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SUMMING POINT OVEREXCITATION LIMITER MODEL

WECC MODELING AND VALIDATION SUBCOMMITTEE MEETING

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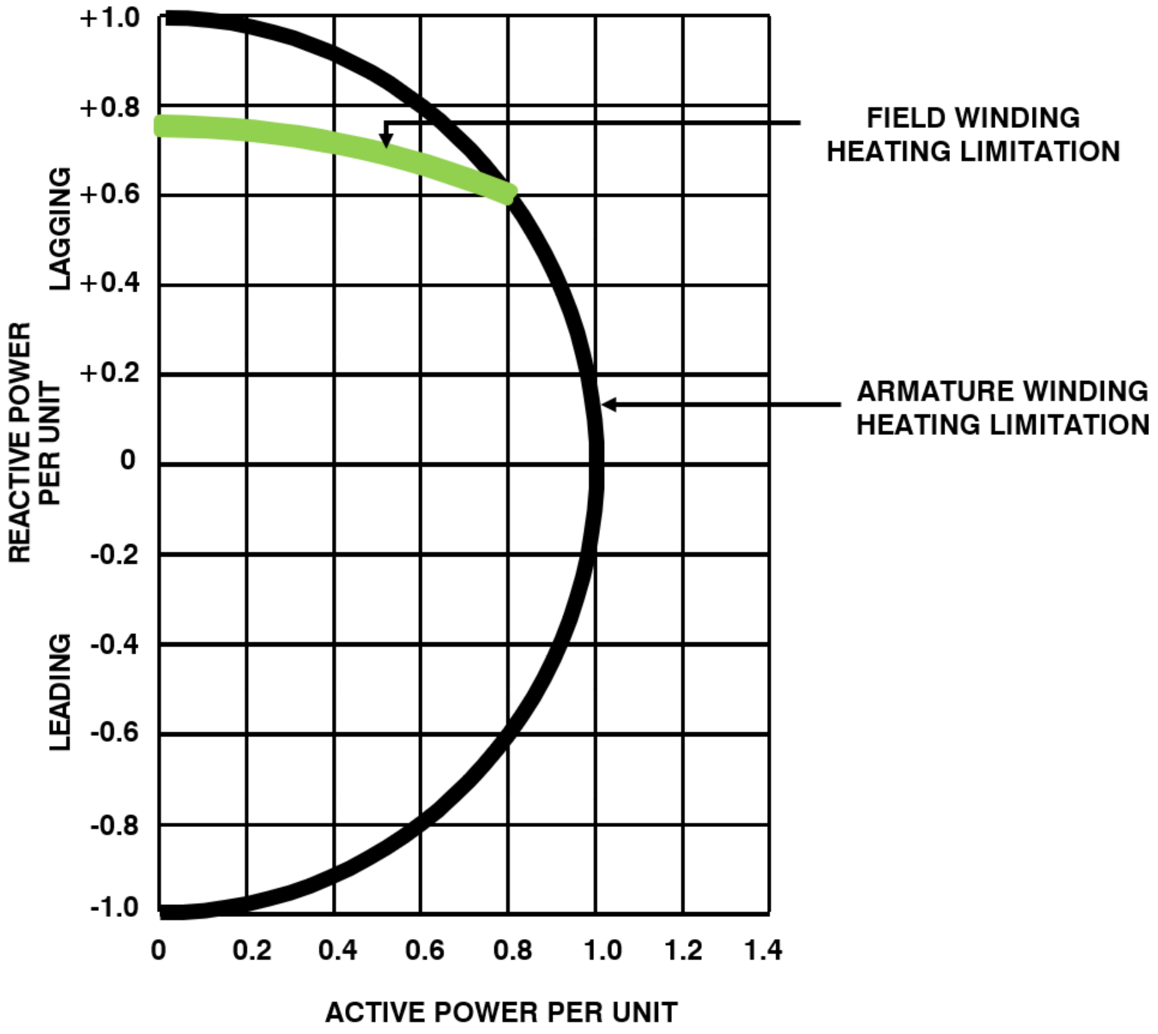
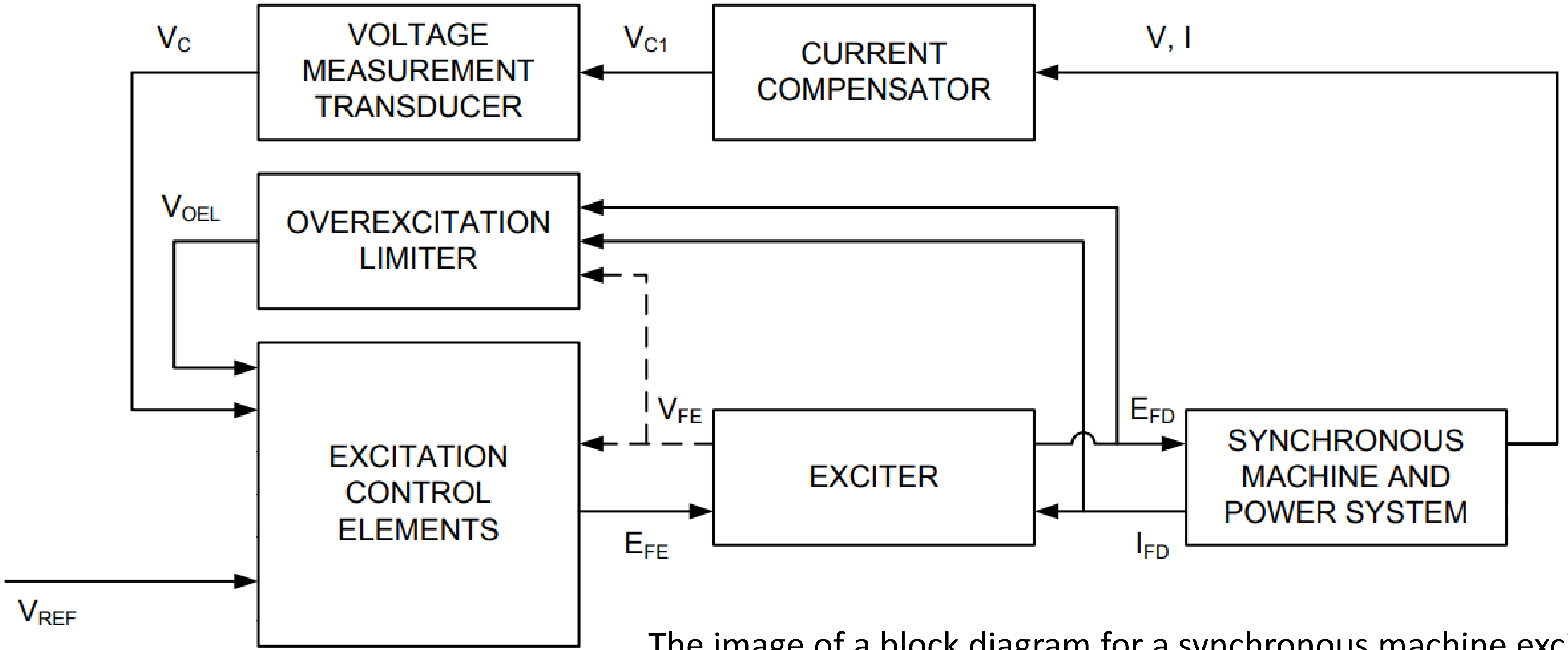
Purpose of the Overexcitation Limiter (OEL)

- The purpose of the OEL is to prevent the connected field winding from being damaged due to extended operation in the overexcited region of the machine's capability curve.
- The limiting action provided by the OEL allows for a controlled amount of field forcing to be used to help stabilize the connected power system.
- The OEL will also protect the excitation system.

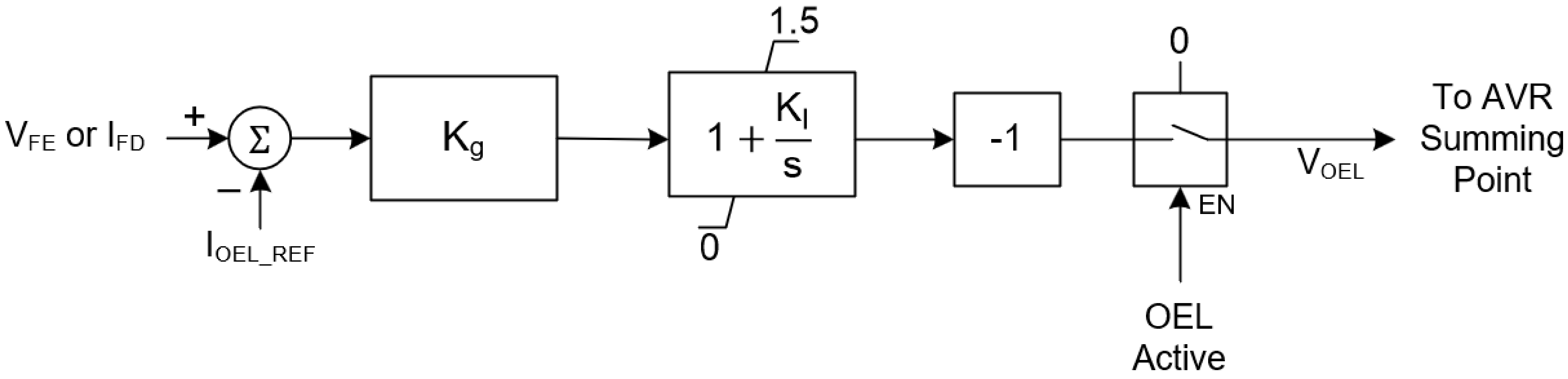


Model Scope and Excitation System Location



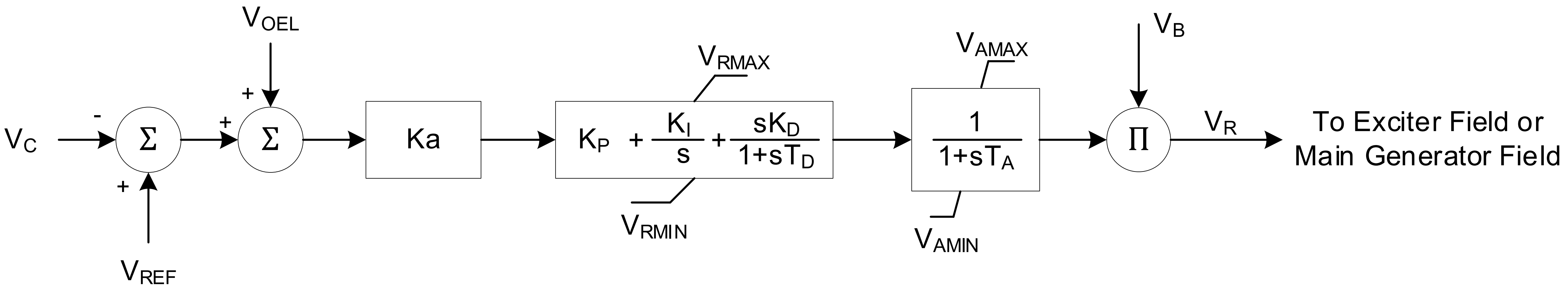
The image of a block diagram for a synchronous machine excitation control system was taken from [1] and edited for this presentation.

Model Scope and Excitation System Location (cont.)



Block Diagram of the Basler Summing Point OEL

Model Scope and Excitation System Location (cont.)



Block Diagram of the Simplified Basler AVR

OEL Signal Definitions and Ranges

- **V_{FE} or I_{FD}**
  - Per-unit measurement of the exciter field current or main field current, respectively.
- **I_{OEL_REF}**
  - Per-unit value of the reference field current used by the OEL algorithm.
- **K_g**
  - Loop gain of the OEL algorithm's proportional-integral (PI) controller.
- **K_I**
  - Integral gain of the OEL algorithm's PI controller.
- **V_{OEL}**
  - Per-unit output of the OEL.

OEL Signal Definitions and Ranges (cont.)

- **V_{FE} or I_{FD}**
  - Range: 0 – 20 pu
  - Practical range is limited by Basler product specifications.
  - For control algorithm use, the per-unit base for V_{FE} and I_{FD} is the rated no-load field current of the machine connected to the Basler device, as per Annex B of IEEE Std 421.5™-2016 [1].
- **I_{OEL_REF}**
  - Range: User-Defined Low Level Threshold – User-Defined High Level Threshold
- **K_g**
  - Range: 0 – 1,000 in increments of 0.001
- **K_I**
  - Range: 0 – 1,000 in increments of 0.001
- **V_{OEL}**
  - Range: -1.5 – 0 pu

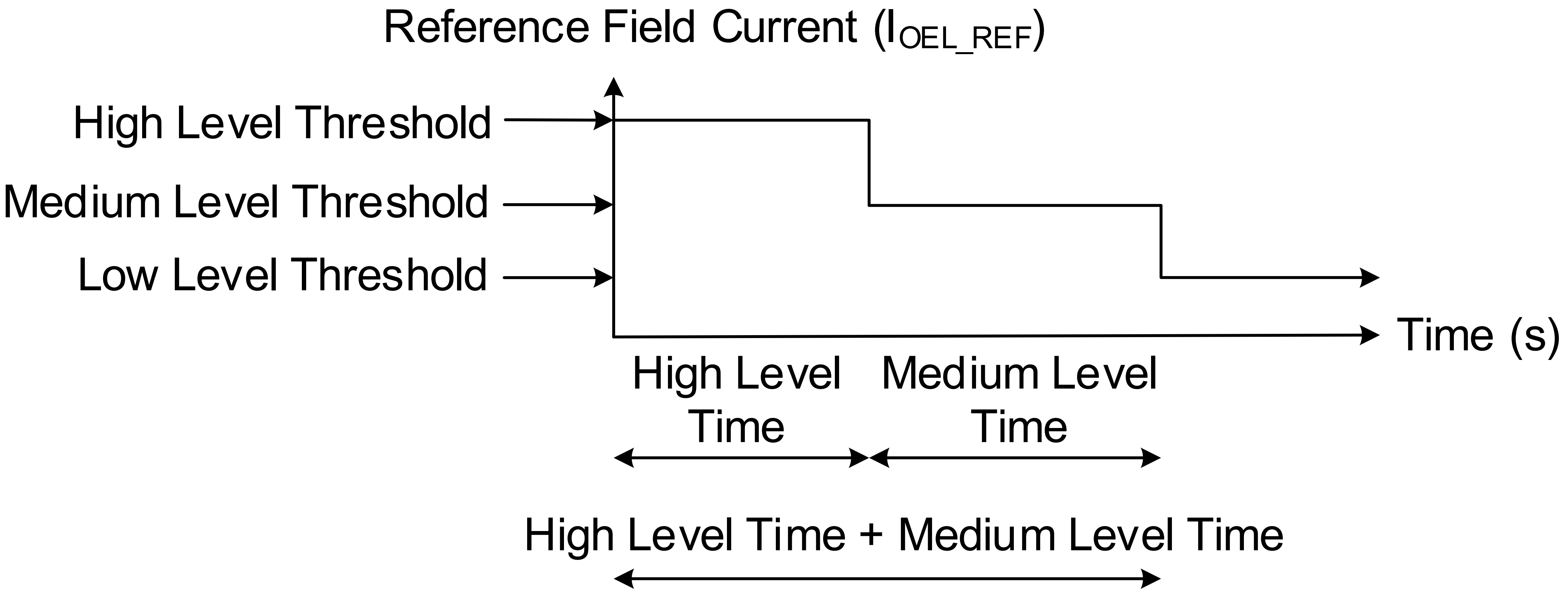
OEL Signal Definitions and Ranges (cont.)

- **Offline OEL Settings:**
  - **High Level Threshold** – Maximum field current level that is allowed before the OEL algorithm will immediately act to limit the field current.
  - **High Level Time** – Amount of time the measured field current is allowed to be above the Low Level Threshold.
  - **Low Level Threshold** – Minimum field current level required before the OEL algorithm will start execution.
    - The value of the Low Level Threshold should be chosen to be within the continuous operating range of the machine as the OEL algorithm will hold the field current at this level indefinitely once the other threshold times expire.

OEL Signal Definitions and Ranges (cont.)

- **Online OEL Settings:**
  - **High Level Threshold** – Same definition as the Offline Settings.
  - **High Level Time** - Amount of time the measured field current is allowed to be above the Medium Level Threshold.
  - **Medium Level Threshold** – Maximum field current level that is allowed after the High Level Time has elapsed.
  - **Medium Level Time** – Amount of time the measured field current is allowed to be above the Low Level Threshold after the High Level Time has elapsed.
    - The Medium Level Time does not begin to be counted until after the High Level Time has elapsed.
  - **Low Level Threshold** – Same definition as the Offline Settings, except with Medium Level Time instead of High Level Time.

OEL Signal Definitions and Ranges (cont.)



OEL Signal Definitions and Ranges (cont.)

- **OEL Threshold and Timings:**
  - **High Level Threshold** – Range: 0 – 8 pu
  - **High Level Time** – Range: 0 – 240 seconds
  - **Medium Level Threshold** – Range: 0 – 8 pu
  - **Medium Level Time** – Range: 0 – 240 seconds
  - **Low Level Threshold** – Range: 0 – 8 pu

Initialization Behavior

- **Initializations:**
  - When the OEL is enabled, the user-defined values for the thresholds, times, and gains are assigned to their corresponding variables in the OEL.
  - The integrator value of the OEL's PI controller is initialized to 0.
  - The reference field current I_{OEL_REF} is initialized to the High Level Threshold value.
  - The OEL will be active if the measured field current exceeds the user-defined Low Level Threshold.
  - Once the measured field current exceeds the user-defined Low Level Threshold, the OEL will take action to limit field current if any of the following are true:
    - The field current exceeds the High Level Threshold.
    - The field current exceeds the Medium Level Threshold after the High Level Time expires.
    - The field current exceeds 98% of the Low Level Threshold after the Medium Level Time expires.

Functional Description of OEL Logic

- **Threshold Behavior:**
  - If the High Level Threshold is exceeded, the OEL will limit the field current back down to the High Level Threshold.
  - After a threshold time has elapsed, the OEL will act to limit the field current down to the next lower threshold.
  - The OEL will hold the field current at the Low Level Threshold indefinitely until an event or control action outside of the OEL causes the field current to drop below 98% of the Low Level Threshold.

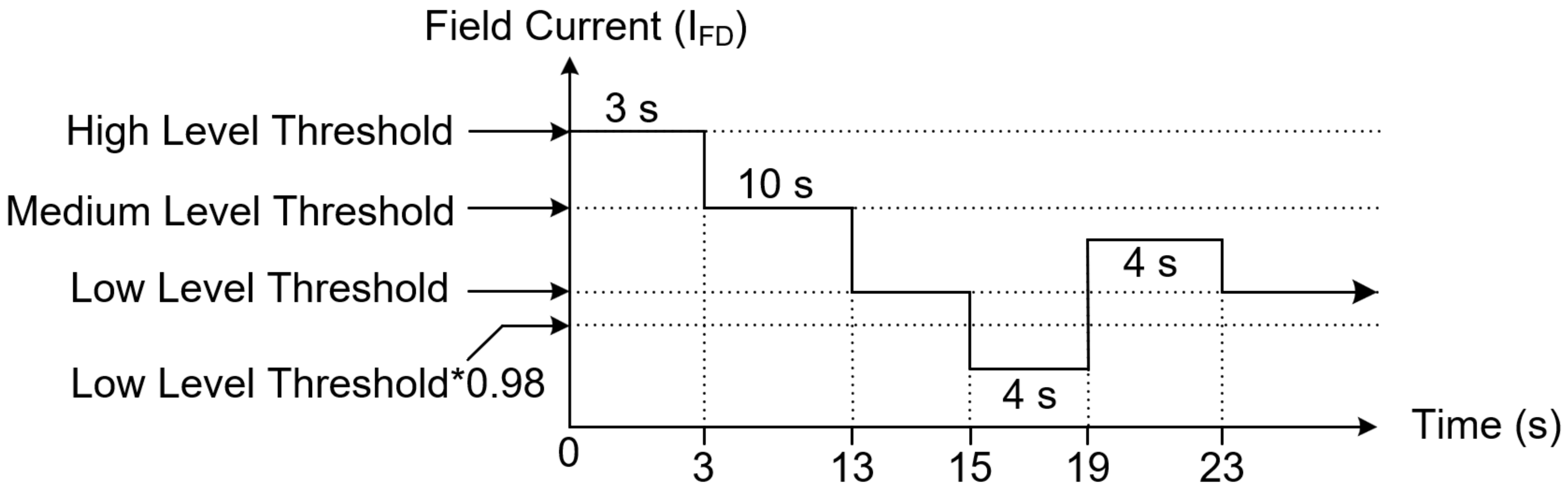
- **Integrator Behavior:**
  - When the OEL begins to reset, the value of the integrator will begin to decay to zero with a time constant of 2 seconds.

Functional Description of OEL Logic (cont.)

- **Reset Time:**
  - The OEL reset time linearly depends on the amount of time spent above the Low Level Threshold.

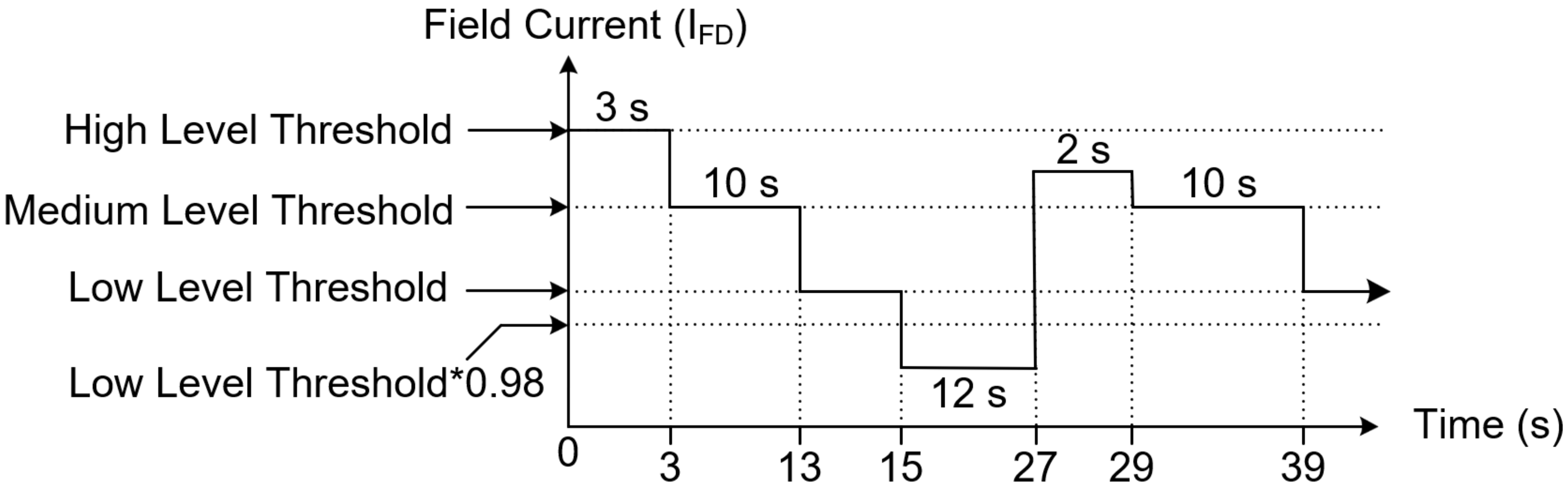
Functional Description of OEL Logic (cont.)

- Example: High Level Time = 3s, Medium Level Time = 10 s



Functional Description of OEL Logic (cont.)

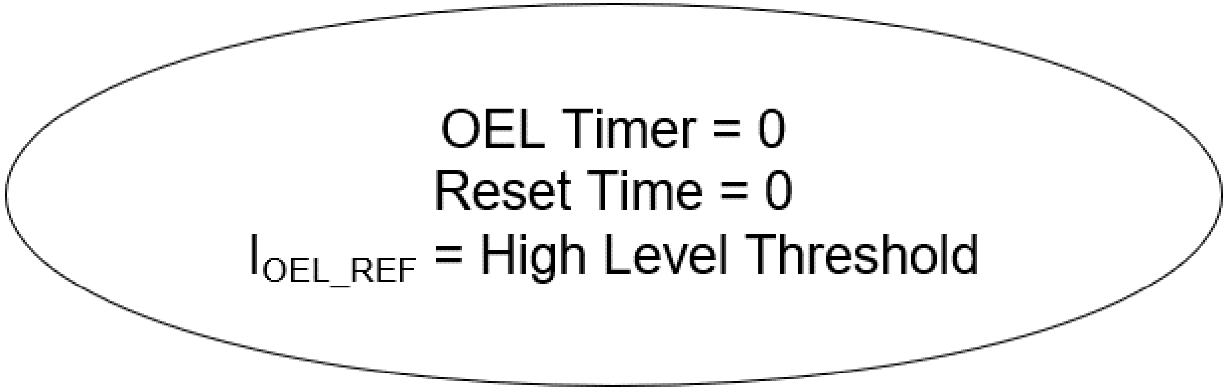
- **Example: High Level Time = 3s, Medium Level Time = 10 s**



Online OEL Algorithm States – State 0

- **Transition Requirements:**
  - State 0: I_{FD} < Low Level Threshold
  - State 1: I_{FD} ≥ Low Level Threshold

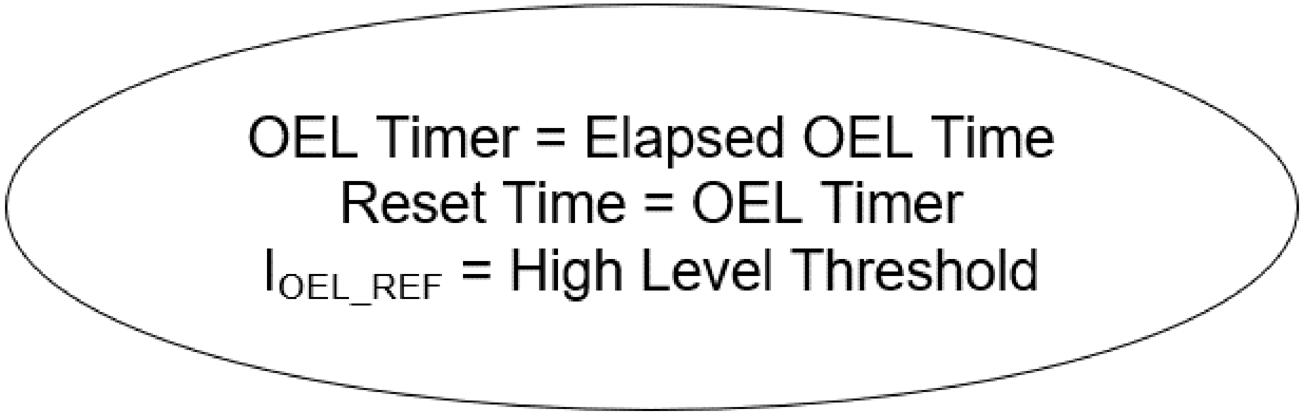
State 0: Inactive



Online OEL Algorithm States – State 1

- **Transition Requirements:**
  - State 1: OEL Timer < High Level Time
  - State 2: OEL Timer ≥ High Level Time
  - State 4: I_{FD} < 0.98 * Low Level Threshold

State 1: Limiting to High Level



Online OEL Algorithm States – State 2

- **Transition Requirements:**
  - State 2: OEL Timer < High + Medium Level Times
  - State 3: OEL Timer ≥ High + Medium Level Times
  - State 4: I_{FD} < 0.98 * Low Level Threshold

State 2: Limiting to Medium Level

OEL Timer = Elapsed OEL Time
Reset Time = OEL Timer
I_{OEL_REF} = Medium Level Threshold

Online OEL Algorithm States – State 3

- **Transition Requirements:**
  - State 3: $I_{FD} \geq 0.98$ * Low Level Threshold
  - State 4: $I_{FD} < 0.98$ * Low Level Threshold

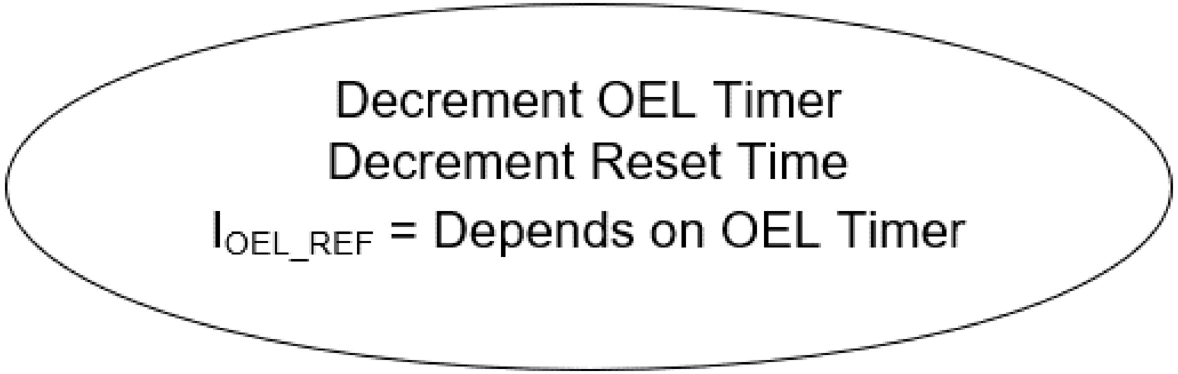
State 3: Limiting to Low Level

OEL Timer = High + Medium Level Times
Reset Time = High + Medium Level Times
I_{OEL_REF} = Low Level Threshold

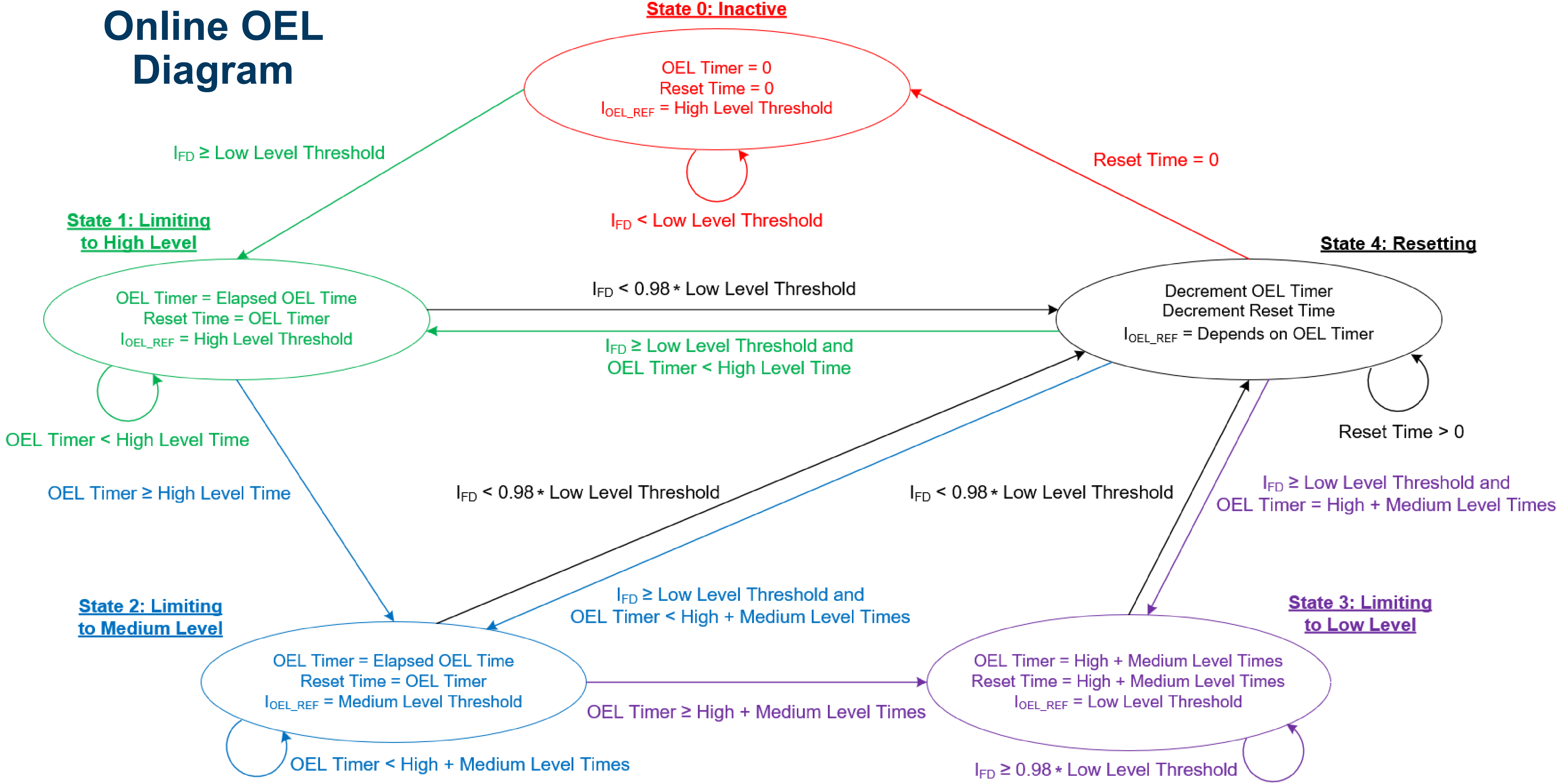
Online OEL Algorithm States – State 4

- **Transition Requirements:**
  - State 0: Reset Time = 0
  - State 1: I_{FD} ≥ Low Level Threshold
    and OEL Timer < High Level Time
  - State 2: I_{FD} ≥ Low Level Threshold
    and OEL Timer < High + Medium Level Times
  - State 3: I_{FD} ≥ Low Level Threshold
    and OEL Timer = High + Medium Level Times
  - State 4: Reset Time > 0

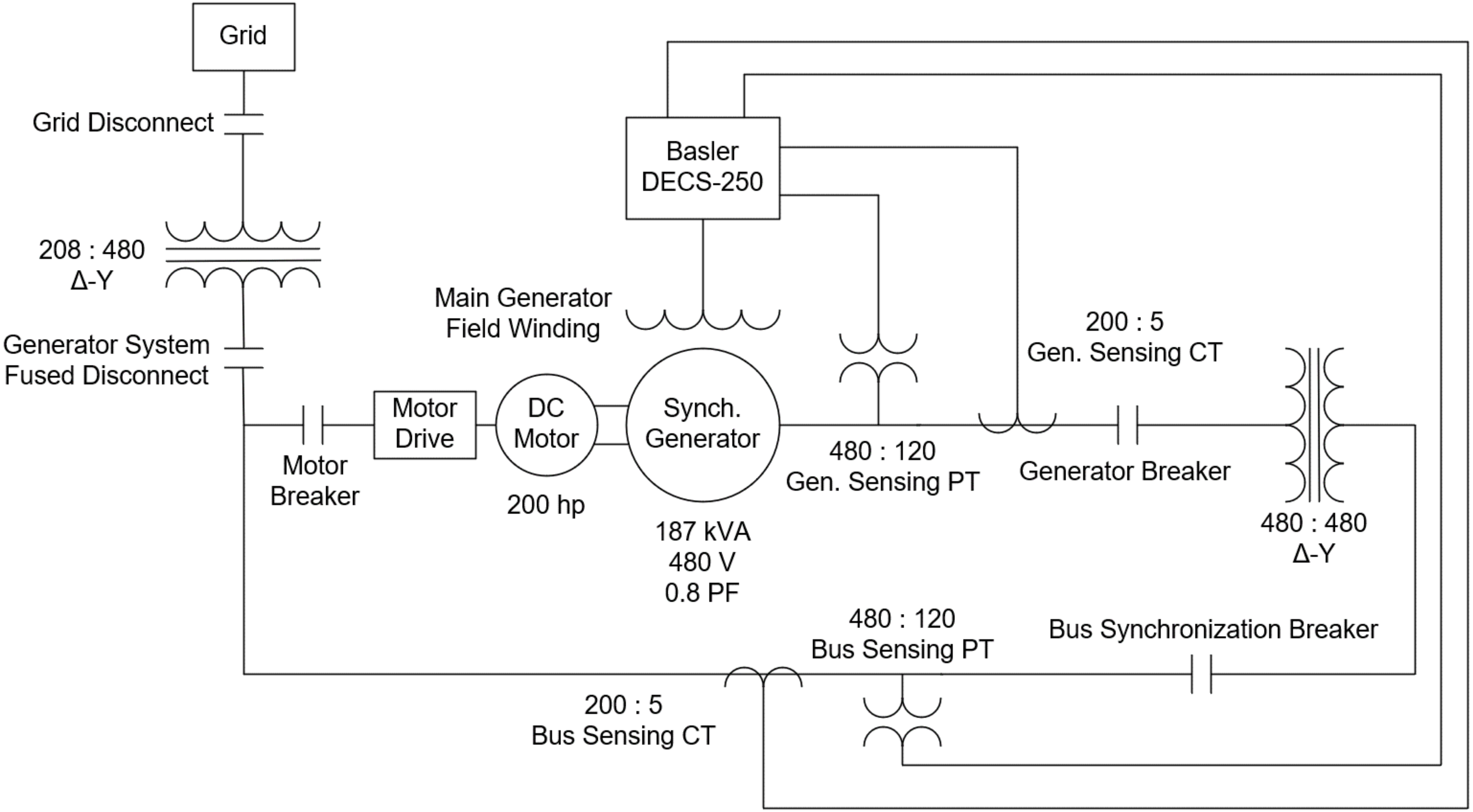
State 4: Resetting



Online OEL Diagram

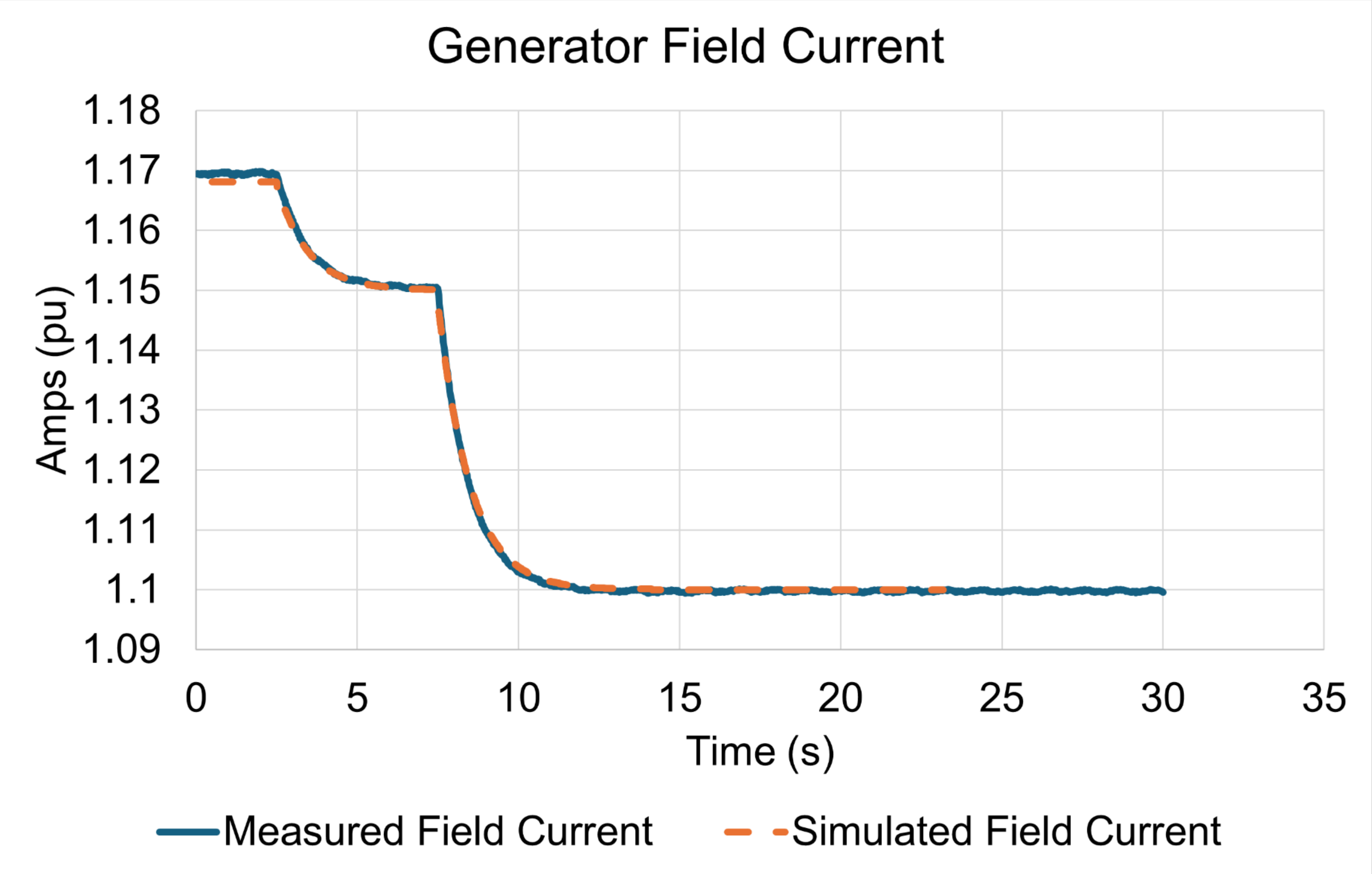


Model Validation Tests in the Time Domain – Test Setup



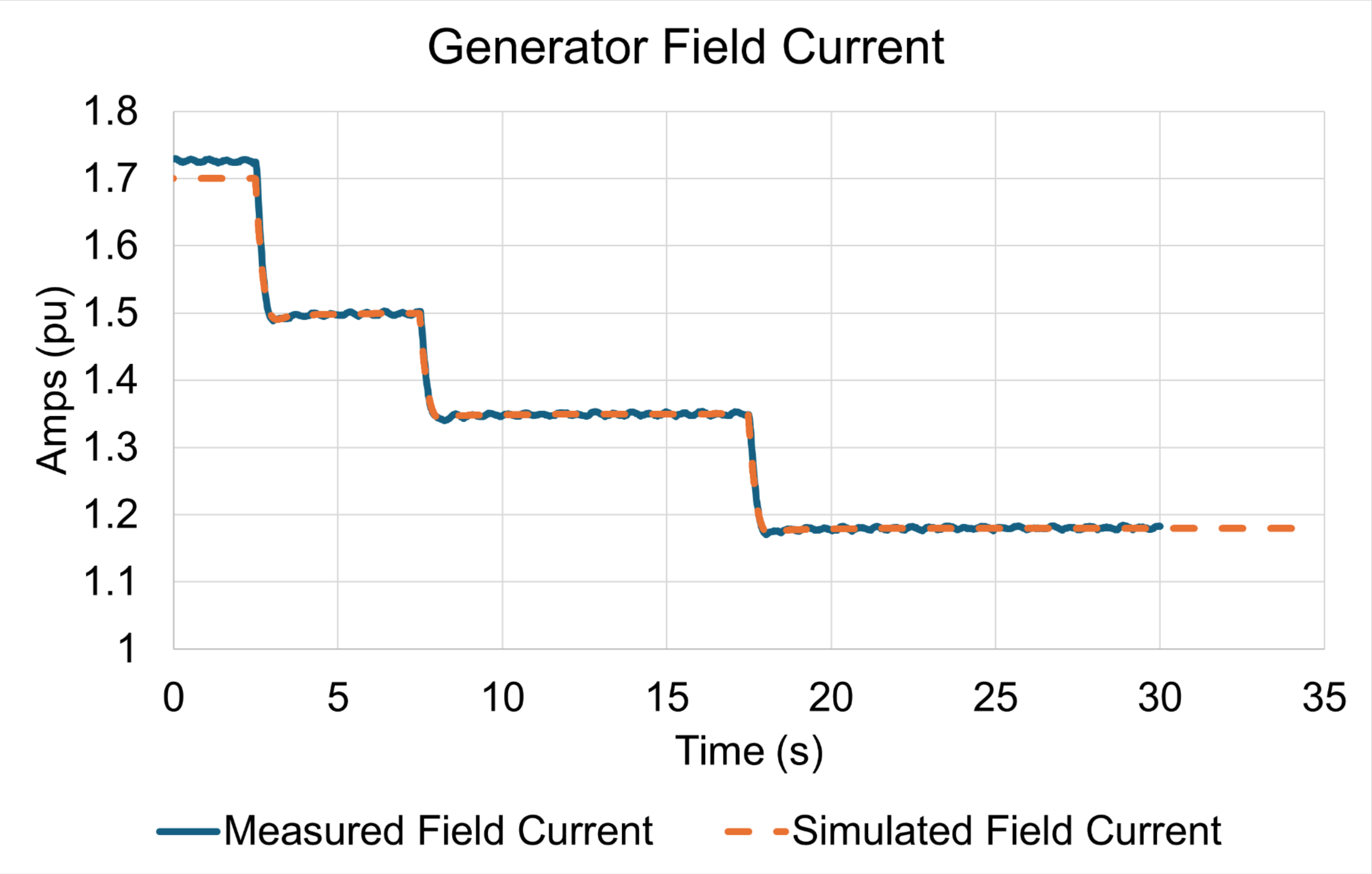
Model Validation Tests in the Time Domain – Offline Testing

- **OEL manually enabled at 2.5 s.**
- **The generator was offline.**
- **The generator field current was above the High Level Threshold before the OEL was manually enabled.**
- **High Level Threshold: 1.15 pu**
- **Low Level Threshold: 1.1 pu**
- **High Level Time: 5 s**



Model Validation Tests in the Time Domain – Online Testing

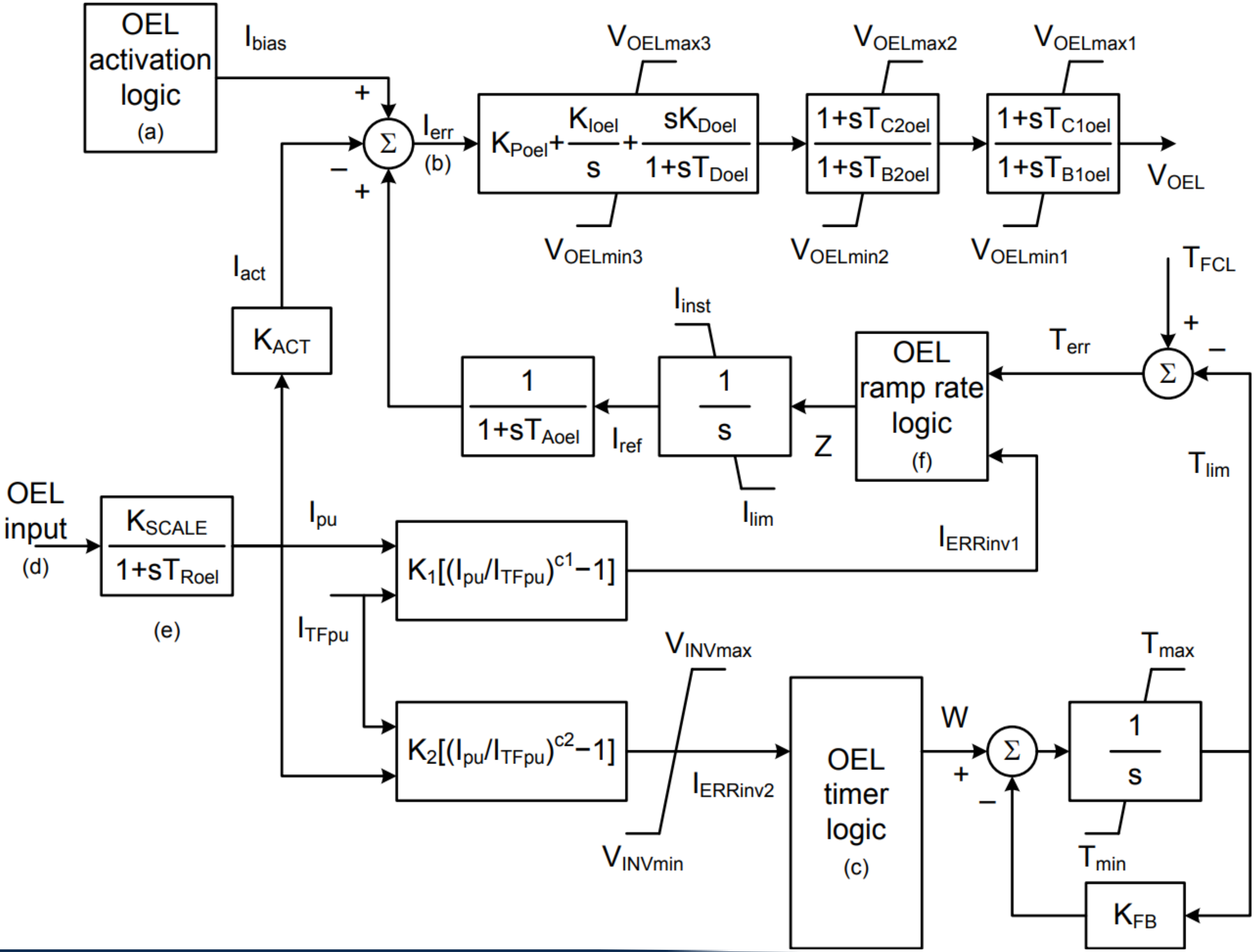
- OEL manually enabled at 2.5 s.
- The generator was online.
- The generator field current was above the High Level Threshold before the OEL was manually enabled.
- High Level Threshold: 1.5 pu
- Medium Level Threshold: 1.35 pu
- Low Level Threshold: 1.18 pu
- High Level Time: 5 s
- Medium Level Time: 10 s



Relationship with IEEE Std 421.5™-2016 OEL2C Model

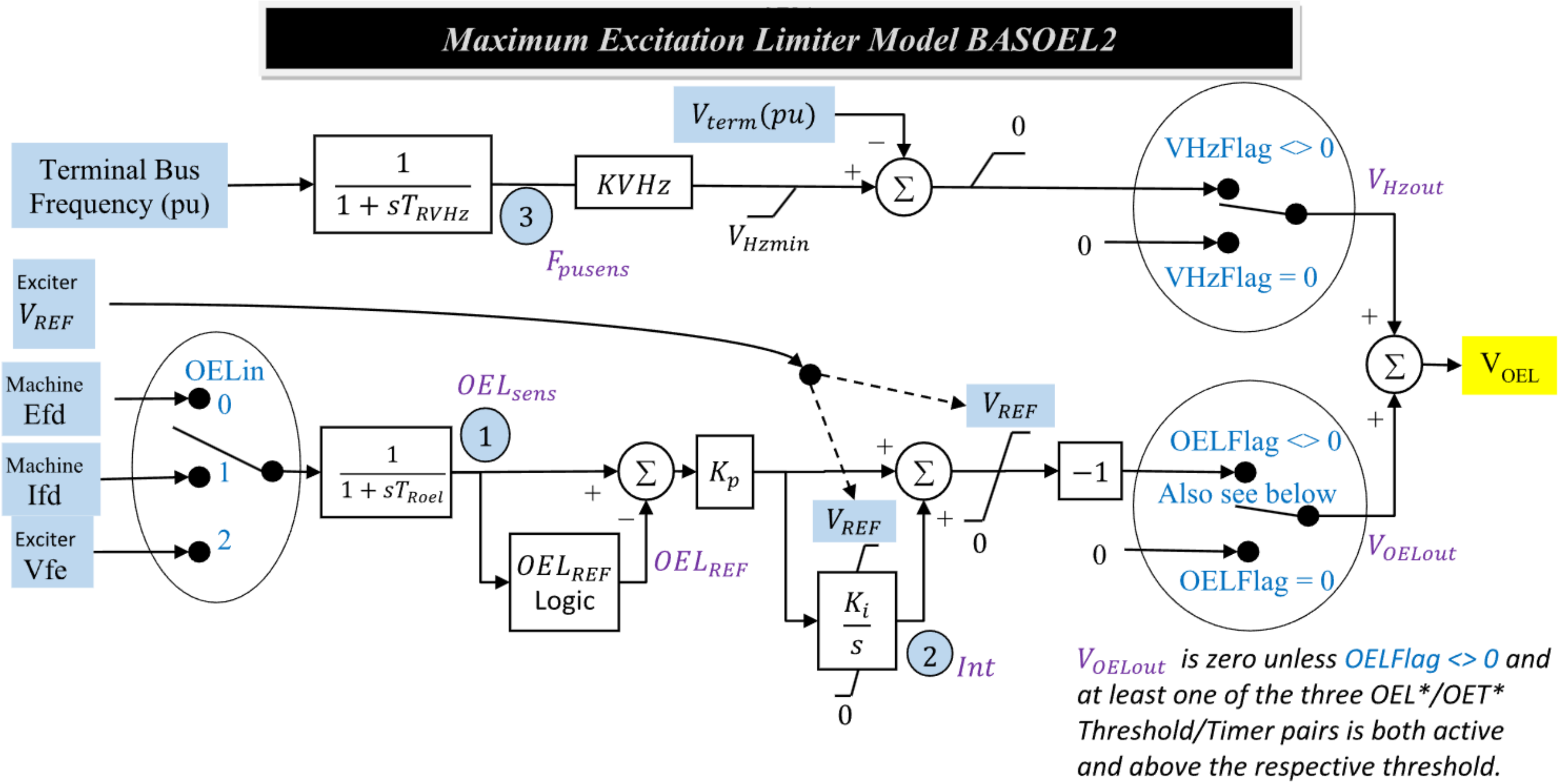
- A reduced form of the Basler summing point OEL can be approximated by the IEEE Std 421.5™-2016 OEL2C model.
- The IEEE OEL2C model cannot replicate the three threshold levels of the Basler OEL or the specific reset characteristics.

The image of the IEEE OEL2C model was taken from [1].



Relationship with BASOEL2 Model

- Added in Version 24 of PowerWorld on Aug. 5, 2025.
- Supported by PSS®E from Siemens.
- Includes a Volts-per-Hertz limiter in addition to the OEL.



The image of the BASOEL2 model was taken from [2] and edited for this presentation.

References

- [1] "IEEE Recommended Practice for Excitation System Models for Power System Stability Studies," in *IEEE Std 421.5-2016*, 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?TocPath=Transient%20Stability%20Add-On%20(TS)%7CTransient%20Models%7CGenerator%7COther%7COver%20Excitation%20Limiter%7C_____1

EXTRA INFORMATION

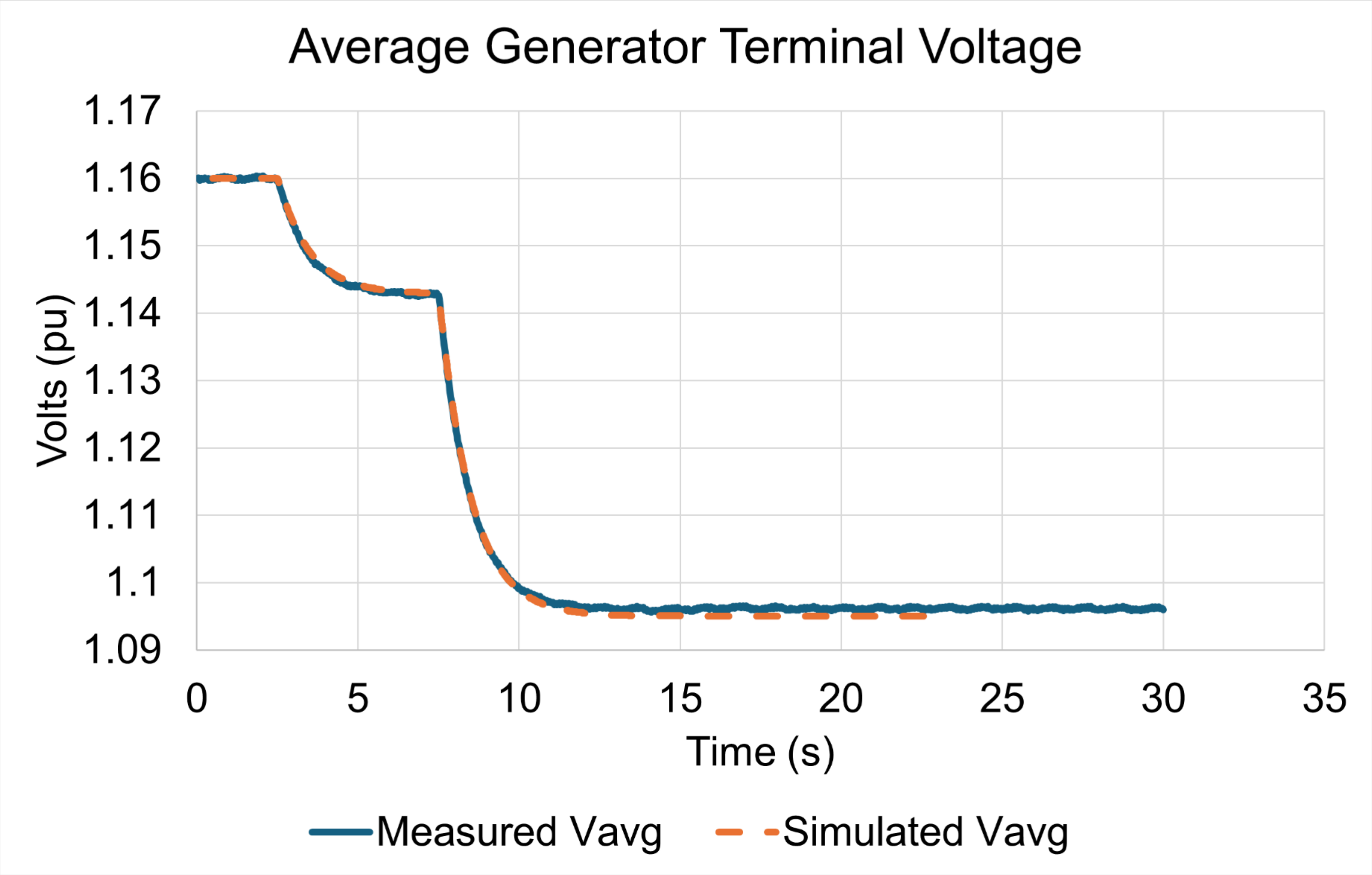
THE FOLLOWING INFORMATION WAS NOT NECESSARILY INTENDED TO BE COVERED DURING THE PRESENTATION BUT HAS BEEN INCLUDED IN TO PROVIDE MORE INFORMATION

Test Generator Information

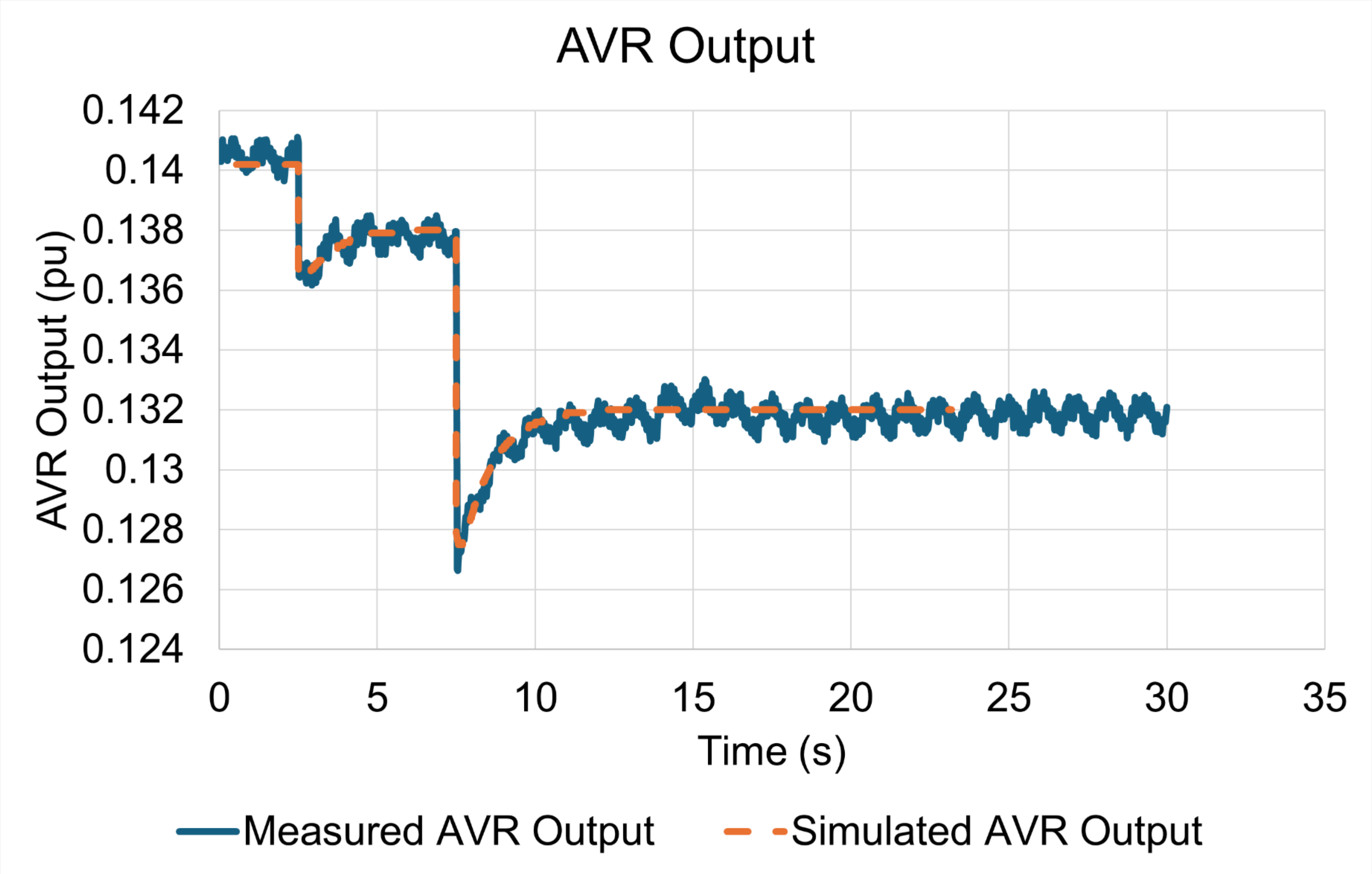
- Rated Terminal Voltage: 480 Vac
- Rated Terminal Current: 225 Aac
- Rated Apparent Power (kVA): 187 kVA
- Rated Real Power (kW): 150 kW
- Rated Power Factor: 0.8
- RPM: 1800
- Rotor Design: Salient Pole with 4 poles
- Nominal Frequency: 60 Hz
- Rated No-Load Field Current: 7.4 Adc
- Rated Full-Load Field Current: 24.5 Adc
- Rated No-Load Field Voltage: 17 Vdc
- Rated Full-Load Field Voltage: 58 Vdc

- T’do = 3.3 s
- T”do = 1.4 s
- Statically Excited
- Exhibits minimal saturation
- Manufacturer: Rockwell Automation / Kato Engineering

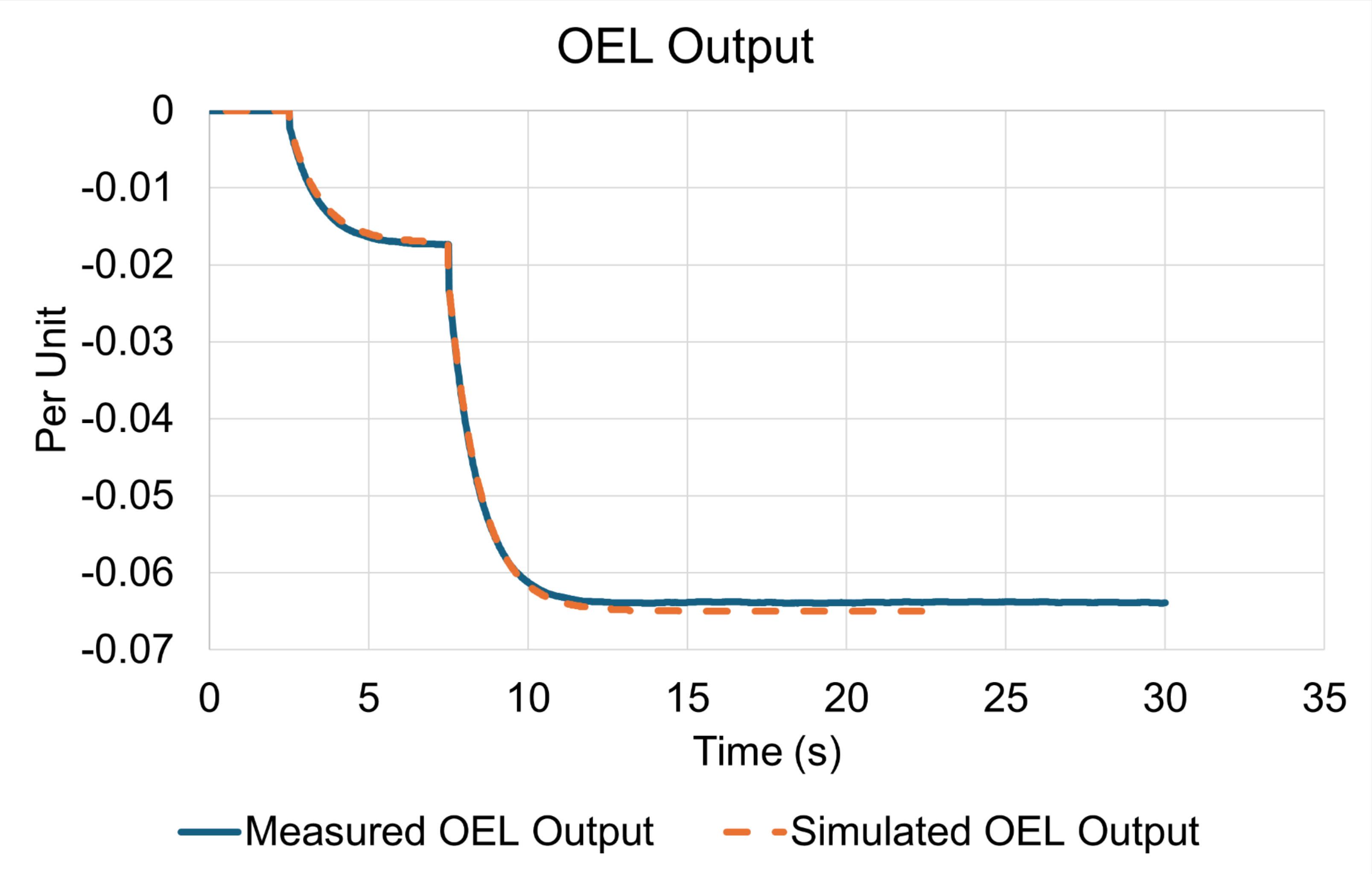
Additional Offline Testing Results



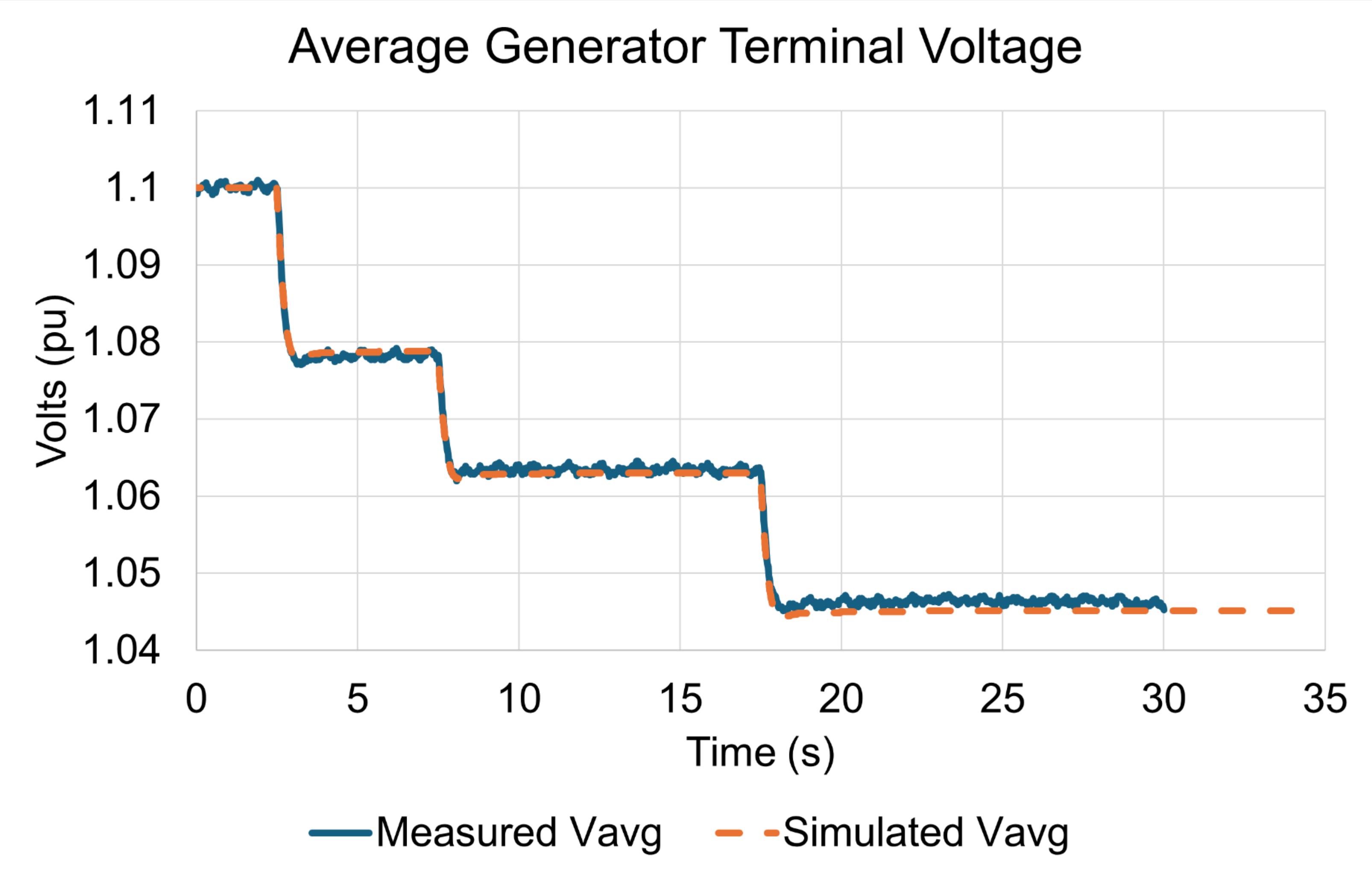
Additional Offline Testing Results – (cont.)



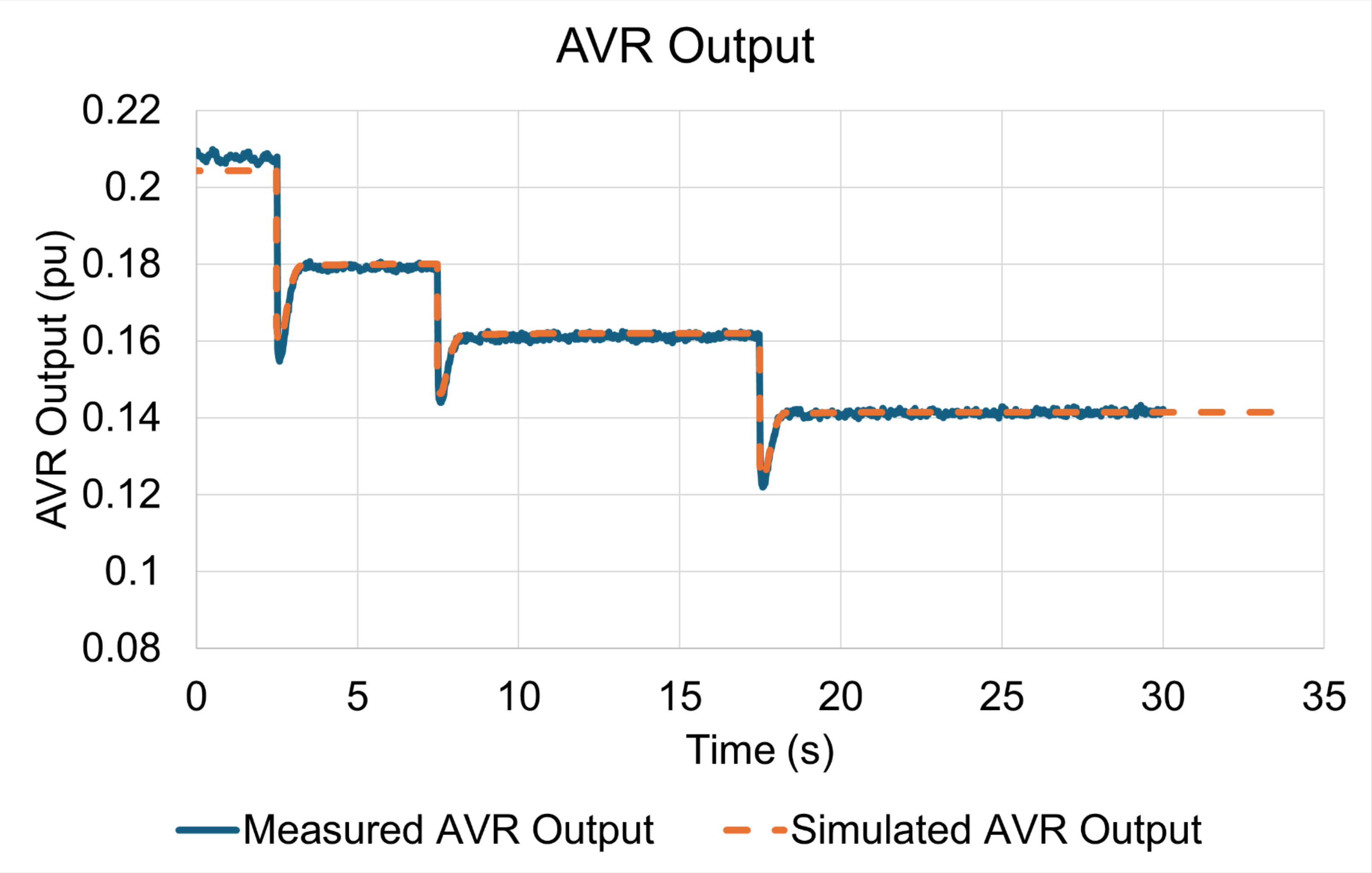
Additional Offline Testing Results – (cont.)



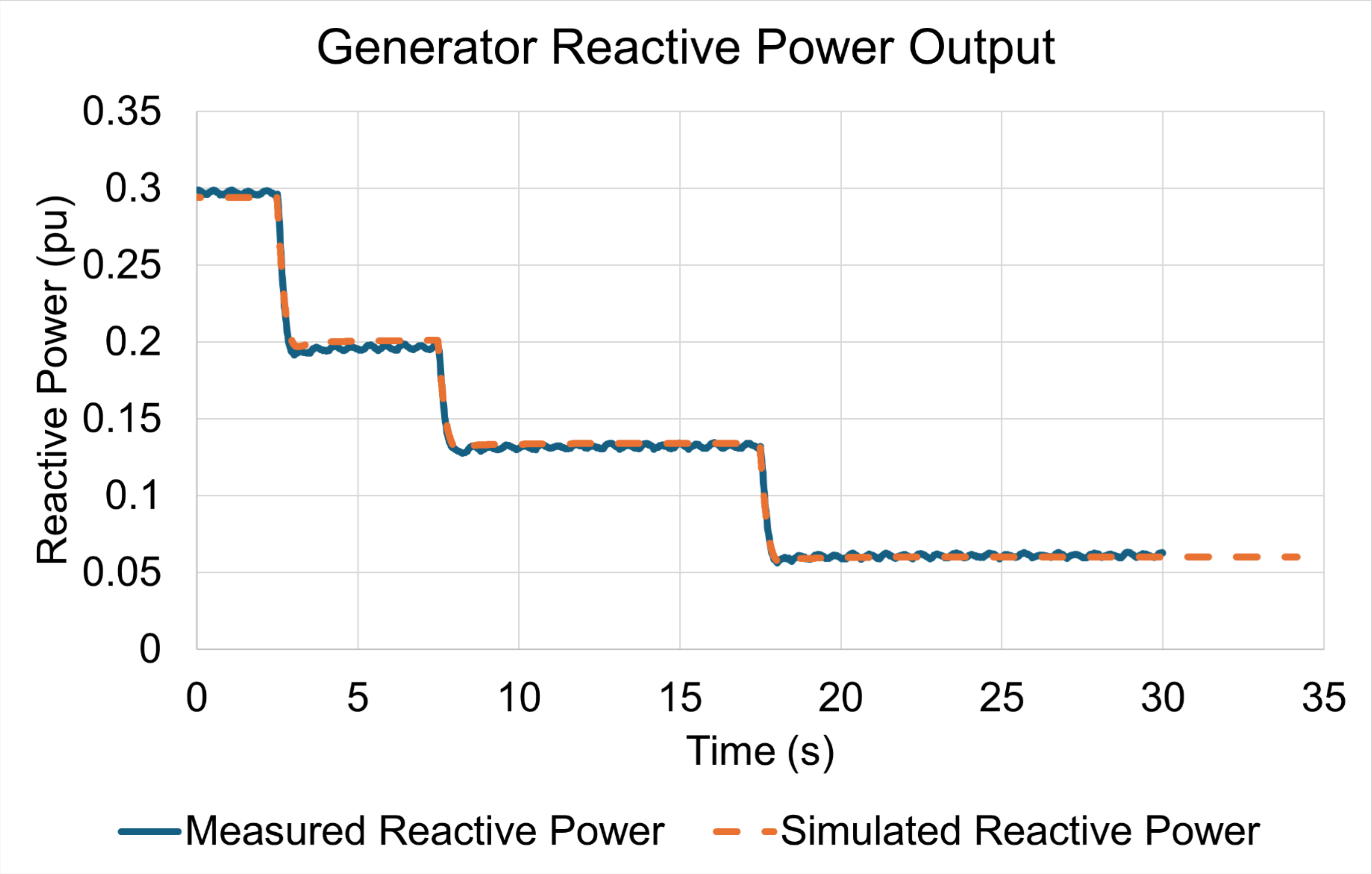
Additional Online Testing Results



Additional Online Testing Results – (cont.)



Additional Online Testing Results – (cont.)



Additional Online Testing Results – (cont.)