



# Specification of Test Sequences

## Inverter compliance tests with Czech National Grid code – PPDS:P4

<b>Specification</b>	Number:	VUT/18320/RESLAB/ZP-ZS(AB)/0425
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<b>Tests specification:</b>	Testing procedure:	Test procedure for verifying the compliance of inverters for power generating modules of category A1/A2 and B1/B2
	Range:	Inverter compliance verification for non-synchronous power generating modules of A1+A2 and B1+B2 category
	Requirements:	(CZ) Pravidla provozování distribučních soustav: Příloha 4, 2022 (PPDS:P4)  Specified by Specific country setup requirements for non-synchronous powergenerating modules in the Czech Republic (12/2024), available: <a href="https://www.cezdistribuce.cz/file/edee/distribuce/czech_country_setup_requirements.pdf">https://www.cezdistribuce.cz/file/edee/distribuce/czech_country_setup_requirements.pdf</a>

## Tests details

### Test evaluation:

For each of the listed tests, a binary result of pass "P" or fail "F" is determined based on the relevant acceptance criteria. In case that the result is not evaluated, e.g. due to the irrelevance of the test for the given type of device, the abbreviation of the English words Not Applicable "N/A" in the meaning of not evaluated is indicated in the result field.

### Test facility:

A basic description of the test workplace, including a block diagram representing the layout of its components, is given in Appendix A.

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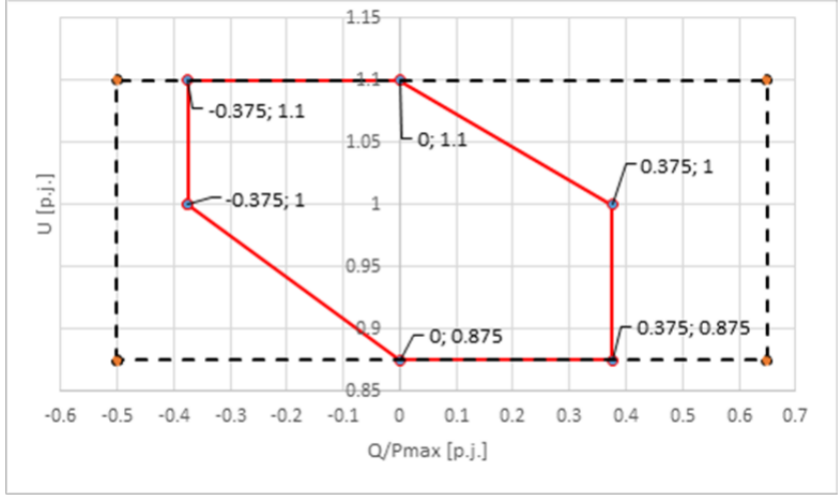
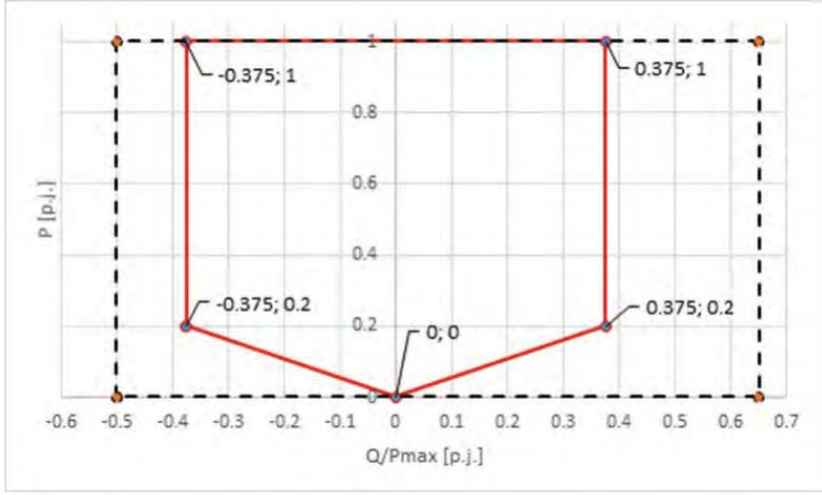
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## Verification

Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM										
Section of PPDS:P4	Description of requirements and acceptance criteria											
1. Maximum delivery of active power												
2 Rozsah platnosti	<p><u>Current applicable requirements</u> The maximum power at the output terminals of the inverter (10-minute mean value) must be limited to no more than 110% of the rated power for all PGM (Power Generating Module) categories.</p> <p><u>Acceptance criterion</u> The test result is considered satisfactory if the active power at the output terminals of the inverter does not exceed the permitted maximum power.</p>	A1 A2 B1 B2										
2. Capability of operation under normal operating frequency range												
9.1 Normální provozní podmínky 9.1.1 Provozní frekvenční rozsah výroben v sítích nn, vn a 110 kV	<p><u>Current applicable requirements</u> PPDS:P4 requires minimum operating times for different frequency ranges according to:</p> <table><tr><td>Frequency range</td><td>Minimum operating time</td></tr><tr><td>47,5-48,5 Hz</td><td>30 min</td></tr><tr><td>48,5-49 Hz</td><td>90 min</td></tr><tr><td>49-51 Hz</td><td>unlimited</td></tr><tr><td>51-51,5 Hz</td><td>30 min</td></tr></table> <p><u>Acceptance criterion</u> The result of the test is considered satisfactory if the device remains connected to the network and active power supply is not disrupted in all frequency ranges. Reduction of active power supply is allowed during the underfrequency and overfrequency in accordance with the currently applicable regulations of PPDS (Chapter 9.3.2 Permissible reduction of active power during underfrequency, or Chapter 9.3.1 Reduction of active power during overfrequency).</p>	Frequency range	Minimum operating time	47,5-48,5 Hz	30 min	48,5-49 Hz	90 min	49-51 Hz	unlimited	51-51,5 Hz	30 min	A1 A2 B1 B2
Frequency range	Minimum operating time											
47,5-48,5 Hz	30 min											
48,5-49 Hz	90 min											
49-51 Hz	unlimited											
51-51,5 Hz	30 min											
3. Minimal requirement for active power delivery at underfrequency												
9.3 Přizpůsobení činného výkonu 9.3.2 Přípustné snížení činného výkonu při podfrekvenci	<p><u>Current applicable requirements</u> Reduction of the maximum power is allowed when the network frequency drops below 49 Hz, with a maximum reduction rate of 2% Pmax/Hz. This applies to the rated conditions of the environment as specified by the device manufacturer.</p>	A1 A2 B1 B2										

Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM
Section of PPDS:P4	Description of requirements and acceptance criteria	
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Section of PPDS:P4	Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type	Type of PGM
	<div data-bbox="459 488 1270 965"> </div> <p data-bbox="427 1016 914 1048"><u>A2+B1+B2 connected to MV and 110 kV</u></p> <p data-bbox="427 1048 1278 1140">The operating area of the inverter in the P-Q space must be defined in accordance with the diagram below – this applies to non-synchronous PGM types A2/B1/B2 connected to the MV and 110 kV grid.</p> <p data-bbox="427 1171 1278 1263">The non-synchronous generation modules A2/B1/B2 must be capable of operating at the maximum delivered active power within the diagram shown in Figure 1-5.</p> <p data-bbox="427 1263 1278 1386">When delivering power below the maximum, the generation module must be capable of operating within the diagram specified in Figure 2-5. If not all generation blocks delivering active power are in operation, the ability to supply P and Q is proportionally reduced.</p> <p data-bbox="427 1417 1278 1541">Non-synchronous PGMs A2/B1/B2 must perform a reactive power change reaching 90% of the requested change without delay, but no later than by <math>t_1 = 4 \text{ s}</math>, with stabilization of parameters as defined in Article 21 (sec. 3 - d) of the RfG by <math>t_2 = 30 \text{ s}</math>.</p>	

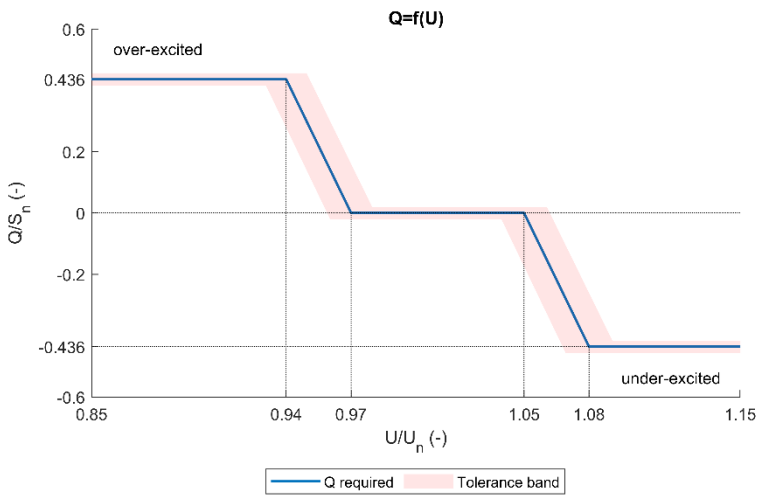
Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM
Section of PPDS:P4	Description of requirements and acceptance criteria	
	 <p style="text-align: center;">Figure 1-5</p>  <p style="text-align: center;">Figure 2-5</p> <p><u>Acceptance criterion</u> The test result is considered satisfactory if all verified points from the working area of the inverter correspond to the required working area. The tolerance of the reactive power supplied by the inverter is <math>\pm 2\% S_n</math>.</p>	
<b>6. Rate of change of frequency immunity</b>		
9.1 Normální provozní podmínky 9.1.1 Provozní frekvenční rozsah výroben v sítích nn, vn a 110 kV	<p><u>Current applicable requirements</u> PGM must not disconnect in the event of a change in network frequency at a rate of change up to <math>\pm 2</math> Hz/s.</p> <p><u>Acceptance criterion</u> The test result is considered satisfactory if the PGM remains in operation and does not disconnect from the network, withstanding frequency changes at the defined rate in accordance with the currently applicable</p>	A1 A2 B1 B2

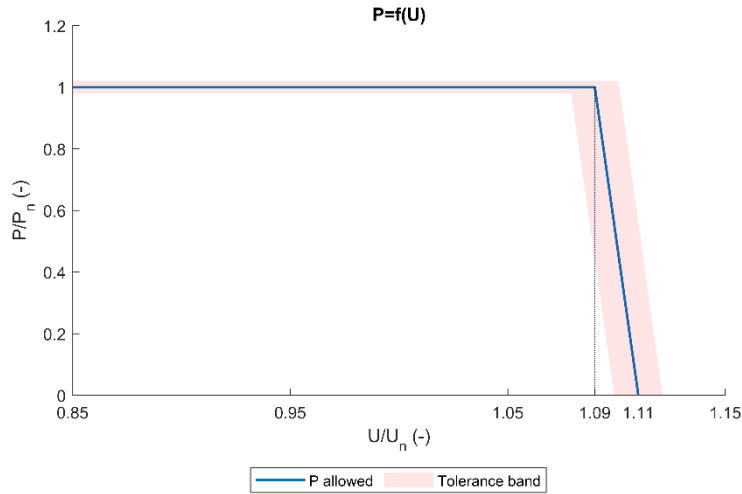
Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM
Section of PPDS:P4	Description of requirements and acceptance criteria	
	regulations of PPDS (9.1.1 Operating frequency range for plants in low voltage networks, medium voltage networks, and 110 kV networks).	
7. Under voltage ride through - UVRT		
9.2.2 Dynamická podpora sítě 9.2.2.1 Překlenutí poruchy při krátkodobém poklesu napětí (Undervoltage ride through - UVRT)	<u>Current applicable requirements</u> The requirement for immunity to UVRT defined by the curve shown in the following figure applies to non-synchronous PGM of category A1-B2.	A1
	<p><u>Acceptance criterion</u> Verification of selected points on capability curve is performed 3 times. The test result is considered satisfactory when the equipment remains in operation (does not disconnect from the network) in at least two out of three series of voltage drops.</p>	A2
		B1
		B2
8. Over voltage ride through - OVRT		
9.2.2 Dynamická podpora sítě 9.2.2.2 Překlenutí poruchy při krátkodobém nadpětí (OVRT)	<u>Current applicable requirements</u> The requirement for immunity to OVRT defined by the curve shown in the following figure applies to non-synchronous PGM of category A1-B2.	A1
		A2
		B1
		B2

Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM
Section of PPDS:P4	Description of requirements and acceptance criteria	
	<p><b>Acceptance criterion</b> Verification of selected points on capability curve is performed 3 times. The test result is considered satisfactory when the equipment remains in operation (does not disconnect from the network) in at least two out of three series of voltage drops.</p>	
<b>9. Recovery of active power after a fault</b>		
9.2.2.4. Velikost a doba obnovy činného výkonu po krátkodobém poklesu napětí	<p><u>Current applicable requirements</u> Non-synchronous PGM of category A2 and higher must restore the active power to the value before the failure (or to the maximum value with regard to the available energy source) with a permissible deviation of <math>\pm 5\%</math> after a fault in the system (transient phenomenon) that did not lead to disconnection of the PGM within 1 second after reaching 85% voltage at the connection point. If the generation module supplies reactive power as a priority during the fault, the restoration of active power starts after reaching 95% of the voltage at the connection point and ends within 1 s.</p> <p><u>Acceptance criterion</u> The test result is considered satisfactory if:</p> <ul style="list-style-type: none"> <li>the inverter is able to restore the supply of active power after a fault to the original value within the prescribed tolerance,</li> <li>the measured recovery time is less than or equal to the required time to restore active power after a fault.</li> </ul>	A2 B1 B2
<b>10. Active power response at overfrequency - P(f)</b>		
9.3 Přizpůsobení činného výkonu 9.3.3 Frekvenční odezva činného výkonu v omezeném frekvenčně závislém režimu	<p><u>Current applicable requirements</u> All PGM must be capable of activating the provision of active power frequency response with parameters and characteristics summarized in the following table. The last row of the table is also based on EN 50549-1, according to which the rate of power increase after deactivating the function should be the same as the rate of power increase after automatic reconnection following a fault.</p>	A1 A2 B1 B2



Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type			Type of PGM										
Section of PPDS:P4	Description of requirements and acceptance criteria												
	<table><tr><td>Reference power</td><td>Momentary output power at function activation</td></tr><tr><td>frequency droop s</td><td>5 %</td></tr><tr><td>Activation threshold <math>f_{TH}</math></td><td>50,2 Hz</td></tr><tr><td>Deactivation threshold <math>f_{STOP}</math></td><td>50,05 Hz</td></tr><tr><td>Rate of Power Increase after Deactivation</td><td>10 % P<sub>n</sub>/min</td></tr></table>	Reference power	Momentary output power at function activation	frequency droop s	5 %	Activation threshold $f_{TH}$	50,2 Hz	Deactivation threshold $f_{STOP}$	50,05 Hz	Rate of Power Increase after Deactivation	10 % P <sub>n</sub> /min		
	Reference power	Momentary output power at function activation											
	frequency droop s	5 %											
	Activation threshold $f_{TH}$	50,2 Hz											
	Deactivation threshold $f_{STOP}$	50,05 Hz											
	Rate of Power Increase after Deactivation	10 % P <sub>n</sub> /min											
Note: The DSOs in document [7] (section 1.5) also define an alternative P(f) setting for non-synchronous PGMs. This setting is requested by the Czech TSO and is expected to be in force with next official revision of the PPDS:P4.													
<u>Acceptance criterion</u> The test result is considered satisfactory if the response parameters are in accordance with the currently applicable requirements of PPDS, meaning: 1. activation and deactivation occur within the correct frequency range, 2. the deviation of 1-minute averages from the expected power, given the required droop and reference power, is not higher than 10% P <sub>n</sub> for all verified frequency levels, 3. the rate of power increase is not greater than the rate required during automatic reconnection after a fault, 4. With increased available power of the inverter, there is no increase in output power beyond the limit value determined by the control characteristic calculated at the time of function activation based on reference power and set droop.													
<b>11. Voltage related control mode for reactive power - Q(U)</b>													
9.4.2 Jalový výkon závislý na napětí – funkce Q(U)	<u>Current applicable requirements</u> According to the PPDS, PGMs must be capable of contributing to maintain the voltage within permissible limits. In case of non-synchronous PGMs connected to the low voltage (category A), reactive power is autonomously controlled and DSO is specifying one of the possible variants. For non-synchronous PGMs category B1/B2, the DSO will specify the mode of reactive power control and Q(U) can be one of them.		A1										
			A2										
			B1										
			B2										
<i>Note: Specifically, ČEZd requires Q(U) only for PGM B1, whereas EG.D does not require this function for PGMs B1 and B2. The recommendation is to have the option in the inverter (generation unit/module) settings to enable or disable the Q(U) function.</i>													
The subject of this test is an autonomous control of reactive power in a voltage-dependent mode using the Q(U) control characteristic with the specific setting (see the following figure) as requested by DSO.													

Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM
Section of PPDS:P4	Description of requirements and acceptance criteria	
	 <p><b>Acceptance criterion</b> The test result is considered satisfactory if the reactive power adheres to the required control characteristic with a permissible deviation of <math>\pm 2</math> % of <math>S_{max}</math> and <math>\pm 1</math> % of <math>U_n</math>.</p>	
<b>12. Dynamic parameters of Q(U)</b>		
9.4.2 Jalový výkon závislý na napětí – funkce Q(U)	<p><u>Current applicable requirements</u> Requested time constant by DSO is <math>\tau = 20s</math>.</p> <p><u>Acceptance criterion</u> Dynamic response is considered passed if the reactive power is within the tolerance band resulting from the behaviour of an equivalent first order filter element and the required time constant. Accepted tolerances are <math>\pm 5</math> % <math>P_n</math> for reactive power values and 3 s for the time delay deviating from an ideal first order filter response.</p>	A1 A2 B1 B2
<b>13. Voltage related active power reduction - P(U)</b>		
9.3.5 Snížení činného výkonu závislé na napětí – funkce P(U)	<p><u>Current applicable requirements</u> Generating plants must be equipped with generators with voltage-dependent active power limitation according to the P(U) control characteristic. The specific values of the P(U) function are determined by the DSO:</p> <ul style="list-style-type: none"> <li>- <math>U1/U_n = 1,09</math> (250,7 V),</li> <li>- <math>U2/U_n = 1,11</math> (255,3 V).</li> </ul> <p>The verification has been conducted for the settings depicted in the following figure.</p>	A1 A2

Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM
Section of PPDS:P4	Description of requirements and acceptance criteria	
	 <p><b>Acceptance criterion</b> The test result is considered satisfactory if the active power adheres to the control characteristic with a permissible deviation of <math>\pm 2\%</math> of <math>S_{max}</math> and <math>\pm 1\%</math> of <math>U_n</math>.</p>	
<b>14. Dynamic parameters of P(U)</b>		
9.3.5 Snížení činného výkonu závislé na napětí – funkce P(U)	<p><b>Current applicable requirements</b> Requested time constant by DSO is <math>\tau = 5s</math>.</p> <p><b>Acceptance criterion</b> Dynamic response is considered passed if the reactive power is within the tolerance band resulting from the behaviour of an equivalent first order filter element and the required time constant. Accepted tolerances are <math>\pm 5\%</math> <math>P_n</math> for reactive power values and 3 s for the time delay deviating from an ideal first order filter response.</p>	A1 A2
<b>15. Automatic connection under normal operating conditions</b>		
Not defined in PPDS	<p><b>Current applicable requirements</b> EN50549-1 assumes the possibility to set the parameters of the function ensuring automatic connection under normal operating conditions, but PPDS does not use this possibility and the parameters are not defined in the current edition. Therefore, the aim of the test is not to verify compliance with the requirements, but to evaluate the behavior of the inverter during automatic connection under normal operating conditions with regard to its settings. Unlike automatic connection after a fault, automatic connection under normal operating conditions applies if the inverter is switched off by the control system before connection, or by disconnecting the DC source, for example for maintenance or inspection.</p>	A1 A2 B1 B2

Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM
Section of PPDS:P4	Description of requirements and acceptance criteria	
	<p><u>Acceptance criterion</u></p> <p>Since the DSO does not use the possibility to define parameters for the automatic connection under normal operating conditions, the acceptance criterion is not defined and if this test is applied, the output of the test is only an evaluation of the parameters in question.</p>	
<b>16. Automatic reconnection after tripping</b>		
9.5. Automatické opětovné připojení výroben	<p><u>Current applicable requirements</u></p> <p>Automatic reconnection and synchronization with the network after protection tripping is possible only when the voltage and frequency are within defined limits for at least a specified observation time. Additionally, the increase in output active power up to the moment of reaching the current available power must occur at a defined rate (in % <math>P_n/\text{min}</math>).</p> <p>The current applicable requirements are follows:</p> <ul style="list-style-type: none"> <li>- voltage range 85 % - 110 % <math>U_n</math></li> <li>- frequency range 47,5 – 50,05 Hz</li> <li>- 300 s observation time</li> <li>- 10 % <math>P_n/\text{min}</math></li> </ul> <p><u>Acceptance criterion</u></p> <p>The test result is considered satisfactory if the following conditions are met:</p> <ol style="list-style-type: none"> <li>1. The inverter does not initiate the reconnection process if the voltage or frequency is outside the allowed limits.</li> <li>2. The inverter does not reconnect before the expiration of the monitoring period, provided that the voltage or frequency remains consistently within the allowed limits during this period.</li> <li>3. The rate of active power rise, evaluated for each minute, stays below the prescribed limit with a tolerance of +1% <math>P_n/\text{min}</math>, or for unregulated or partially regulated inverters, reconnection occurs within the desired time interval or later.</li> </ol>	A1 A2 B1 B2
<b>17. Logic interface for ceasing active power</b>		
9.3. Přizpůsobení činného výkonu 9.3.6 Řízení činného výkonu v závislosti na provozních podmínkách	<p><u>Current applicable requirements</u></p> <p>Generating plants must be equipped with a logic interface (input port) to allow the interruption of active power delivery within 5 seconds of receiving a command on the input port. The disconnecting element enabling remote disconnection must be installed in a way that it remains functional even after the power generation plant is disconnected from the distribution system, allowing the automation of this process.</p> <p><u>Acceptance criterion</u></p> <p>The test result for the interruption of active power delivery is considered satisfactory when the interruption occurs no later than 5 seconds from the moment the command is sent. The interruption of active power delivery is understood as a decrease in active power to 0 W with a tolerance of +5% <math>P_n</math>, taking measurement uncertainties into account.</p>	A1 A2 B1

Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM										
Section of PPDS:P4	Description of requirements and acceptance criteria											
18. Undervoltage protection [27]												
8. Ochrany 8.1 Mikro zdroje 8.2 Výrobní elektrárny s fázovým proudem nad 16A v sítích nn a výrobní připojené do sítí vn a 110kV (VM A1,B1, B2, C, D)	<u>Current applicable requirements</u> According to the currently applicable edition of PPDS, the default recommended setting for undervoltage protection is in accordance with the tables below:	A1										
	A1	A2										
		B1										
		B2										
	<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Maximum trip time</th></tr><tr><td>Undervoltage</td><td>0,85xU<sub>n</sub></td><td>1,5 s</td></tr></table>	Protection	Required setting		Tripping value	Maximum trip time	Undervoltage	0,85xU <sub>n</sub>	1,5 s			
	Protection		Required setting									
		Tripping value	Maximum trip time									
	Undervoltage	0,85xU <sub>n</sub>	1,5 s									
	A2, B1, B2											
	<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Maximum trip time</th></tr><tr><td>Undervoltage 1st level</td><td>0,7xU<sub>n</sub></td><td>0 – 2,7 s</td></tr><tr><td>Undervoltage 2nd level</td><td>0,45xU<sub>n</sub></td><td>≥ 0,15 s</td></tr></table>	Protection	Required setting		Tripping value	Maximum trip time	Undervoltage 1st level	0,7xU <sub>n</sub>	0 – 2,7 s	Undervoltage 2nd level	0,45xU <sub>n</sub>	≥ 0,15 s
Protection	Required setting											
	Tripping value	Maximum trip time										
Undervoltage 1st level	0,7xU <sub>n</sub>	0 – 2,7 s										
Undervoltage 2nd level	0,45xU <sub>n</sub>	≥ 0,15 s										
The DSO specifies protection settings for all PGM categories in document [7] as shown in the table below:												
A1, A2, B1, B2												
<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Maximum trip time</th></tr><tr><td>Undervoltage 1st level</td><td>0,7xU<sub>n</sub></td><td>2,7 s</td></tr><tr><td>Undervoltage 2nd level</td><td>0,45xU<sub>n</sub></td><td>0,2 s</td></tr></table>	Protection	Required setting		Tripping value	Maximum trip time	Undervoltage 1st level	0,7xU <sub>n</sub>	2,7 s	Undervoltage 2nd level	0,45xU <sub>n</sub>	0,2 s	
Protection		Required setting										
	Tripping value	Maximum trip time										
Undervoltage 1st level	0,7xU <sub>n</sub>	2,7 s										
Undervoltage 2nd level	0,45xU <sub>n</sub>	0,2 s										
<u>Acceptance criterion</u> In terms of accuracy, the verification is considered successful if the protection is triggered at the desired value, taking into account the required voltage measurement tolerance for protection purposes (± 1 % U <sub>n</sub> according to both the EN 50549-1 and EN 50549-2). Verification of protection trip time is considered successful if the specified protection trip time is equal to the required trip time within tolerance of ± 100ms.												

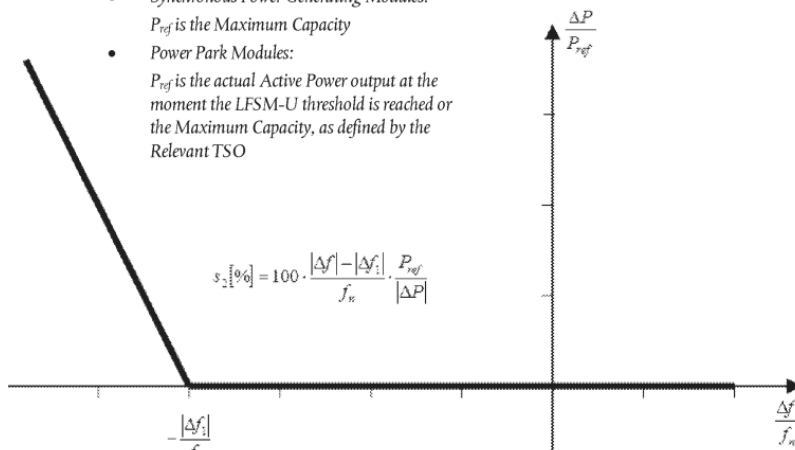
Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM											
Section of PPDS:P4	Description of requirements and acceptance criteria												
19. Overvoltage protection [59]													
8. Ochrany 8.1 Mikro zdroje 8.2 Výrobný elektrifiny s fázovým proudem nad 16A v sítích nn a výrobný připojené do sítí vn a 110kV (VM A1,B1, B2, C, D)	<u>Current applicable requirements</u> According to the currently applicable edition of PPDS, the default recommended setting for overvoltage protection is in accordance with the tables below:	A1											
	<u>A1</u>	A2											
		B1											
		B2											
	<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Maximum trip time</th></tr><tr><td>Overvoltage 1st level</td><td>1,15xUn</td><td>1 s</td></tr><tr><td>Overvoltage 2nd level</td><td>1,20xUn</td><td>0,1 s</td></tr></table>	Protection	Required setting		Tripping value	Maximum trip time	Overvoltage 1st level	1,15xUn	1 s	Overvoltage 2nd level	1,20xUn	0,1 s	
	Protection		Required setting										
		Tripping value	Maximum trip time										
	Overvoltage 1st level	1,15xUn	1 s										
	Overvoltage 2nd level	1,20xUn	0,1 s										
	<u>A2, B1, B2</u>												
<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Maximum trip time</th></tr><tr><td>Overvoltage 1st level</td><td>1,2xUn</td><td>5 s</td></tr><tr><td>Overvoltage 2nd level</td><td>1,25xUn</td><td>0,1 s</td></tr></table>	Protection	Required setting		Tripping value	Maximum trip time	Overvoltage 1st level	1,2xUn	5 s	Overvoltage 2nd level	1,25xUn	0,1 s		
Protection		Required setting											
	Tripping value	Maximum trip time											
Overvoltage 1st level	1,2xUn	5 s											
Overvoltage 2nd level	1,25xUn	0,1 s											
The DSO specifies protection settings for all PGM categories in document [7] as shown in the table below:													
<u>A1, A2, B1, B2</u>													
<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Maximum trip time</th></tr><tr><td>Overvoltage 1st level</td><td>1,15xUn</td><td>5 s</td></tr><tr><td>Overvoltage 2nd level</td><td>1,20xUn</td><td>0,1 s</td></tr></table>	Protection	Required setting		Tripping value	Maximum trip time	Overvoltage 1st level	1,15xUn	5 s	Overvoltage 2nd level	1,20xUn	0,1 s		
Protection		Required setting											
	Tripping value	Maximum trip time											
Overvoltage 1st level	1,15xUn	5 s											
Overvoltage 2nd level	1,20xUn	0,1 s											
<u>Acceptance criterion</u> In terms of accuracy, the verification is considered successful if the protection is triggered at the desired value, taking into account the required voltage measurement tolerance for protections purposes (± 1													

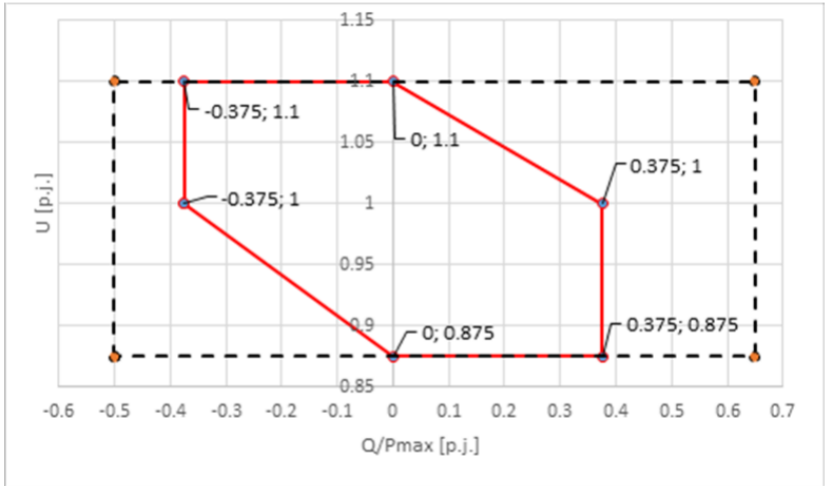
Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM								
Section of PPDS:P4	Description of requirements and acceptance criteria									
	% U <sub>n</sub> according to both the EN 50549-1 and EN 50549-2). Verification of protection trip time is considered successful if the specified protection trip time is equal to the required trip time within tolerance of ± 100ms.									
20. Overvoltage 10 min mean protection										
8. Ochrany 8.1 Mikro zdroje 8.2 Výrobní elektriny s fázovým proudem nad 16A v sítích nn a výrobní připojené do sítí vn a 110kV (VM A1,B1, B2, C, D)	<u>Current applicable requirements</u> According to the currently applicable edition of PPDS, the default recommended setting for the 10-minute overvoltage protection is in accordance with the tables below. The calculation of the mean value is realized in a moving window with a length of 10 minutes.	A1								
	<u>A1</u>	A2								
	<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Trip time</th></tr><tr><td>Overvoltage - 10 min mean value</td><td>1,10xU<sub>n</sub></td><td>3 s</td></tr></table>	Protection	Required setting		Tripping value	Trip time	Overvoltage - 10 min mean value	1,10xU <sub>n</sub>	3 s	B1
	Protection		Required setting							
		Tripping value	Trip time							
	Overvoltage - 10 min mean value	1,10xU <sub>n</sub>	3 s							
			B2							
	<u>A2, B1, B2</u>									
	<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Trip time</th></tr><tr><td>Overvoltage - 10 min mean value</td><td>1,15xU<sub>n</sub></td><td>≤ 60 s</td></tr></table>	Protection	Required setting		Tripping value	Trip time	Overvoltage - 10 min mean value	1,15xU <sub>n</sub>	≤ 60 s	
	Protection		Required setting							
Tripping value		Trip time								
Overvoltage - 10 min mean value	1,15xU <sub>n</sub>	≤ 60 s								
The DSO specifies protection settings for all PGM categories in document [7] as shown in the table below:										
<u>A1, A2, B1, B2</u>										
<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Trip time</th></tr><tr><td>Overvoltage - 10 min mean value</td><td>1,11xU<sub>n</sub></td><td>60 s</td></tr></table>	Protection	Required setting		Tripping value	Trip time	Overvoltage - 10 min mean value	1,11xU <sub>n</sub>	60 s		
Protection		Required setting								
	Tripping value	Trip time								
Overvoltage - 10 min mean value	1,11xU <sub>n</sub>	60 s								
<u>Acceptance criterion</u> Verification of the 10-minute overvoltage protection tripping value, trip time, and voltage measurement accuracy for evaluating the moving average is considered successful if the trip time is within the limits defined by the times T <sub>1</sub> and T <sub>2</sub> according to the following relationships:										
<ul style="list-style-type: none"><li><math>T_1 = \frac{(G_{S,U10min}-A_{r,U}) - U_{Start}}{U_{End} - U_{Start}} \times 600</math></li><li><math>T_2 = \frac{(G_{S,U10min}+A_{r,U}) - U_{Start}}{U_{End} - U_{Start}} \times 600 + T_{vyp}</math></li></ul>										

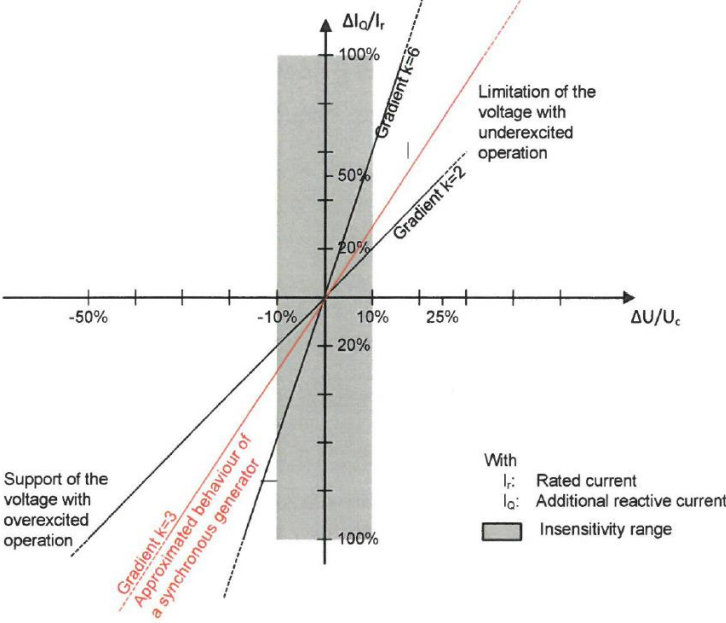
Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM								
Section of PPDS:P4	Description of requirements and acceptance criteria									
	<p>where:</p> <ul style="list-style-type: none"><li>• <math>G_{S\_U10min}</math> – tripping value,</li><li>• <math>A_{r\_U}</math> – required accuracy for voltage protections,</li><li>• <math>U_{Start}</math> – initial voltage level (<math>U_n</math>),</li><li>• <math>T_{vyp}</math> – trip time.</li></ul>									
21. Underfrequency protection [81<]										
8. Ochrany 8.1 Mikrozdroje 8.2 Výrobní elektřiny s fázovým proudem nad 16A v sítích nn a výrobní připojené do sítí vn a 110kV (VM A1,B1, B2, C, D)	<p><u>Current applicable requirements</u></p> <p>According to the currently applicable edition of PPDS, the default recommended setting for underfrequency protection is in accordance with the tables below:</p>	A1								
	<p><u>A1</u></p> <table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Trip time</th></tr><tr><td>Underfrequency</td><td>47,5 Hz</td><td>0,5 s</td></tr></table>	Protection	Required setting		Tripping value	Trip time	Underfrequency	47,5 Hz	0,5 s	A2
	Protection		Required setting							
		Tripping value	Trip time							
	Underfrequency	47,5 Hz	0,5 s							
	<p><u>A2, B1, B2</u></p> <table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Trip time</th></tr><tr><td>Underfrequency</td><td>47,5 Hz</td><td>≤ 100 ms</td></tr></table>	Protection	Required setting		Tripping value	Trip time	Underfrequency	47,5 Hz	≤ 100 ms	B1
	Protection		Required setting							
		Tripping value	Trip time							
	Underfrequency	47,5 Hz	≤ 100 ms							
	<p>The DSO specifies protection settings for all PGM categories in document [7] as shown in the table below:</p> <p><u>A1, A2, B1, B2</u></p> <table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Trip time</th></tr><tr><td>Underfrequency</td><td>47,5 Hz</td><td>≤ 100 ms</td></tr></table>	Protection	Required setting		Tripping value	Trip time	Underfrequency	47,5 Hz	≤ 100 ms	B2
Protection	Required setting									
	Tripping value	Trip time								
Underfrequency	47,5 Hz	≤ 100 ms								
<p><u>Acceptance criterion</u></p> <p>In terms of accuracy, the verification is considered successful if the protection is triggered at the desired value, taking into account the required frequency measurement tolerance for protections purposes (± 50 mHz according to both the EN 50549-1 and EN 50549-2). Verification of protection trip time is considered successful if the specified protection trip time is equal to the required trip time within tolerance of ± 100ms.</p>										



Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM								
Section of PPDS:P4	Description of requirements and acceptance criteria									
22. Overfrequency protection [81>]										
8. Ochrany 8.1 Mikro zdroje 8.2 Výrobní elektrárny s fázovým proudem nad 16A v sítích nn a výrobní připojené do sítí vn a 110kV (VM A1,B1, B2, C, D)	<u>Current applicable requirements</u> According to the currently applicable edition of PPDS, the default recommended setting for overfrequency protection is in accordance with the tables below:	A1								
	A1	A2								
		B1								
		B2								
	<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Trip time</th></tr><tr><td>Overfrequency</td><td>52 Hz</td><td>0,5 s</td></tr></table>	Protection	Required setting		Tripping value	Trip time	Overfrequency	52 Hz	0,5 s	
	Protection		Required setting							
		Tripping value	Trip time							
	Overfrequency	52 Hz	0,5 s							
	A1, A2, B1, B2									
	<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Trip time</th></tr><tr><td>Overfrequency</td><td>51,5 Hz</td><td>≤ 100 ms</td></tr></table>	Protection	Required setting		Tripping value	Trip time	Overfrequency	51,5 Hz	≤ 100 ms	
Protection	Required setting									
	Tripping value	Trip time								
Overfrequency	51,5 Hz	≤ 100 ms								
The DSO specifies protection settings for all PGM categories in document [7] as shown in the table below:										
A1, A2, B1, B2										
<table><tr><th rowspan="2">Protection</th><th colspan="2">Required setting</th></tr><tr><th>Tripping value</th><th>Trip time</th></tr><tr><td>Overfrequency</td><td>51,5 Hz</td><td>≤ 100 ms</td></tr></table>	Protection	Required setting		Tripping value	Trip time	Overfrequency	51,5 Hz	≤ 100 ms		
Protection		Required setting								
	Tripping value	Trip time								
Overfrequency	51,5 Hz	≤ 100 ms								
<u>Acceptance criterion</u> In terms of accuracy, the verification is considered successful if the protection is triggered at the desired value, taking into account the required frequency measurement tolerance for protections purposes (± 50 mHz according to both the EN 50549-1 and EN 50549-2). Verification of protection trip time is considered successful if the specified protection trip time is equal to the required trip time within tolerance of ± 100ms.										
23. Parametrization and security against unauthorized access to settings										
Not defined in PPDS	<u>Current applicable requirements</u> According to the currently valid edition of the PPDS, there are no requirements for securing the settings of the inverter by unauthorized persons.	A1								
		A2								
	<u>Acceptance criterion</u> The test result is considered satisfactory if the setting of all adjustable functions is available and is protected against unauthorized access by a suitable means, for example a password or a seal.	B1								
		B2								

Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM
Section of PPDS:P4	Description of requirements and acceptance criteria	
<b>24. Active power response to underfrequency – P(f)</b>		
9.3.3 Frekvenční odezva činného výkonu v omezeném frekvenčně závislém režimu	<p><b>Current applicable requirements</b></p> <p>Newly installed generating modules of category B2 must be capable of activating the provision of active power frequency response in the limited frequency sensitive mode underfrequency (LFSM-U) according to figure. The threshold value and droop must be settable. The threshold value must be adjustable within the range of 49.5–49.8 Hz, and the droop within 4–10%.</p> <p>Default settings for connection to the grid:</p> <ul style="list-style-type: none"> <li>- Frequency threshold: 49.8 Hz</li> <li>- Droop: 5%</li> </ul> <p>The generating modules must be capable of increasing active power output up to their maximum capacity</p> <div style="display: flex; align-items: center;"> <ul style="list-style-type: none"> <li>Synchronous Power Generating Modules: <math>P_{ref}</math> is the Maximum Capacity</li> <li>Power Park Modules: <math>P_{ref}</math> is the actual Active Power output at the moment the LFSM-U threshold is reached or the Maximum Capacity, as defined by the Relevant TSO</li> </ul>  </div> <p><b>Acceptance criterion</b></p> <p>The test result is considered satisfactory if the response parameters comply with the currently applicable requirements of PPDS:P4, meaning:</p> <ol style="list-style-type: none"> <li>1. The activation and deactivation of the function occur within the correct frequency ranges (f2–f3 or f1–f2 respectively),</li> <li>2. The deviation of 1-minute average values from the expected power—defined by the required droop and reference power—does not exceed 10% of Pn for all verified frequency levels.</li> <li>3. The rate of change of power after function deactivation does not exceed the rate required for automatic reconnection after a fault.</li> </ol>	B2

Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type		Type of PGM
Section of PPDS:P4	Description of requirements and acceptance criteria	
<b>25. Supply/absorption of reactive power (Q) at maximum active power (P) output of asynchronous power-generating modules B2</b>		
9.2.1.2 Podpora napětí pomocí jalového výkonu VM A2, B1, B2, C a D (v sítích vn a 110 kV)	<p><u>Current applicable requirements</u></p> <p>A non-synchronous generating module of category B2 must, in accordance with Article 21.3 a), b), and c) of the RfG, be capable of supplying additional reactive power. This additional reactive power compensates for the charging power of the overhead line or high-voltage cable between the high-voltage terminals of the block transformer of the non-synchronous generating module—or, if no block transformer exists, between the inverter terminals—and the point of connection. The reactive power is supplied by the responsible owner of the line or cable during active power delivery at the point of connection.</p> <p>Non-synchronous generating modules of categories B2 must be capable of operating at maximum active power delivery within the capability diagram shown below.</p>  <p><u>Acceptance criterion</u></p> <p>The test result is considered satisfactory if all verified points within the operating U-Q/P area of the inverter comply with the required operating range as defined in the currently valid edition of PPDS:P4.</p>	B2
<b>26. Fast fault current in case of a fault and priority of active or reactive power contribution</b>		
9.2.2.3 Požadavky na zkratový proud nesynchronních VM 9.2.2.5 Priorita příspěvků činného nebo jalového výkonu	<p><u>Current applicable requirements</u></p> <p>Non-synchronous generating modules B1 and B2 must be capable of activating fault current contribution, either by:</p> <ul style="list-style-type: none"> <li>- supplying a fast fault current at the point of connection, or</li> <li>- measuring voltage deviations at the terminals of individual blocks of the non-synchronous generating module and supplying</li> <li>- a fast fault current at the terminals of these blocks.</li> </ul> <p>The principle of the requirement for reactive fault current delivery is illustrated below.</p>	B1 B2

Section of PPDS:P4	Inverter compliance tests with Czech National Grid code – PPDS:P4 requirements for A1/A2 and B1/B2 type	Type of PGM
	<p>The required magnitude of the fault current is given by the following formula: <math>D_i = k \cdot D_u</math>,</p> <p>where:</p> <ul style="list-style-type: none"> <li>- <math>D_i</math> = instantaneous current contribution as a percentage of rated current,</li> <li>- <math>k</math> = coefficient expressing the range of reactive current contribution (primarily dependent on the transformer's short-circuit voltage, <math>u_k</math>),</li> <li>- <math>D_u</math> = voltage deviation from the nominal value in percentage.</li> </ul> <p>According to PPDS:P4, the coefficient <math>k</math> must be within the range <math>2 \leq k \leq 6</math>.</p> <p>The DSO specifies the <math>k</math> coefficient = 3 in the document [7] .</p> <p>During a fault, non-synchronous generating modules B1 and B2 must prioritize reactive power delivery over active power.</p>  <p><u>Acceptance criterion</u></p> <p>The test result is considered satisfactory if, based on the measured data, the reactive power was delivered within the required time and magnitude, within the prescribed tolerance, and if the insensitivity band is respected in accordance with the currently valid PPDS:P4 requirements and DSO specification.</p>	

## Annex A:

### Basic description of the test workplace

The diagram of the used test system for testing 3-phase inverters is shown in Fig. 1 and the real form of the test workplace then in Fig. 2. Further, the list of equipment of the test system is in Tab. 1.

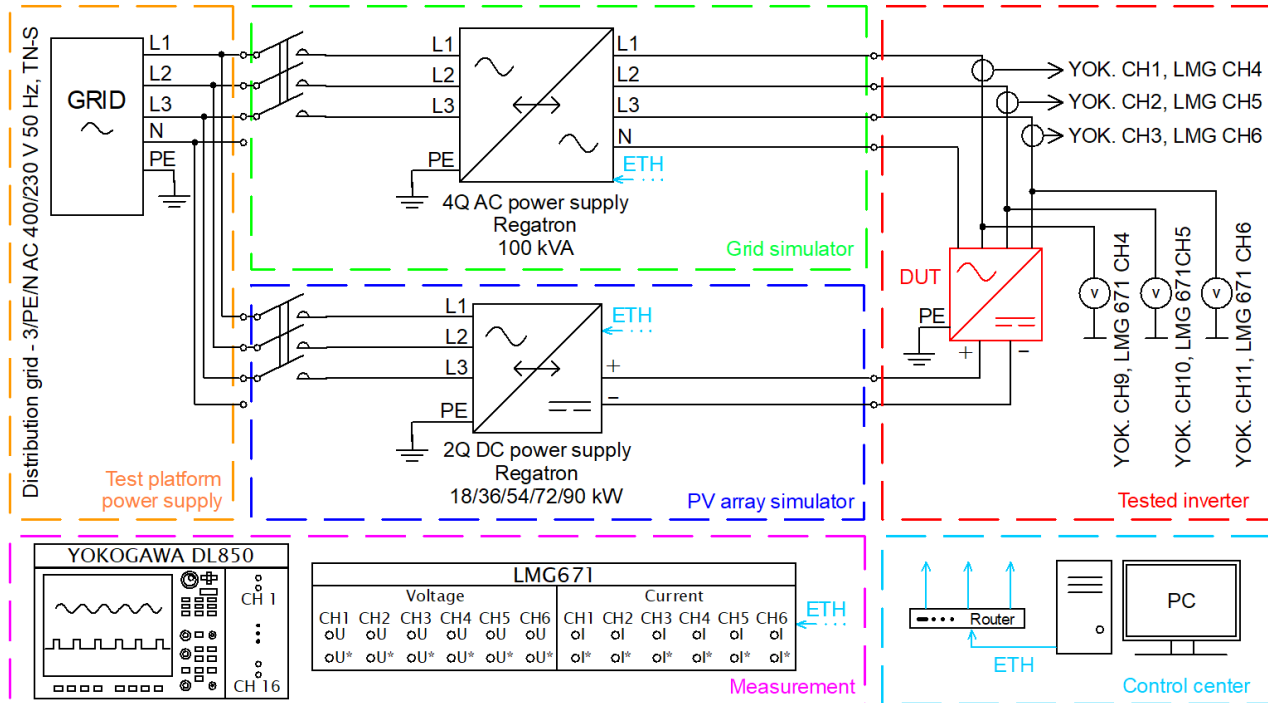


Fig. 1 Schematic diagram of test workplace

The test circuit consists of a programmable power supply and a tested inverter powered by a PV string simulator. A 2x50 kVA power supply (grid simulator) are used to simulate various operating conditions, which enable the static and dynamic response of the tested device to be verified. The programmable DC simulators are used to simulate the nonlinear I-V characteristic of the PV string according to the input parameters of the tested device up to a power of 18 kW. For the tests, a standard course of the VA characteristic corresponding to the mathematical model defined in EN50530 [1] was set.

The workplace also includes the necessary measuring technology, which ensures the monitoring of electrical quantities. A HIOKI power analyzer with aggregation and recording of measured values every 50ms is used to examine longer periods of time. For tests that require greater accuracy for accurate evaluation, a Yokogawa oscilloscope with a sampling time of 10 kS/s or higher is used. The accuracy of measuring devices is summarized in Tab. 2. For specific evaluation of the PU/QU regulation the precise power meter LMG500 and LMG671 are used to measure the relevant active and reactive power on 1st harmonic

Tab. 1. List of used equipment

Device	Type
Scopecorder	Yokogawa DL850
PV and Battery simulator	EA-PSB 9750-40
PV string simulator	Chroma 62150H-1000S
PV and Battery string simulator (5x)	Regatron G5.UNV.18
Grid Simulator (2x)	Regatron TC.ACS 50 kVA
SW for PV string control	SASControl
SW for grid simulator control	ACSCControl
Power analyzer	ZES Zimmer LMG671
Power analyzer	ZES Zimmer LMG500
Power analyzer	Hioki PW3390
Current clamps (3x)	Chauvin arnoux C100



Fig. 2 Test workplace

Tab. 2. Accuracy of measuring devices

Device	Quantity	Basic accuracy
Hioki 3390 Power analyzer	Voltage	$\pm 0,04 \% \text{ rdg. } \pm 0,05 \% \text{ f.s.}$
	Current	$\pm 0,04 \% \text{ rdg. } \pm 0,05 \% \text{ f.s.}$
	Active power	$\pm 0,04 \% \text{ rdg. } \pm 0,05 \% \text{ f.s.}$
Hioki 9272-10 Current clamps	Current – amplitude	$\pm 0,3 \% \text{ rdg. } \pm 0,01 \% \text{ f.s.}$
	Current – phase	$\pm 0,2^\circ$
Yokogawa DL 850 - 701260	Voltage	$\pm (1,5 \% \text{ of } 10 \text{ div})$
Yokogawa DL 850 - 701251	Current	$\pm (0,25 \% \text{ of } 10 \text{ div})$
Chauvin arnoux C100	Current	$< 3\%$
	Phase error	$< 3\%$
LMG500 (45Hz...65Hz)	Voltage	$\pm 0.01 \% \text{ rdg. } \pm 0,02 \% \text{ f.s.}$
	Current	$\pm 0.01 \% \text{ rdg. } \pm 0,02 \% \text{ f.s.}$
	Power	$\pm 0.015 \% \text{ rdg. } \pm 0,01 \% \text{ f.s.}$
LMG671 (45Hz...65Hz)	Voltage	$\pm 0.01 \% \text{ rdg. } \pm 0,02 \% \text{ f.s.}$
	Current	$\pm 0.01 \% \text{ rdg. } \pm 0,02 \% \text{ f.s.}$
	Power	$\pm 0.015 \% \text{ rdg. } \pm 0,01 \% \text{ f.s.}$



## References

- [1] ČSN EN 50530: 2010. Celková účinnost fotovoltaických inverterů spojených s elektrorozvodnou sítí
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- [4] ČSN EN 50549-2: 2019. Požadavky na paralelně připojené výrobní s distribučními sítěmi - Část 2: Připojení k distribuční síti středního napětí - Výrobní do typu B a včetně
- [5] ČSN EN 50549-10: 2023. Požadavky na paralelně připojené výrobní s distribučními sítěmi - Část 10: Zkoušky výroben elektřiny pro posouzení shody
- [6] VUT/18320/RESLAB/ZP-ZS(A)/0923. Zkušební postup pro ověření souladu střídačů pro výrobní moduly kategorie A1 a A2. Vysoké učení technické v Brně, 2023
- [7] DSO – Specific country setup requirements for non-synchronous power generating modules in the Czech Republic (12/2024), available:  
[https://www.cezdistribuce.cz/file/edee/distribuce/czech\\_country\\_setup\\_requirements.pdf](https://www.cezdistribuce.cz/file/edee/distribuce/czech_country_setup_requirements.pdf)