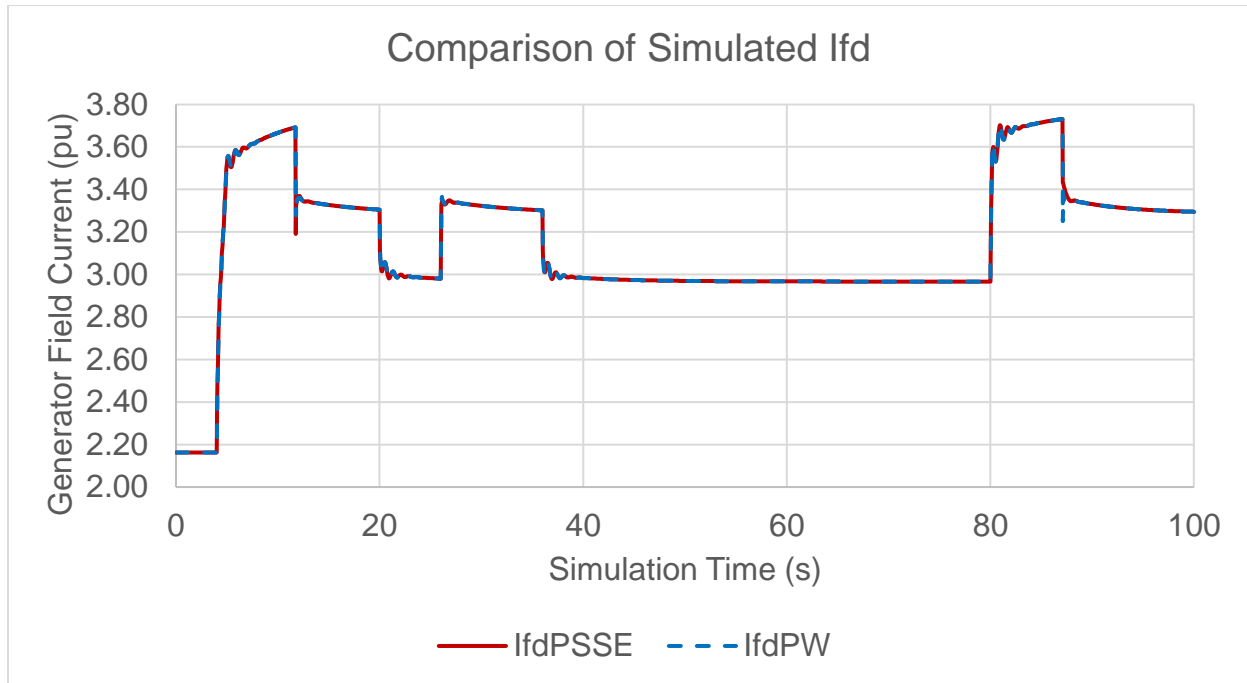


Figure 5. Depiction of the simulated generator field current from PSSE and PowerWorld when the BASOEL2 model was implemented in both simulation environments.

For the results depicted in Figure 6, the OEL reference value remained at OEL1 until $t = \sim 11$ s, because the OEL reference value does not change from OEL1 until the corresponding OELActive variable is set to TRUE. Once OEL3Active was set to TRUE at $t = \sim 11$ s, the OEL reference value was set to OEL3. This caused the OEL to begin limiting the generator's field current down to OEL3. At $t = 36.96$ s, the OEL3Timer had fully counted back down and the OEL was fully reset. Since the OEL was fully reset, the OEL reference value returned to OEL1 since OEL3Active was now FALSE. When the exciter setpoint was stepped back up again at $t = \sim 80$ s, the value of the OEL reference behaved similarly to how it did at the start of the simulation. The OEL reference did not change until $t = \sim 87$ s, where the OEL3Active variable was set to TRUE and the OEL limited the generator's field current to OEL3.

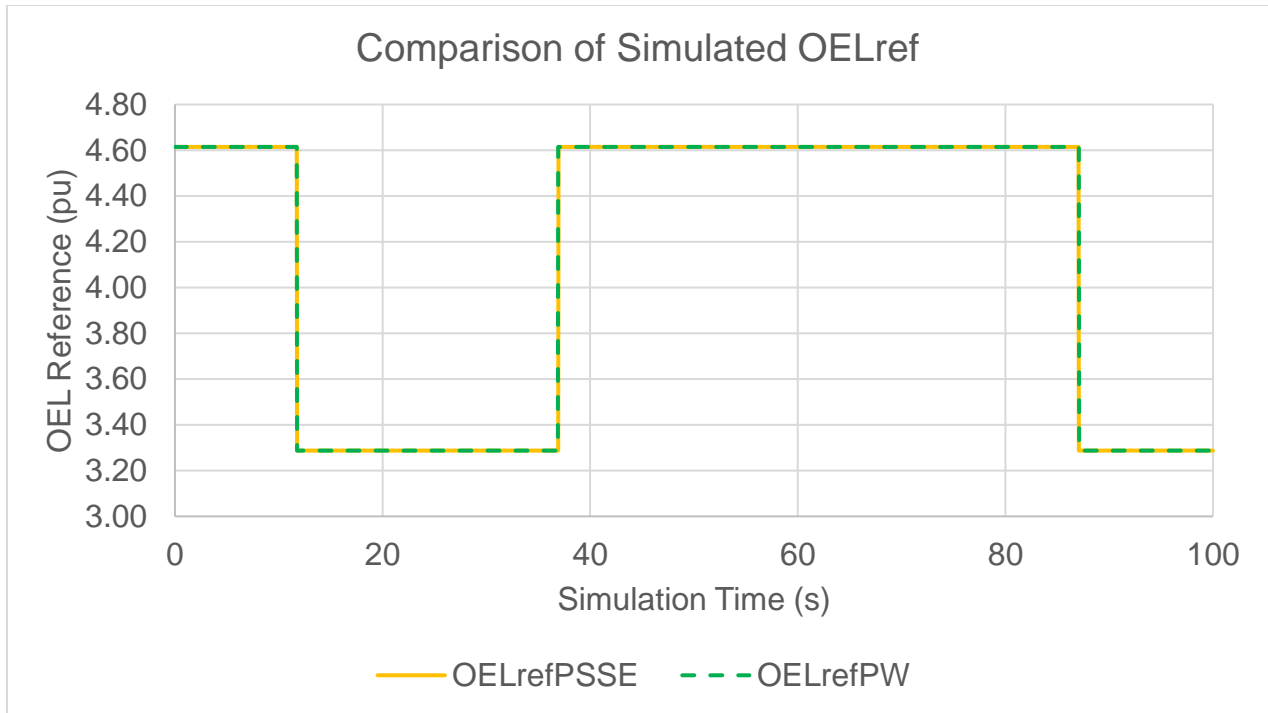


Figure 6. Depiction of the simulated OEL reference from PSSE and PowerWorld when the BASOEL2 model was implemented in both simulation environments.

For the results depicted in Figure 7, the output of the OEL became non-zero when the OEL took control action to reduce the generator's field current to the desired level. Since the generator's field current did not need to be limited until OEL3Active became TRUE at $t = \sim 11$ s, the output of the OEL remained at 0 from $t = 0$ s through $t = \sim 11$ s. Once OEL3Active became TRUE at $t = \sim 11$ s, the proportional and integral terms of the OEL's PI controller acted upon the difference between the desired generator field current and the OEL's reference. The resulting PI controller output was subtracted from the regulator setpoint to drive the generator's field current to OEL3.

The OEL's output remained fairly constant from $t = \sim 11$ s to $t = \sim 20$ s until the exciter's setpoint was changed at $t = \sim 20$ s and the generator's field current dropped below 99.9% of OEL3. Since the OEL was inactive from $t = \sim 20$ s through $t = \sim 26$ s, the OEL's output was 0 during that time.

When the exciter's setpoint was changed at $t = \sim 26$ s, the OEL's output returned to the same value it had from $t = \sim 11$ s through $t = \sim 20$ s because the OEL was still working to limit the generator's field current to OEL3. Once the exciter's setpoint decreased at $t = \sim 36$ s and the generator's field current dropped below 99.9% of OEL3, the OEL deactivated again and reduced its output to 0. The OEL's output remained at 0 until $t = \sim 87$ s when the OEL acted again to limit the generator's field current to OEL3.

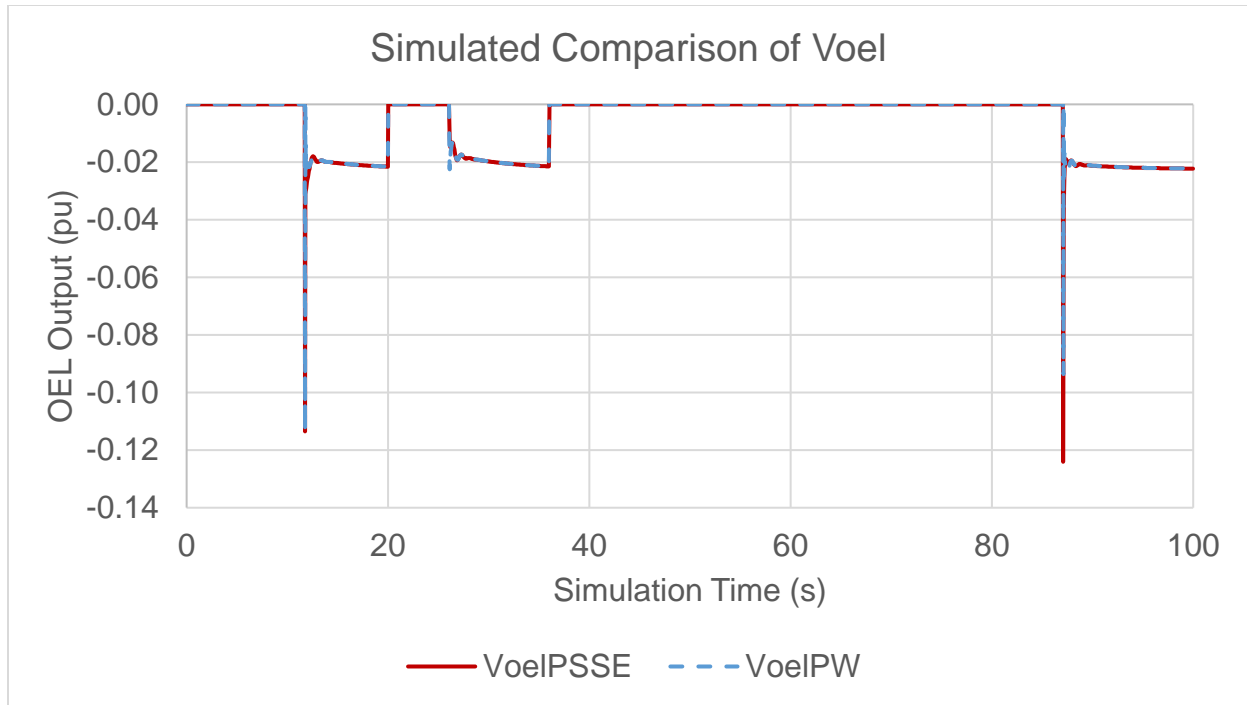


Figure 7. Depiction of the simulated OEL output from PSSE and PowerWorld when the BASOEL2 model was implemented in both simulation environments.

References

- [1] "Type OEL—Overexcitation limiters," in *IEEE Std 421.5-2016 - IEEE Recommended Practice for Excitation System Models for Power System Stability Studies*, 26 Aug. 2016, doi: 10.1109/IEEESTD.2016.7553421.
- [2] Power World. "Over Excitation Limiter Model: BASOEL2." PowerWorld.com. Accessed: Dec. 12, 2025. [Online.] Available: https://www.powerworld.com/WebHelp/Content/TransientModels_HTML/Over%20Excitation%20Limiter%20BASOEL2.htm

Appendix: Pseudocode Related to the Operation of the BASOEL2 Model

The following sections provide pseudocode of how the BASOEL2 model is implemented. The information has been taken with permission from [2] for the purposes of providing additional background information on how the BASOEL2 model functions.

Following are Initialized at start of simulation

```
OEL1Active = OEL2Active = OEL3Active = FALSE
OEL1Limit  = OEL2Limit  = OEL3Limit  = FALSE
OEL1Timer  = OEL2Timer  = OEL3Timer  = 0 // timer is used to accumulate time either to set or reset OELRef
```

Update Each Time Step

```
// This local procedure is called three times (once for each timer)
LocalProcedureForTimer( Inputs: theOEL, theOET, IncrementTime; Outputs: theOELLimit, theOELActive, theOELTimer)
// use 0.999 multiplier to make it act above the limit until it drops 0.1% below the limit
// This helps prevent a numerical oscillation if the system is coming to a steady state near theOEL threshold
If theOELLimit then
    theOELLimit = (State1 > theOEL*0.999)
Else
    theOELLimit = (State1 > theOEL)
EndIf
If ( theOELLimit) and (not theOELActive) then
    theOELTimer = theOELTimer + IncrementTime // count up
ElseIf (not theOELLimit) and ( theOELActive) then
    theOELTimer = theOELTimer - IncrementTime // count down
EndIf
If OELTimer <= 0 Then
    // When timer drops below 0 then it will reset the respective Active flag
    theOELTimer = 0
    theOELActive = FALSE // reset the Timer
ElseIf OEL1Timer >= (theOET) then
    // When timer goes above the theOET time for the respective timer then the Active Flag is set
    theOELTimer = theOET
    theOELActive = TRUE // Timer has expired so OELRef has an output and VOELout may be non-zero
EndIf
```

IncrementTime = time difference between now and the previous time step

```
LocalProcedureForTimer ( OEL1, OET1 , IncrementTime, OEL1Limit, OEL1Active, OEL1Timer )
LocalProcedureForTimer ( OEL2, OET1 + OET2 , IncrementTime, OEL2Limit, OEL2Active, OEL2Timer )
LocalProcedureForTimer ( OEL3, OET1 + OET2 + OET3, IncrementTime, OEL3Limit, OEL3Active, OEL3Timer )
```

Calculation of VOELout

```
If (OELFlag <> 0) AND
  ( (OEL1Active AND OEL1Limit) // VOELout is only used if at least
    OR (OEL2Active AND OEL2Limit) // one of the 3 timers is
    OR (OEL3Active AND OEL3Limit) // BOTH active AND the OELsens is above the OEL limit threshold
  )
Then Calculate VOELout from the block diagram
Else VOELout = 0
```

Calculation of OELRef

```
OELRef = OEL1
If OEL2Active AND (OELRef > OEL2) then OELRef = OEL2
If OEL3Active AND (OELRef > OEL3) then OELRef = OEL3
```