Dynamic grid Compliance Verification Report

Electrical Performance Verification

for Power Park Modules

RTE

May 23, 2025

Contents

1 Summary

Run on 2025-05-23 10:51 CEST
Dynawo version: 1.8.0 (rev:master-42ec24e)
Model: examples/Performance/SingleAux/IECB2015/Dynawo

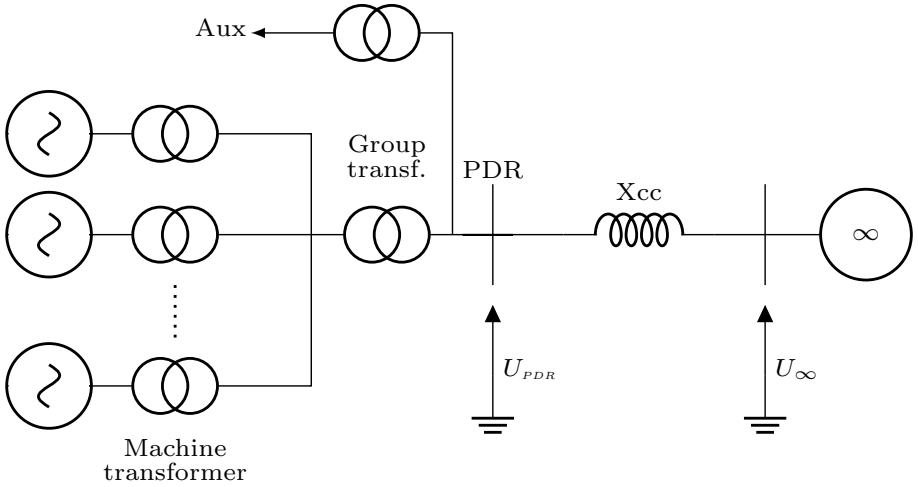
Pcs	Benchmark	Operating Condition	Overall Result
PCS_RTE-I2	USetPointStep	AReactance	Compliant
PCS_RTE-I2	USetPointStep	BReactance	Compliant
PCS_RTE-I5	ThreePhaseFault	TransientBolted	Compliant
PCS_RTE-I6	GridVoltageDip	Qzero	Compliant
PCS_RTE-I7	GridVoltageSwell	QMax	Compliant
PCS_RTE-I7	GridVoltageSwell	QMin	Compliant
PCS_RTE-I10	Islanding	DeltaP10DeltaQ4	Failed simulation

2 Results for PCS I2

2.1 Overview of DTR PCS I2 ($X_{cc} = X_a$)

Checks the compliance behavior of the power park module (PPM) in a network scenario where there is a step adjustment in the setpoint of the primary voltage control.

The grid model and its operational point is as in the following schematic:



Note: This schematic is only a reminder of the test setup on the TSO's side — the Producer's side may vary, depending on the user-provided model.

where the connecting branch has the value $X_{cc} = X_a$, as specified in the DTR.

Initial conditions used at the PDR bus:

- $P = P_{max\_unite}$
- $Q = 0$
- $U = U_{dim}$

2.1.1 Simulation parameters

Solver and parameters used in the simulation:

Parameter	Value (default)
lib	dynawo_SolverIDA (dynawo_SolverIDA)
parId	IDA (IDA)
order	2 (2)
initStep	1e-06 (1e-06)
minStep	1e-06 (1e-06)
maxStep	0.01 (0.01)
absAccuracy	1e-06 (1e-06)
relAccuracy	0.0001 (0.0001)
minimalAcceptableStep	1e-06 (1e-06)

2.1.2 Simulation

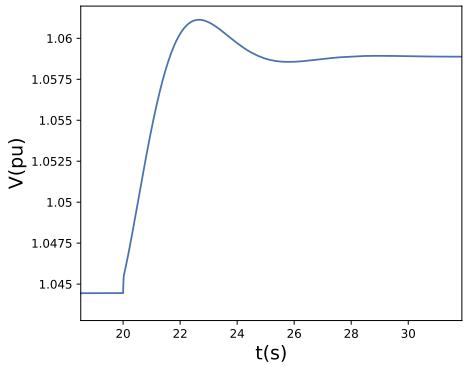
As required by the DTR PCS I2, the figures below show the following magnitudes:

- Voltage at connection point: modulus of the AC complex voltage at the PDR bus.
- Reactive power supplied at the connection point: sum of reactive power over all lines on TSO side.

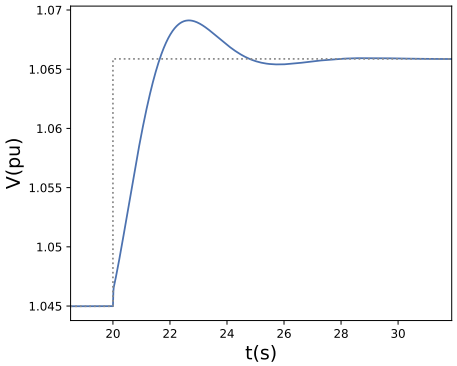
- Active power supplied at the connection point: sum of active power over all lines on TSO side.
- Magnitude controlled by the AVR: modulus of the voltage at the REPC. All PPM units are plotted on the same graph.

2.1.3 Simulation results

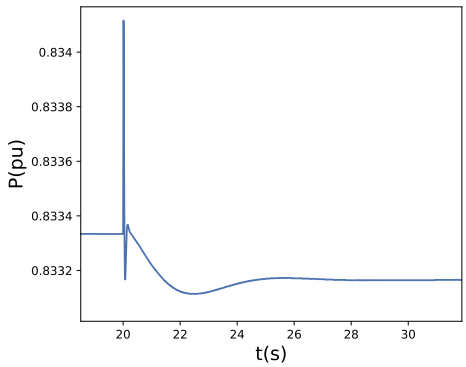
The blue line shows the calculated curve, if a reference curve has been entered it is shown in orange.



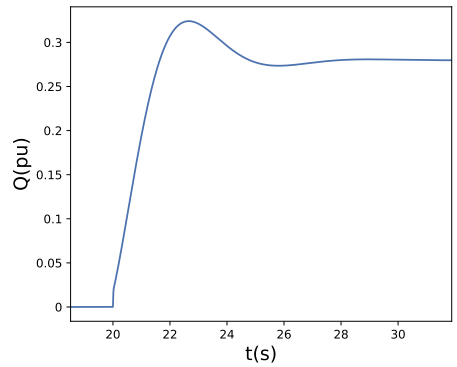
Voltage magnitude measured at the PDR bus.



Magnitude controlled by the AVR: modulus of the voltage at the REPC, in pu. The gray dotted line show the AVR setpoint. All PPM units are plotted on the same graph.



Real power output P, measured at the PDR bus.



Reactive power output Q, measured at the PDR bus.

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2.1.4 Analysis of results

Analysis of results for PCS I2. Values extracted from the simulation:

Parameter	value
T_{10U}	3.55 s
T_{5U}	4.07 s
ϵ	0.0

Key:

Response time T_{10U}: time at which the suplied voltage V stays within the +/-10% tube centered on the final value of V.

Settling time T_{5U}: time at which the suplied voltage V stays within the +/-5% tube centered on the final value of V.

Static difference ϵ: difference between the controlled quantity injected into the primary voltage regulator and the voltage adjustment setpoint.

2.1.5 Compliance checks

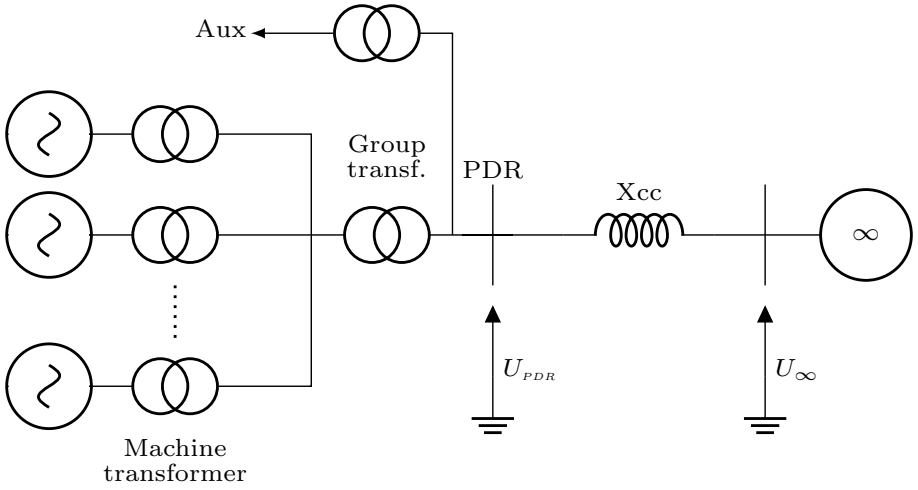
Compliance checks required by PCS I2:

Check	**value**	**Compliant?**
Unit not disconnected by protections	—	True
Unit remains stable (rotor stability)	—	True
$\epsilon < 0.2\%$	0.0	True
$T_{5U} < 10s$	4.07	True
$T_{10U} < 5s$	3.55	True

2.2 Overview of DTR PCS I2 ($X_{cc} = X_b$)

Checks the compliance behavior of the power park module (PPM) in a network scenario where there is a step adjustment in the setpoint of the primary voltage control.

The grid model and its operational point is as in the following schematic:



Note: This schematic is only a reminder of the test setup on the TSO's side — the Producer's side may vary, depending on the user-provided model.

where the connecting branch has the value $X_{cc} = X_b$, as specified in the DTR.

Initial conditions used at the PDR bus:

- $P = P_{max\_unite}$
- $Q = 0$
- $U = U_{dim}$

2.2.1 Simulation parameters

Solver and parameters used in the simulation:

Parameter	Value (default)
lib	dynawo_SolverIDA (dynawo_SolverIDA)
parId	IDA (IDA)
order	2 (2)
initStep	1e-06 (1e-06)
minStep	1e-06 (1e-06)
maxStep	0.01 (0.01)
absAccuracy	1e-06 (1e-06)
relAccuracy	0.0001 (0.0001)
minimalAcceptableStep	1e-06 (1e-06)

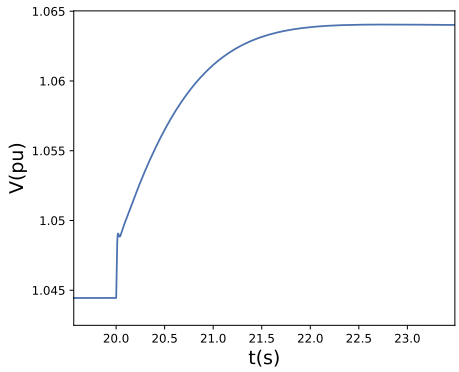
2.2.2 Simulation

As required by the DTR PCS I2, the figures below show the following magnitudes:

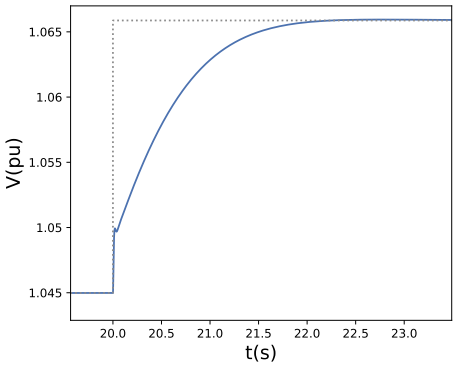
- Voltage at connection point: modulus of the AC complex voltage at the PDR bus.
- Reactive power supplied at the connection point: sum of reactive power over all lines on TSO side.
- Active power supplied at the connection point: sum of active power over all lines on TSO side.
- Magnitude controlled by the AVR: modulus of the voltage at the REPC. All PPM units are plotted on the same graph.

2.2.3 Simulation results

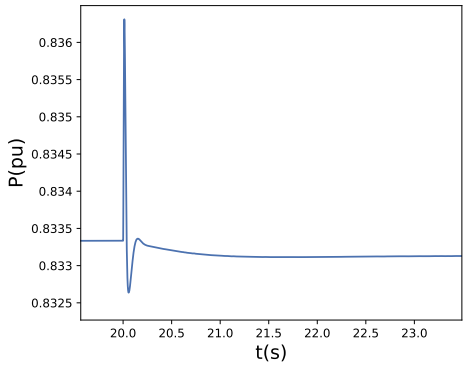
The blue line shows the calculated curve, if a reference curve has been entered it is shown in orange.



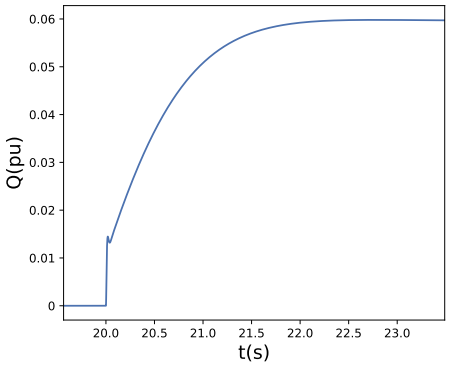
Voltage magnitude measured at the PDR bus.



Magnitude controlled by the AVR: modulus of the voltage at the REPC, in pu. The gray dotted line show the AVR setpoint. All PPM units are plotted on the same graph.



Real power output P, measured at the PDR bus.



Reactive power output Q, measured at the PDR bus.

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2.2.4 Analysis of results

Analysis of results for PCS I2. Values extracted from the simulation:

Parameter	value
T_{10U}	1.16 s
T_{5U}	1.44 s
ϵ	0.0

Key:

Response time T_{10U}: time at which the suplied voltage V stays within the +/-10% tube centered on the final value of V.

Settling time T_{5U}: time at which the suplied voltage V stays within the +/-5% tube centered on the final value of V.

Static difference ϵ: difference between the controlled quantity injected into the primary voltage regulator and the voltage adjustment setpoint.

2.2.5 Compliance checks

Compliance checks required by PCS I2:

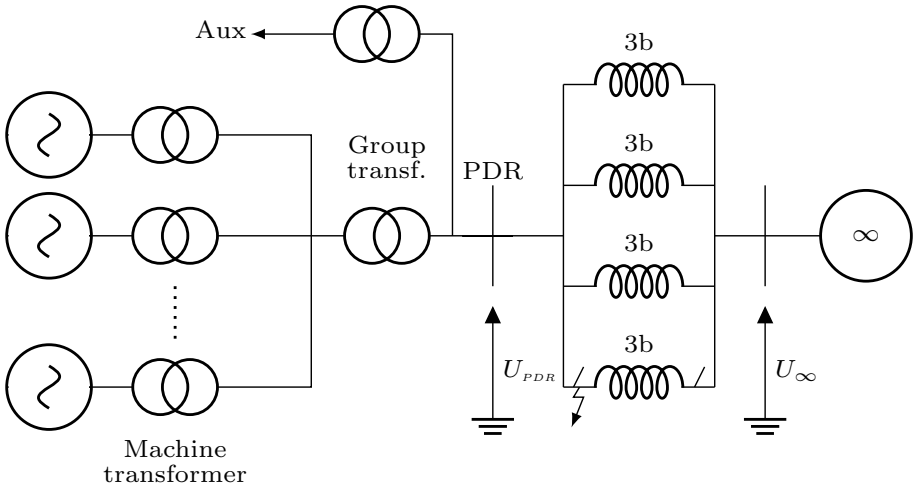
Check	**value**	**Compliant?**
Unit not disconnected by protections	—	True
Unit remains stable (rotor stability)	—	True
$\epsilon < 0.2\%$	0.0	True
$T_{5U} < 10s$	1.44	True
$T_{10U} < 5s$	1.16	True

3 Results for PCS I5

3.1 Overview of DTR PCS I5

Checks for compliant behavior of the PPM under a grid scenario where there is a symmetric three-phase fault at one of the four transmission lines (at a 1% distance from the PDR). The PPM should remain connected and be able to supply the necessary reactive injection.

The grid model and its operational point is as in the following schematic:



Note: This schematic is only a reminder of the test setup on the TSO's side — the Producer's side may vary, depending on the user-provided model.

Important reminders:

- The time for fault clearance, T_{clear}, is a parameter that is specified in the DTR and depends on the voltage level in question:
  - HTB3 (400 kV): $T_{clear} = 85$ ms
  - HTB2 (150 kV and 225 kV): $T_{clear} = 85$ ms
  - HTB1 (63 kV and 90 kV): $T_{clear} = 150$ ms

In Dynaωo this fault has been modeled by splitting `Line4` into `Line4a` and `Line4b`, and then inserting an intermediate bus between them, to which a `NodeFault` object is attached.

Note that although the DTR PCS also requires simulating a one-phase fault, this tool will not implement it, as it would require the simulation of a three-phase model. All simulations are only positive-sequence.

Initial conditions used at the PDR bus:

- $P = P_{max\_unite}$
- $Q = 0$
- $U = U_{dim}$

3.1.1 Simulation parameters

Solver and parameters used in the simulation:

Parameter	Value (default)
lib	dynawo_SolverIDA (dynawo_SolverIDA)
parId	IDA (IDA)
order	2 (2)
initStep	1e-06 (1e-06)
minStep	1e-06 (1e-06)
maxStep	0.01 (0.01)
absAccuracy	1e-06 (1e-06)
relAccuracy	0.0001 (0.0001)
minimalAcceptableStep	1e-06 (1e-06)

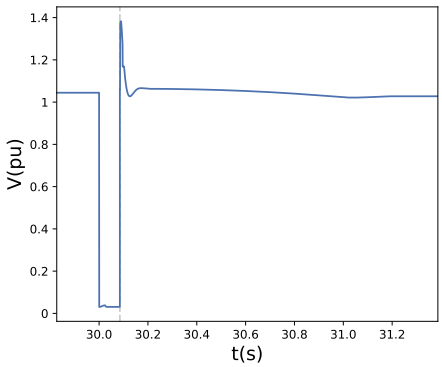
3.1.2 Simulation

As required by the DTR PCS I5, the figures below show the following magnitudes:

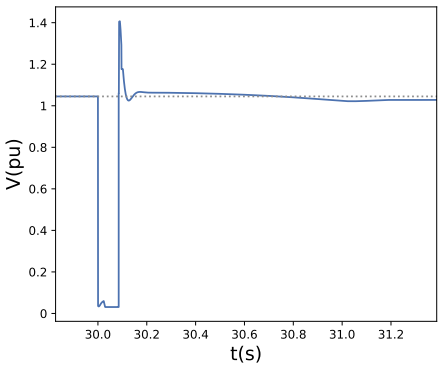
- Voltage at connection point: modulus of the AC complex voltage at the PDR bus.
- Reactive power supplied at the connection point: sum of reactive power over all lines on TSO side.
- Active power supplied at the connection point: sum of active power over all lines on TSO side.
- The injected active and reactive currents. All PPM units are plotted on the same graph.
- Magnitude controlled by the AVR: modulus of the voltage at the REPC. All PPM units are plotted on the same graph.
- The PPM's main transformer tap ratio. if it is a transformer with an automatic tap changer.

3.1.3 Simulation results

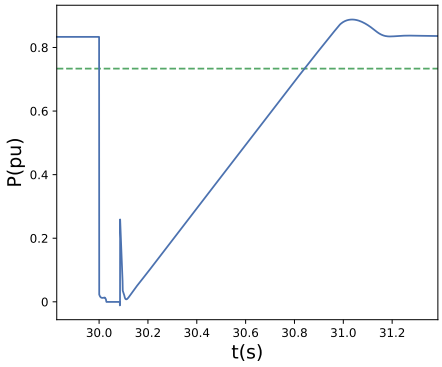
The blue line shows the calculated curve, if a reference curve has been entered it is shown in orange.



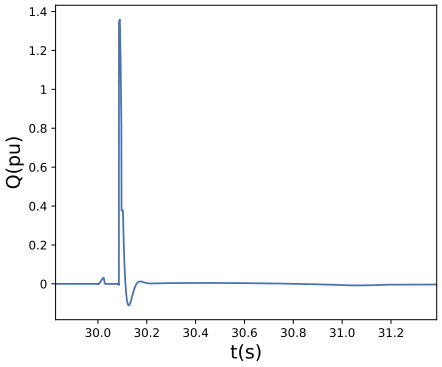
Voltage magnitude measured at the PDR bus. The vertical dashed line marks the rise time T_{85U}.



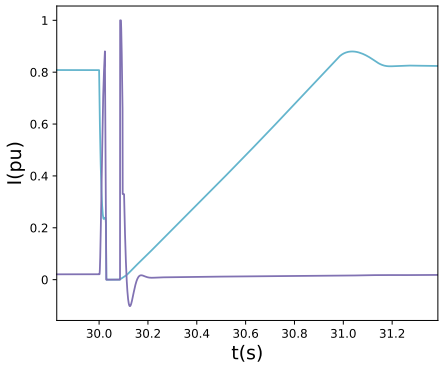
Magnitude controlled by the AVR: modulus of the voltage at the REPC, in pu. The gray dotted line show the AVR setpoint. All PPM units are plotted on the same graph.



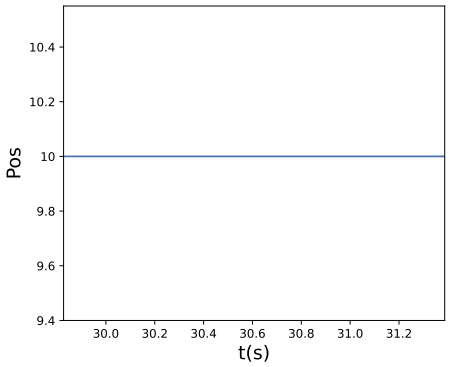
Real power output P, measured at the PDR bus. Green-dashed line: −10% "floor" below the final value of P.



Reactive power output Q, measured at the PDR bus.



Injected active (light blue line) and reactive (violet line) currents. All PPM units are plotted on the same graph.



The PPM's main transformer tap ratio (if it is a transformer with an automatic tap changer).

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3.1.4 Analysis of results

Analysis of results for PCS I5. Values extracted from the simulation:

Parameter	value
$T_{10P_{floor}}$	0.84 s
T_{85U}	0.085 s

Key:

Recovery time $T_{10P_{floor}}$: time at which the suplied power P recovers and stays above -10% of the final value of P (note how this is not a "tube", but a "floor").

Rise time T_{85U}: time at which the the voltage at the PDR bus returns back above 0.85 pu, regardless of any possible overshooting / undershooting that may take place later on.

3.1.5 Compliance checks

Compliance checks required by PCS I5:

Check	**value**	**Compliant?**
Unit not disconnected by protections	—	True
Unit remains stable (rotor stability)	—	True
Reactive inj. prioritized if Imax reached	[a]—	True
$T_{10P_{floor}} - T_{clear} < 2s$	0.755	True
$T_{10P_{floor}} - T_{85U} < 2s$	0.755	True

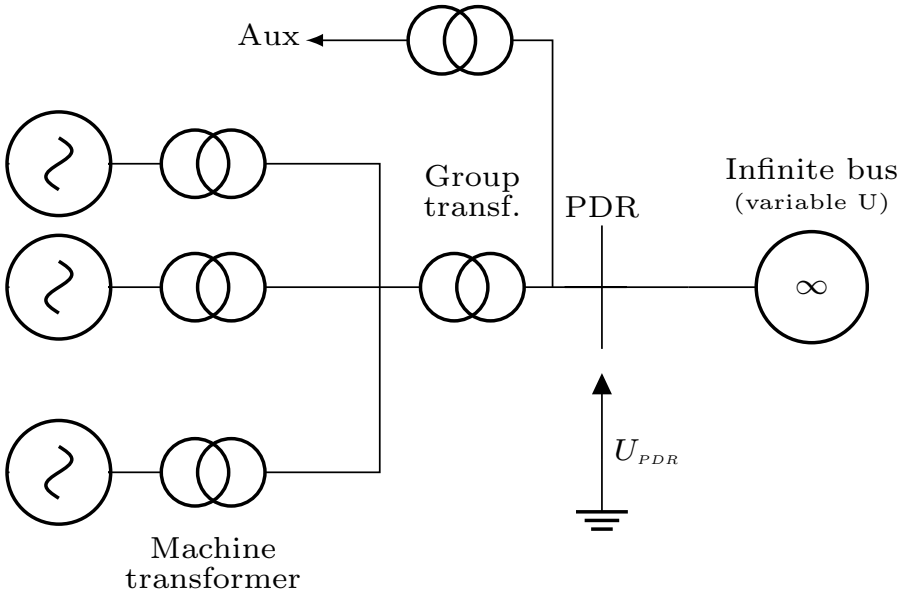
[a] If non-compliant, time at which this happens.

4 Results for PCS I6

4.1 Overview of DTR PCS I6

Checks for compliant behavior of the PPM under a grid scenario where there is a severe drop of voltage at the PDR bus (which simulates the effect of a fault nearby in the network).

The grid model and its operational point is as in the following schematic:



Note: This schematic is only a reminder of the test setup on the TSO's side — the Producer's side may vary, depending on the user-provided model.

Important reminders:

- Contrary to the modeling that the DTR suggests for this PCS, which uses a variable shunt impedance Zv and a short-circuit network impedance Zcc, here the voltage drop is simulated via a variable Infinite Bus source (Modelica model `ControllableSource`), directly attached to the PDR bus, and for which we specify a voltage curve that faithfully follows the shape prescribed by PCS I6.

In this PCS there are several events, which correspond to the changes that are forced upon the PDR bus voltage curve:

- At $t = T_0$, voltage drops to U_{fault}
- At $t = T_{clear}$, voltage rises to U_{clear}
- At $t = T_{rec1}$, voltage starts ramping up linearly, from U_{clear} to U_{rec2} (reached at $t = T_{rec2}$).
- At $t = T_{rec2}$ the voltage stops ramping up and remains at U_{rec2} indefinitely.

These values of time and voltage are specified by the DTR as follows. (Remember that the classification of generators into class A, B, C, D, is in the DTR under Chapter 5, Article 5.1.1, Section 3. See the reminder in the document `Summary_data_from_the_DTR.md`.)

For PPMs of classes B, C, and Offshore (under 110 kV in this last case):

variable	all Volt Levels
$U_{initial}$	1.0 pu
T_0	(free)
U_{fault}	0.05 pu
T_{clear}	T_0 + 150 ms
T_{rec2}	T_0 + 1150 ms
U_{rec2}	0.85 pu

For PPMs of class D and Offshore systems at 110 kV and above:

variable	all Volt levels
$U_{initial}$	1.0 pu
T_0	(free)
U_{fault}	0.00 pu
T_{clear}	T_0 + 150 ms
T_{rec2}	T_0 + 1500 ms
U_{rec2}	0.85 pu

Initial conditions used at the PDR bus:

- $P = P_{max\_unite}$
- $Q = 0$
- $U = U_{dim}$

4.1.1 Simulation parameters

Solver and parameters used in the simulation:

Parameter	Value (default)
lib	dynawo_SolverIDA (dynawo_SolverIDA)
parId	IDA (IDA)
order	2 (2)
initStep	1e-06 (1e-06)
minStep	1e-07 (1e-06)
maxStep	0.01 (0.01)
absAccuracy	1e-05 (1e-06)
relAccuracy	0.001 (0.0001)
minimalAcceptableStep	1e-07 (1e-06)

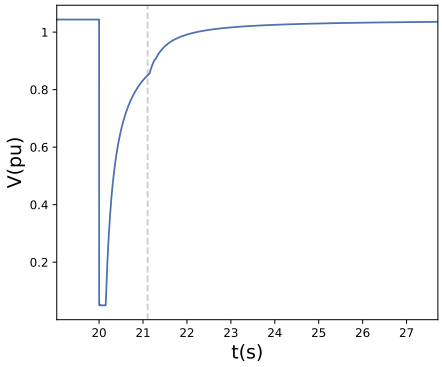
4.1.2 Simulation

The following figures show the magnitudes that DTR PCS I6requires to be monitored:

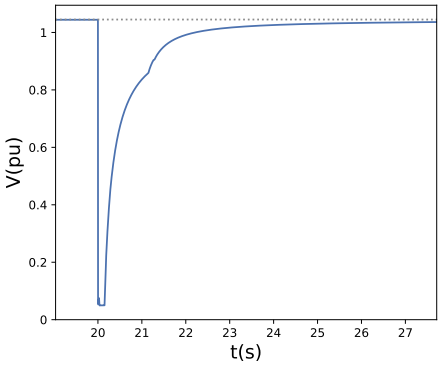
- Voltage at connection point: modulus of the AC complex voltage at the PDR bus.
- Reactive power supplied at the connection point (obtained from the controllable Infinite Bus on TSO side).
- Active power supplied at the connection point (obtained from the controllable Infinite Bus on TSO side).
- Magnitude controlled by the AVR: modulus of the voltage at the REPC. All PPM units are plotted on the same graph.

4.1.3 Simulation results

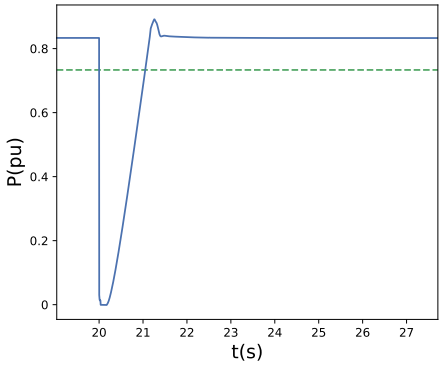
The blue line shows the calculated curve, if a reference curve has been entered it is shown in orange.



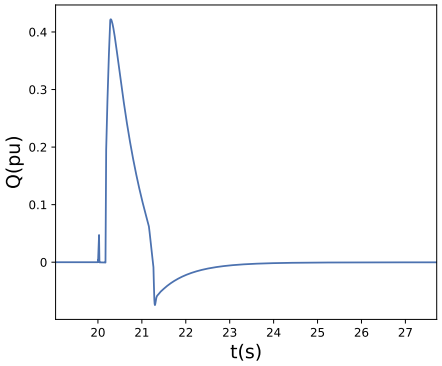
Voltage magnitude measured at the PDR bus. The vertical dashed line marks the rise time T_{85U}.



Magnitude controlled by the AVR: modulus of the voltage at the REPC, in pu. The gray dotted line show the AVR setpoint. All PPM units are plotted on the same graph.



Real power output P, measured at the PDR bus. Green-dashed line: -10% "floor" below the final value of P.



Reactive power output Q, measured at the PDR bus.

Go to html figures

4.1.4 Analysis of results

Analysis of results for PCS I6. Values extracted from the simulation:

Parameter	value
$T_{10P_{floor}}$	1.05 s
T_{85U}	1.1 s

Key:

Recovery time $T_{10P_{floor}}$: time at which the suplied power P recovers and stays above -10% of the final value of P (note how this is not a "tube", but a "floor").

Rise time T_{85U}: time at which the the voltage at the PDR bus returns back above 0.85pu, regardless of any possible overshooting/undershooting that may take place later on.

4.1.5 Compliance checks

Compliance checks required by PCS I6:

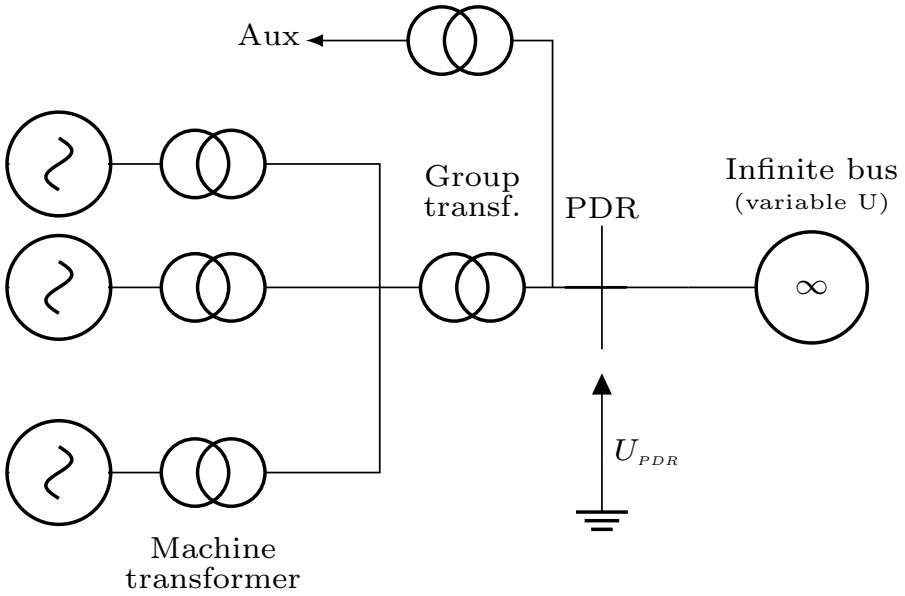
Check	**value**	**Compliant?**
Unit not disconnected by protections	—	True
Unit remains stable (rotor stability)	—	True
Aux not disconnected by protections	—	True
$T_{10P_{floor}} - T_{clear} < 2s$	0.895	True
$T_{10P_{floor}} - T_{85U} < 2s$	0.0	True

5 Results for PCS I7

5.1 Overview of DTR PCS I7 ($Q_{\mathbf{PDR}} = Q_{\mathbf{max}}$)

Checks for compliant behavior of the PPM under a grid scenario where there is a severe overvoltage at the PDR bus (which simulates the effect of clearing a fault nearby in the network).

The grid model and its operational point is as in the following schematic:



Note: This schematic is only a reminder of the test setup on the TSO's side — the Producer's side may vary, depending on the user-provided model.

where $Q_{\mathrm{PDR}} = Q_{\mathrm{max}}$.
Important reminders:

- Contrary to the modeling that the DTR suggests for this PCS, which uses a variable shunt impedance Zv, here the voltage drop is simulated via a variable Infinite Bus source (Modelica model `ControllableSource`), directly attached to the PDR bus, and for which we specify a voltage curve that faithfully follows the shape prescribed by PCS I7.

In this PCS there are several events, which correspond to the changes that are forced upon the PDR bus voltage curve:

- At $t = T_0$, the voltage swells to U_{swell}
- At $t = T_{rec1}$, the voltage drops to U_{rec2}
- At $t = T_{rec2}$, the voltage drops to U_{rec3}
- At $t = T_{rec3}$, the voltage drops to U_{rec4}

These values of time and voltage are specified by the DTR as follows. (Remember that the classification of generators into class A, B, C, D, is in the DTR under Chapter 5, Article 5.1.1, Section 3. See the reminder in the document `Summary_data_from_the_DTR.md`.)

variable	all Volt Levels
$U_{initial}$	1.0 pu
T_0	(free)
U_{swell}	1.3 pu
T_{rec1}	T_0 + 50 ms
U_{rec2}	1.25 pu
T_{rec2}	T_0 + 2.5 s
U_{rec3}	1.15 pu
T_{rec3}	T_0 + 30 s
U_{rec4}	1.10 pu

Initial conditions used at the PDR bus:

- $P = P_{max\_unite}$
- $Q = Q_{max}$
- $U = U_{dim}$

5.1.1 Simulation parameters

Solver and parameters used in the simulation:

Parameter	Value (default)
lib	dynawo_SolverIDA (dynawo_SolverIDA)
parId	IDA (IDA)
order	2 (2)
initStep	1e-06 (1e-06)
minStep	1e-06 (1e-06)
maxStep	0.01 (0.01)
absAccuracy	1e-06 (1e-06)
relAccuracy	0.0001 (0.0001)
minimalAcceptableStep	1e-06 (1e-06)

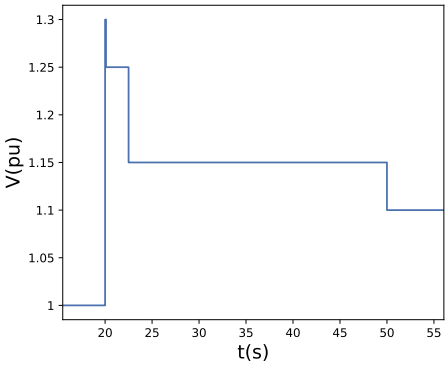
5.1.2 Simulation

The following figures show the magnitudes that DTR PCS I7requires to be monitored:

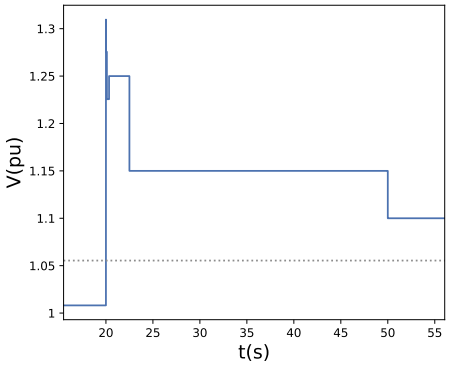
- Voltage at connection point: modulus of the AC complex voltage at the PDR bus.
- Reactive power supplied at the connection point (obtained from the controllable Infinite Bus on TSO side).
- Active power supplied at the connection point (obtained from the controllable Infinite Bus on TSO side).
- The injected active and reactive currents. All PPM units are plotted on the same graph.
- Magnitude controlled by the AVR: modulus of the voltage at the REPC. All PPM units are plotted on the same graph.

5.1.3 Simulation results

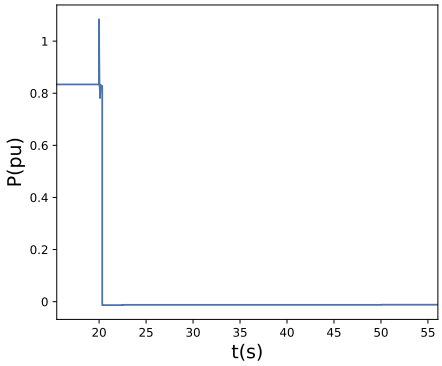
The blue line shows the calculated curve, if a reference curve has been entered it is shown in orange.



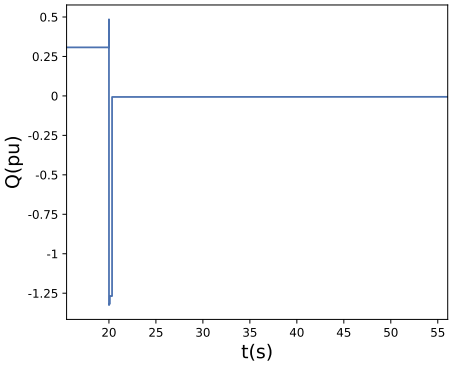
Voltage magnitude measured at the PDR bus.



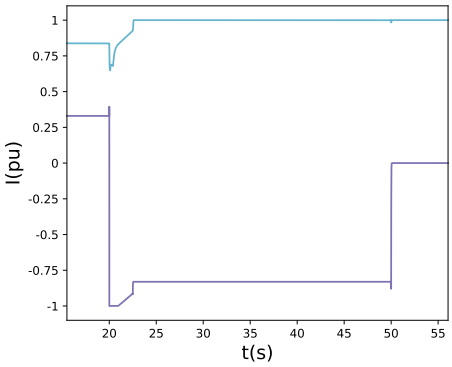
Magnitude controlled by the AVR: modulus of the voltage at the REPC, in pu. The gray dotted line show the AVR setpoint. All PPM units are plotted on the same graph.



Real power output P, measured at the PDR bus.



Reactive power output Q, measured at the PDR bus.



Injected active (light blue line) and reactive (violet line) currents. All PPM units are plotted on the same graph.

Go to html figures

5.1.4 Analysis of results

No analysis is needed in PCS I7.

5.1.5 Compliance checks

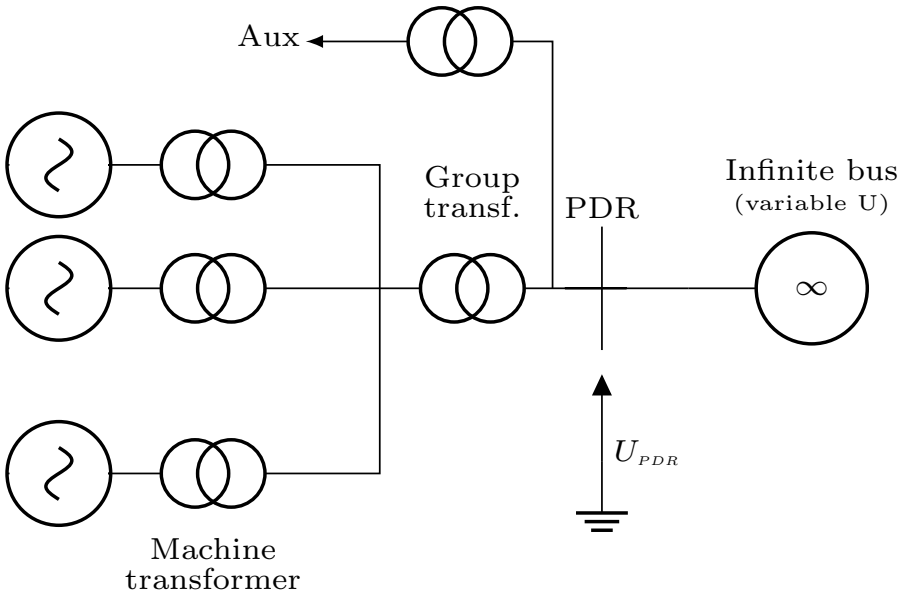
Compliance checks required by PCS I7:

Check	value	Compliant?
Unit not disconnected by protections	—	True
Unit remains stable (rotor stability)	—	True

5.2 Overview of DTR PCS I7 ($Q_{\mathbf{PDR}} = Q_{\mathbf{min}}$)

Checks for compliant behavior of the PPM under a grid scenario where there is a severe overvoltage at the PDR bus (which simulates the effect of clearing a fault nearby in the network).

The grid model and its operational point is as in the following schematic:



Note: This schematic is only a reminder of the test setup on the TSO's side — the Producer's side may vary, depending on the user-provided model.

where $Q_{\mathrm{PDR}} = Q_{\mathrm{min}}$.
Important reminders:

- Contrary to the modeling that the DTR suggests for this PCS, which uses a variable shunt impedance Zv, here the voltage drop is simulated via a variable Infinite Bus source (Modelica model `ControllableSource`), directly attached to the PDR bus, and for which we specify a voltage curve that faithfully follows the shape prescribed by PCS I7.

In this PCS there are several events, which correspond to the changes that are forced upon the PDR bus voltage curve:

- At $t = T_0$, the voltage swells to U_{swell}
- At $t = T_{rec1}$, the voltage drops to U_{rec2}
- At $t = T_{rec2}$, the voltage drops to U_{rec3}
- At $t = T_{rec3}$, the voltage drops to U_{rec4}

These values of time and voltage are specified by the DTR as follows. (Remember that the classification of generators into class A, B, C, D, is in the DTR under Chapter 5, Article 5.1.1, Section 3. See the reminder in the document `Summary_data_from_the_DTR.md`.)

variable	all Volt Levels
$U_{initial}$	1.0 pu
T_0	(free)
U_{swell}	1.3 pu
T_{rec1}	T_0 + 50 ms
U_{rec2}	1.25 pu
T_{rec2}	T_0 + 2.5 s
U_{rec3}	1.15 pu
T_{rec3}	T_0 + 30 s
U_{rec4}	1.10 pu

Initial conditions used at the PDR bus:

- $P = P_{max\_unite}$
- $Q = Q_{min}$
- $U = U_{dim}$

5.2.1 Simulation parameters

Solver and parameters used in the simulation:

Parameter	Value (default)
lib	dynawo_SolverIDA (dynawo_SolverIDA)
parId	IDA (IDA)
order	2 (2)
initStep	1e-06 (1e-06)
minStep	1e-06 (1e-06)
maxStep	0.01 (0.01)
absAccuracy	1e-06 (1e-06)
relAccuracy	0.0001 (0.0001)
minimalAcceptableStep	1e-06 (1e-06)

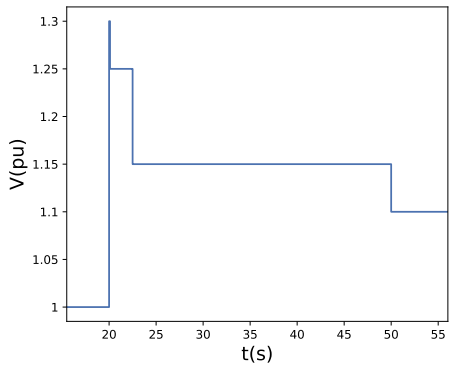
5.2.2 Simulation

The following figures show the magnitudes that DTR PCS I7requires to be monitored:

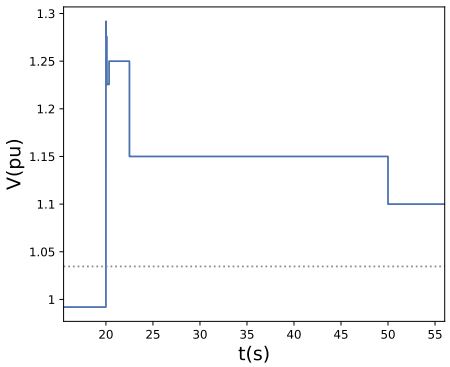
- Voltage at connection point: modulus of the AC complex voltage at the PDR bus.
- Reactive power supplied at the connection point (obtained from the controllable Infinite Bus on TSO side).
- Active power supplied at the connection point (obtained from the controllable Infinite Bus on TSO side).
- The injected active and reactive currents. All PPM units are plotted on the same graph.
- Magnitude controlled by the AVR: modulus of the voltage at the REPC. All PPM units are plotted on the same graph.

5.2.3 Simulation results

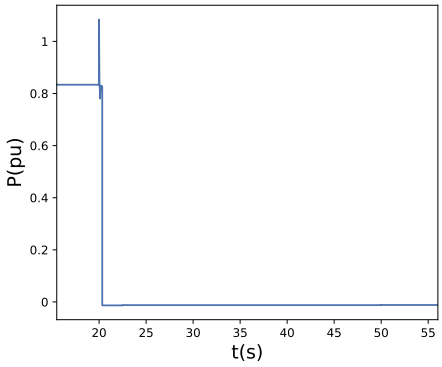
The blue line shows the calculated curve, if a reference curve has been entered it is shown in orange.



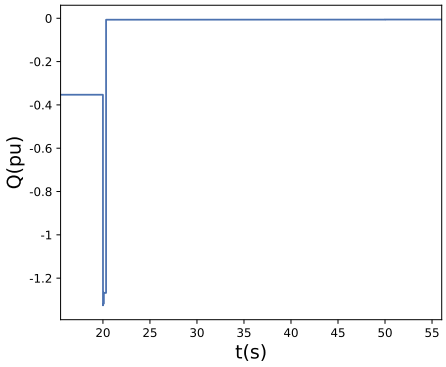
Voltage magnitude measured at the PDR bus.



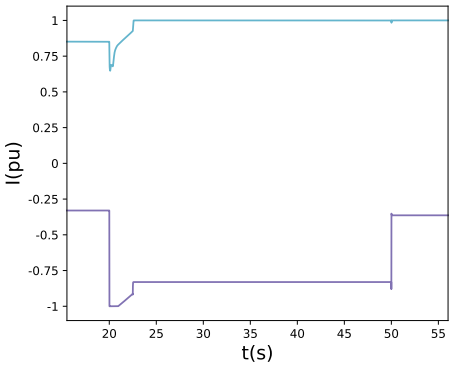
Magnitude controlled by the AVR: modulus of the voltage at the REPC, in pu. The gray dotted line show the AVR setpoint. All PPM units are plotted on the same graph.



Real power output P, measured at the PDR bus.



Reactive power output Q, measured at the PDR bus.



Injected active (light blue line) and reactive (violet line) currents. All PPM units are plotted on the same graph.

Go to html figures

5.2.4 Analysis of results

No analysis is needed in PCS I7.

5.2.5 Compliance checks

Compliance checks required by PCS I7:

Check	value	Compliant?
Unit not disconnected by protections	—	True
Unit remains stable (rotor stability)	—	True

References

[1] *Documentation technique de référence en cours de validité*. RTE. 2024. URL: https://www.services-rte.com/fr/decouvrez-nos-offres-de-service/raccorder-une-installation-de-production.html.

[2] *Dynaωo— A hybrid C++/Modelica open source suite of simulation tools for power systems*. RTE. 2015–2024. URL: https://dynawo.github.io.

Appendix: step-response characteristics

Illustration depicting the definition of the step-response characteristics, taken from IEC 61400-21-1 (Section 3, Terms and definitions).