Modeling Notification

Recommended Practices for Modeling Momentary Cessation
Initial Distribution: February 2018

This Modeling Notification provides Generator Owners who own inverter-based resources, particularly solar photovoltaic (PV) resources, with recommendations for accurately modeling momentary cessation for existing resources that are not able to eliminate its use. Specific modeling requirements and steps to accurately model this behavior in the second-generation positive sequence generic renewable energy system models are provided in the notification.

Primary Interest Groups

Generator Owners (GOs), Generation Operators (GOPs), Transmission Planners (TPs), Planning Coordinators (PCs), Reliability Coordinators (RCs), MOD-032 Designees

Background

The Blue Cut Fire in August 2016 identified that the vast majority of solar PV resources connected to the bulk power system (BPS) use an operating mode known as momentary cessation. Momentary cessation is an inverter operating state where the power electronic "firing commands" are blocked such that both active current and reactive current go to zero output.[1] The NERC Inverter-Based Resource Performance Task Force (IRPTF)[2] is developing recommended performance specifications for inverter-based resources, including recommendations for momentary cessation. The task force has determined that momentary cessation should not be used for newly interconnecting resources to the BPS and should be eliminated to the greatest extent possible for existing resources on the BPS due to the reliability risk that the operating mode poses.

However, the NERC IRPTF recognizes that older vintages of inverters may require that momentary cessation be used due to design considerations at the time of commissioning. This is considered an equipment limitation that should be reported by the GO to their TP and PC. For these resources, it is critical that momentary cessation be captured with the dynamic models used to plan and operate the BPS. The second-generation generic renewable energy system models are, in general, recommended for modeling inverter-based resources in interconnection-wide base cases.[3][4][5] These models have some capability to model momentary cessation, and are described in detail in this notification.

[1] Momentary cessation is sometimes referred to as "blocking" for this reason.
[2] The NERC IRPTF consists of inverter manufacturers, GOs, GOPs, TPs, PCs, Balancing Authorities (BAs), Flexible AC Transmission System (FACTS) device manufacturers, renewable energy resource modeling experts, Regional Entities, NERC, and FERC.
[3] "The second-generation generic renewable energy system models" refer to the latest generic models used to represent inverter-based resources (e.g., regc_a and reec_a models).
[4] More detailed vendor-specific models may be used for local planning studies. These models may already capture momentary cessation. However, they are generally not allowed or recommended for the interconnection-wide cases. The focus of this guideline is on the generic models used for interconnection-wide modeling, and recommends the use of the second-generation renewable energy system models for this reason.
[5] Some interconnections, for example the Texas Interconnection, allow for more detailed, user-written models in their interconnection-wide cases. This is left to the discretion of the MOD-032 Designees for each interconnection.

Modeling momentary cessions should be based on the actual control/protection settings in the inverters (i.e., the voltage-current (VI) characteristics). Testing these characteristics in the field is not practical. Therefore, the momentary cessation settings should be determined by the GO in close coordination with the inverter manufacturer. This may be based on factory testing and confirmed control or protection settings in the inverter.

Modeling Notification

All recipients of this Modeling Notification should review the following recommendations for actions to ensure correct modeling of momentary cessation in stability studies:

Generator Owners

1. GOs should contact their inverter manufacturer(s) to understand whether the specific makes and models of their inverters, as configured at each specific generating facility, use momentary cessation.
2. GOs should obtain the following information from the inverter manufacturer(s) for any inverters that use momentary cessation[6]:
    a. Momentary Cessation Low Voltage Threshold or Curve: The low voltage at which the inverter enters momentary cessation (ceases firing of power electronics commands such that the inverter does not produce active or reactive current). If the limit is based on a time duration (i.e., different levels for different times), then a curve should be provided.
    b. Momentary Cessation High Voltage Threshold or Curve: The high voltage at which the inverter enters momentary cessation (ceases firing of power electronics commands such that the inverter does not produce active or reactive current). If the limit is based on a time duration (i.e., different levels for different times), then a curve should be provided.
    c. Recovery Delay: The time following restoration of terminal voltage to above the momentary cessation low voltage threshold within acceptable levels[7] before the inverter begins injecting current once again.
    d. Active Current Recovery Ramp Rate: The ramp rate (expressed in terms of percent of rated current per second) of recovery in active current injection following momentary cessation.
    e. Reactive Current Recovery Limits: Any limits imposed on the reactive current should be described. This may be a ramp rate limit, a reduced current limit for a specified period of time, or no limit imposed. Most inverters may not have these limits on reactive current injection, but this should be verified with the manufacturer.
3. GOs should ensure that the dynamic models, both generic and vendor-specific, used to represent their inverter-based resource(s) capture momentary cessation. See Appendix A for guidance regarding updating second-generation generic renewable energy system model parameter values

[6] For inverter-based resources that do not use momentary cessation, this guideline is not applicable and no immediate model changes are recommended.

[7] Either above the low voltage or below the high voltage momentary cessation voltage thresholds.

for momentary cessation. Any updates to the model should be coordinated with the inverter manufacturer, TP, and PC.

4. GOs should provide the updated model(s) (using the second-generation renewable energy system models or user-defined model, as applicable) to their TP and PC as quickly as possible.

Transmission Planners and Planning Coordinators

1. TPs should verify that these models initialize appropriately, exhibit positive damping, and have reasonable model parameter values.
2. TPs may also consider verifying that the dynamic response from the updated models matches relatively closely to the previously used models for small disturbances where voltage does not fall below the momentary cessation threshold.
3. TPs and PCs should provide any updated dynamic models received from GOs to their associated Reliability Coordinator and other applicable operating personnel (e.g., operations planning department) for use in Operational Planning Analysis (OPA).

MOD-032 Designees

1. The MOD-032 Designees should coordinate efforts with their stakeholders to ensure that momentary cessation is modeled appropriately for all modeled inverter-based generating resources in the interconnection-wide cases.

Appendix A: Modeling Momentary Cessation

Momentary cessation can be characterized using the response shown in Figure 1. Accurately modeling momentary cessation consists of the following key aspects:

- **Active and Reactive Current Reduction Capability:** Momentary cessation causes a reduction in active and reactive current to zero when voltage drops below a given threshold. Models must have the capability to set both components of current to zero for a certain duration.
- **Ramped Recovery of Active and Reactive Current:** Inverters apply a ramped recovery of active and reactive current following the restoration of voltage. Models must have the ability to control the rate of this ramped recovery.
- **Independent Control/Priority for Active and Reactive Current:** Inverters may recover active and reactive current differently based on design, control settings, etc. Models must have the ability to independently control or assign a priority to control of active and reactive current during recovery from momentary cessation.
- **Recovery Delay:** Inverters may use a delay following the restoration of terminal voltage before they start ramping recovery of current (represented with Δt_{sr} in Figure 1). While no delay is recommended, models should have the capability to accurately model this delay, if it exists.
- **High Voltage Ride Through:** Inverters also use momentary cessation when voltage exceeds a high voltage limit.

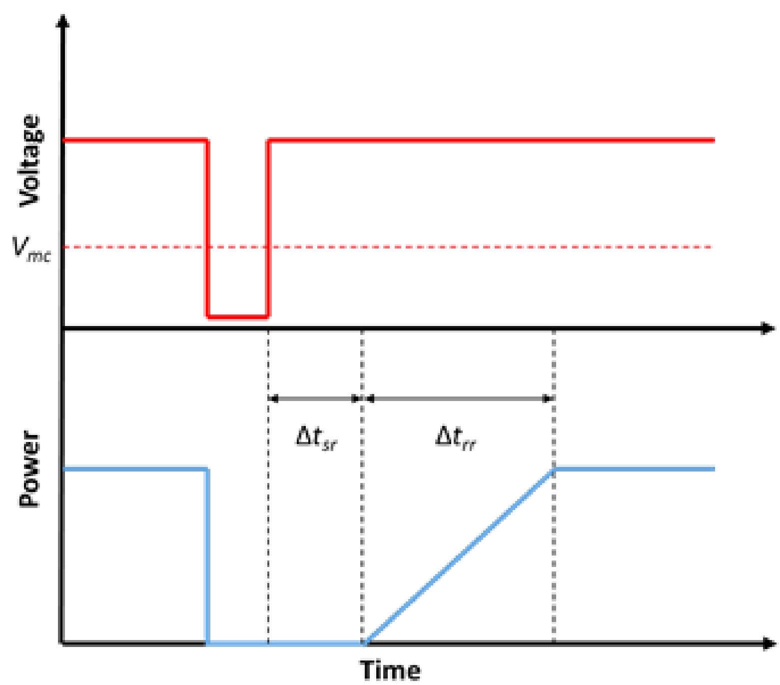

Figure 1: Illustration of Momentary Cessation

Most characteristics of momentary cessation can be modeled using the second-generation generic renewable energy system models. GOs using the first-generation generic models are encouraged to work with the equipment manufacturer, and their TP and PC to transition to the second-generation models for modeling these resources. This is important to capture the large disturbance dynamic performance of these resources more accurately. The inaccuracies and numerical issues with the first-generation generic models can adversely impact system reliability studies and study results. While either set of the second-generation renewable models shown in Table 1 can be used to model solar PV resources, the combination of regc_a and reec_a are recommended for modeling BPS-connected solar PV resources.[8]

Table 1: Model Structure Options for Solar PV Resources	
Resource Type	**Considerations, Benefits, and Drawbacks**
Solar PV Option A (Recommended)	REGC_A – Generator/Converter Model REEC_A – Electrical Control Model REPC_A – Power Plant Controller Model (as applicable)
Solar PV Option B	REGC_A – Generator/Converter Model REEC_B – Electrical Control Model REPC_A – Power Plant Controller Model (as applicable)

Figures 2 and 3 show the block diagrams for the regc_a and reec_a models, respectively.

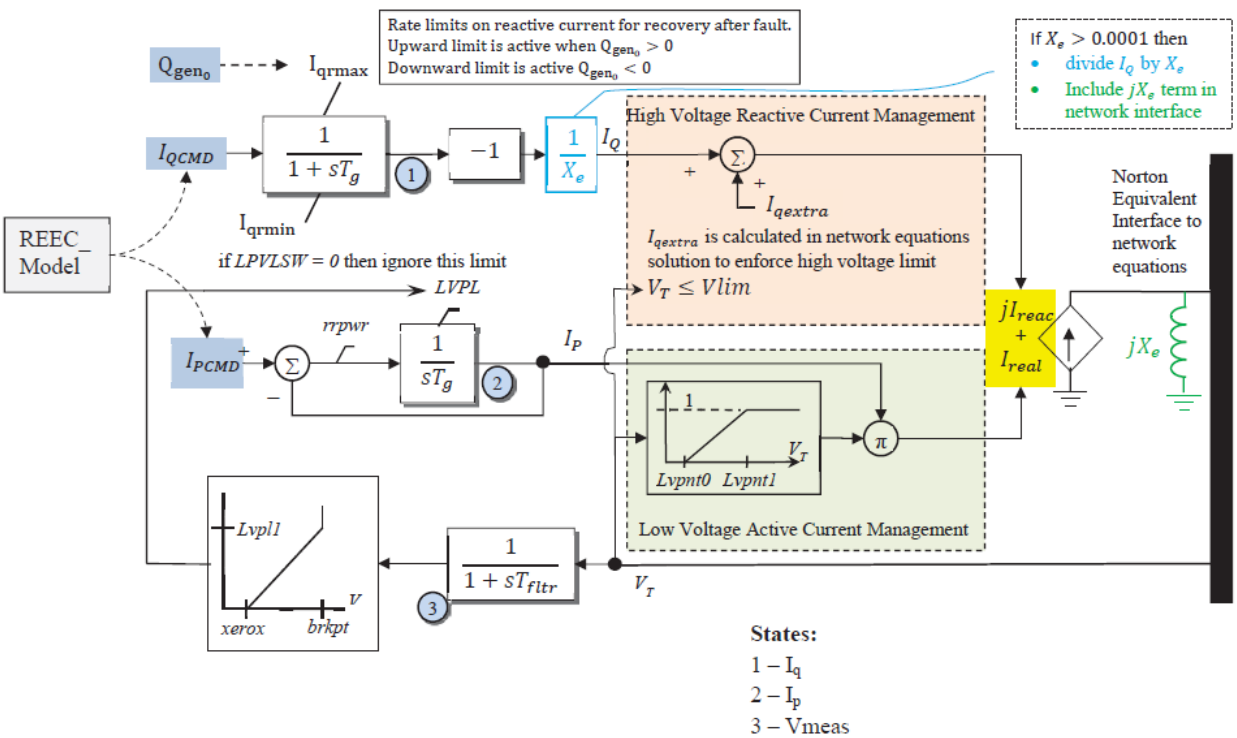

Figure 2: Block Diagram of REGC_A Model [Source: PowerWorld][9]

[8] Some modeling guides and software manuals list the *reec_b* model as the electrical controls model for PV generation. This is based on the history of the development of the models. This is not to be taken as a mandatory requirement. The *reec_a* is the more general and complex model and can be used for all solar PV inverter, and should be used to accurately model momentary cessation.
[9] https://www.powerworld.com/WebHelp/Content/TransientModels_HTML/Exciter%20REEC_A.htm

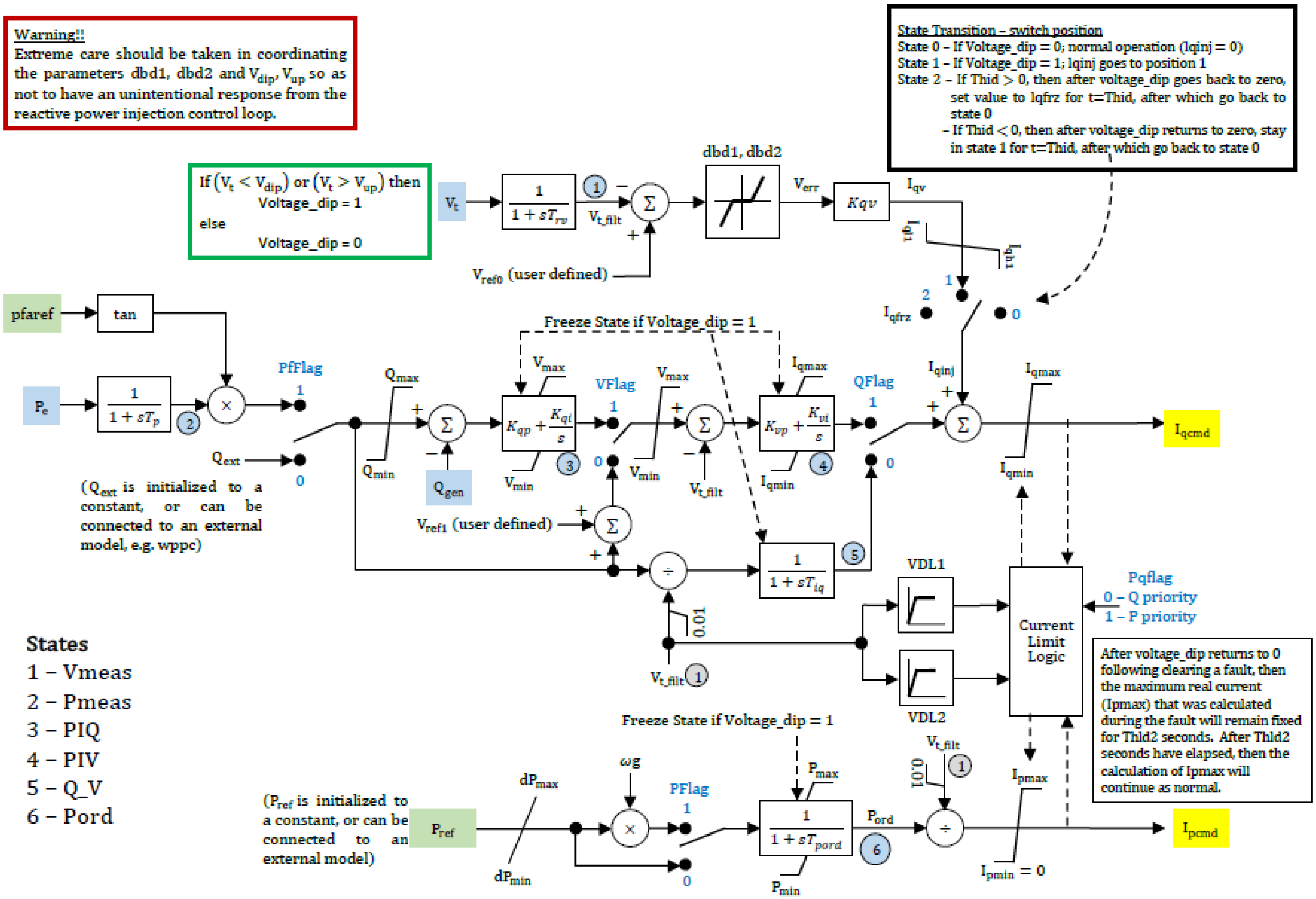

Figure 3: Block Diagram of REEC_A Model [Source: PowerWorld][10]

The following things need to be taken into consideration:

- **Voltage-dependent active and reactive current reduction:** The voltage-dependent current limits (VDL) tables (VDL1 and VDL2) are used to model cessation of both active and reactive current, respectively, when the voltage is below $V_{mc\text{-}lv}$ or above $V_{mc\text{-}hv}$. An example is provided in Table 2 and Figures 4 and 5. In this example for voltages below 0.75 pu or higher than 1.1 pu, the active and reactive currents are set to zero.

[10] https://www.powerworld.com/WebHelp/Content/TransientModels_HTML/Exciter%20REEC_A.htm

Table 2: VDL1 and VDL2 Settings

VDL1		VDL2	
vq	iq	vp	ip
0	0	0	0
0.749	0	0.749	0
0.75	1.45	0.75	1.1
1.1	1.45	1.1	1.1
1.101	0	1.101	0
2	0	2	0

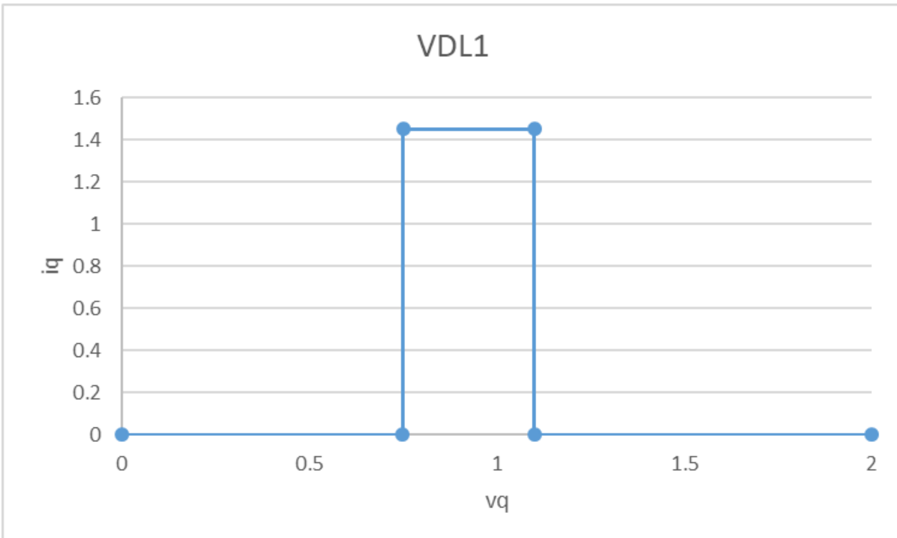

Figure 4: VDL1 Block Curve Points

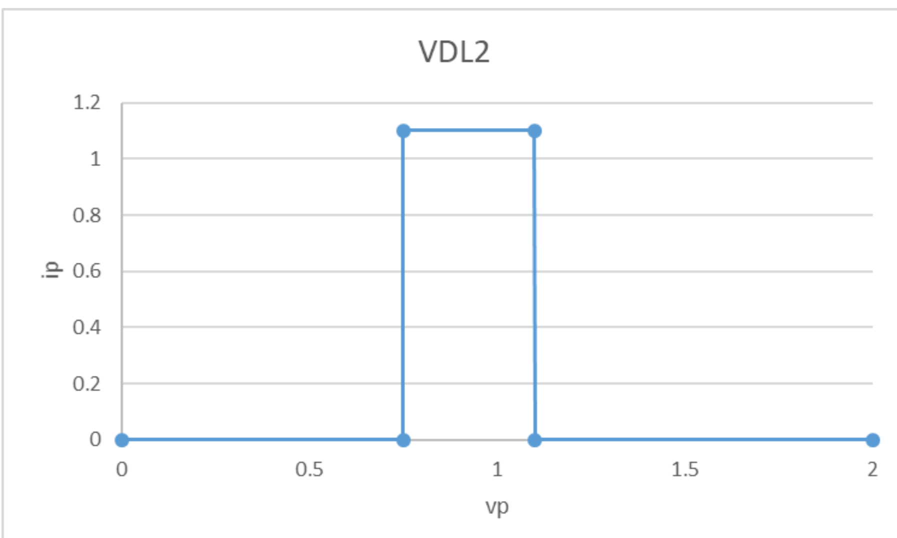

Figure 5: VDL2 Block Curve Points

Modeling limitation: The current reec_a model only supports four break points for VDL1 and VDL2 functions. As the four break points are not sufficient to model both low voltage and high voltage momentary cessation, priority should be given to modeling low voltage momentary cessation for most simulations. It is expected that VDL1 and VDL2 functions will be expanded to model both low voltage and high voltage momentary cessation, the high voltage momentary cessation could be added when the model is available.[11]

- **Ramp control of active and reactive current:** Both active and reactive current ramp rates and limits can be modeled in regc_a by rrpwr, iqrmax, and iqrmin. Parameter rrpwr is the ramp rate limit for active current. It should be set to the active current recovery rate from momentary cessation. Iqrmax and iqrmin are the upward and downward ramp rate limits on reactive current. The upward ramp limit iqrmax is active if the initial reactive power is positive, and the downward ramp limit qrmin is active if the initial reactive power is negative.

- **Active and reactive current control priority:** The flag pqflag in the reec_a model shall be set to represent P or Q priority selection on inverter current limit. The flag pqflag should be set to 1 if priority is given to active current and 0 if reactive current has the priority.

- **Voltage dip logic:** The parameter vdip in reec_a shall be set to the low voltage momentary cessation threshold $V_{mc\text{-}lv}$ and vup shall be set to the high voltage threshold $V_{mc\text{-}hv}$ to ensure inverter controls are frozen during the cessation period.

- **Recovery delay:** The delay in recovery of active current[12] can be represented by using a non-zero value for the thld2 parameter in the reec_a model. This delay is activated once the measured terminal voltage comes back within vdip and vup i.e. following a low voltage (Vt < vdip) or high voltage event (Vt > vup). From the time instant of vdip < Vt < vup, the active current command will be held at the previous value (zero in the case of momentary cessation) for a period of *thld2* seconds. If the value of vdip/vup is set as mentioned above to comply with the **Voltage dip logic** (vdip = $V_{mc\text{-}lv}$ and vup = $V_{mc\text{-}hv}$), then the active current will be held at zero for a period of *thld2* seconds. A hypothetical example is shown in Figure 6 with vdip = 0.9 pu and thld2 = 1.0s. The blue curve represents voltage and the red curve represents current. Active current command is delayed one second after voltage recovers to above vdip.

[11] Possible improvements to the VDL tables are currently being discussed by the WECC Renewable Energy Modeling Task Force (REMTF), as of January 2018.

[12] There is currently no capability to accurately model a delay in reactive current injection in the reec_a model.

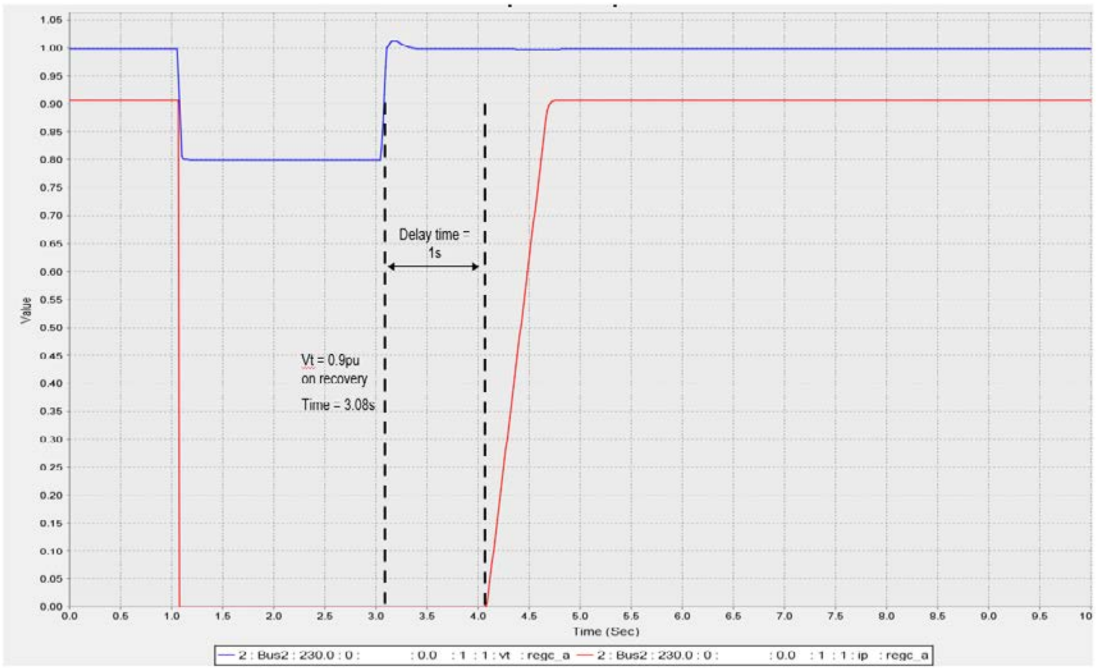

Figure 6: Example of Active Current Recovery Delay