

Content

- Foreword..... 4**
- 1 Introduction..... 6**
 - 1.1 Stability properties of power-generating units..... 6
 - 1.2 Current requirements for frequency and active power control 7
 - 1.2.1 Island operation and separate network operability in accordance with Chapter 10.2.1.4 from VDE-AR-N 4130..... 7
 - 1.2.2 Active power output in accordance with Chapter 10.2.4..... 7
 - 1.2.3 Primary control power in accordance with Chapter 10.5.3 8
 - 1.3 Assessment and further development of requirements..... 8
- 2 Abbreviations and definitions..... 9**
 - 2.1 Abbreviations 9
 - 2.2 Definitions 9
- 3 Requirements for power-generating modules and continuously adjustable storage systems and consumption equipment 13**
 - 3.1 Response to a critical network frequency 13
 - 3.2 Response to steep frequency gradients (RoCoF) and to angular steps..... 13
 - 3.3 Requirements for type 1 and type 2 power-generating modules..... 13
 - 3.3.1 Contribution to primary control based on network security 13
 - 3.3.2 Requirements limited or extended due to technology-specific restrictions..... 16
 - 3.3.3 Further requirements for frequency deviations..... 16
 - 3.4 Requirements for continuously adjustable storage systems 17
 - 3.4.1 Contribution to primary control based on network security 17
 - 3.5 Requirements for continuously adjustable consumption equipment 18
 - 3.6 End of critical network state and return to normal operation 18
- 4 Basic approach for verification of the primary control based on network security 19**
 - 4.1 Verification procedure for type 1 PGMs..... 19
 - 4.1.1 Simulation verification (detailed modelling, measurements and simulation) 19
 - 4.1.2 Example for verification of the requirements for type 1 PGUs in a fictitious island network..... 20
 - 4.1.3 Extent of simulation verifications for primary control based on network security 22
 - 4.1.4 Description and characteristic values of the model for a steam turbine generation unit 22
 - 4.1.5 Small-signal behaviour 23
 - 4.1.6 Large-signal behaviour 23
 - 4.2 Verification procedure for type 2 PGMs..... 25
 - 4.2.1 Detailed modelling, measurements and simulation 26
 - 4.2.2 Example for the verification of the requirements for type 2 PGUs in a fictitious island network..... 27
 - 4.3 Verification procedure for type 2 PGCM 30
 - 4.3.1 Detailed modelling, measurements and simulation 30
 - 4.4 Verification procedure for continuously adjustable consumption equipment 32
 - 4.5 Additional reports within the PGM certification process 32
- Annex A – Dynamic frequency response with rule-compliant turbine control 33**
- Bibliography 36**

Table of Figures

Figure 1 - Requirement for the output power of power-generating modules in dynamic short-time operation	16
Figure 2 - Fictitious island network for verifying the properties of a type 1 PGU.....	21
Figure 3 - Step response of type 1 PGUs at a load application of 10% (standard and classic models)	21
Figure 4 - Principal block diagram of the frequency-controlled power controller in a summation circuit	22
Figure 5 - Checking the small-signal stability within the operating range of 75% to 100%	23
Figure 6 - Partial load disconnection of the PGM from full load to a partial load of 55%.....	24
Figure 7 - Load increase of the PGM from a partial load of 55% to 70%.....	24
Figure 8 - Fictitious low-voltage island network for verifying the properties of a type 2 PGU..	25
Figure 9 - Fictitious MV and HV island network for verifying the properties of a type 2 PGU..	25
Figure 10 - Simulation of a type 2 PGM (PV plant in accordance with a WECC model [15]); load disconnection from 100% to 55%.....	28
Figure 11 - Simulation of a type 2 PGM (PV plant in accordance with a WECC model [15]); load disconnection from 55% to 10%.....	28
Figure 12 - Simulation of a step load application from 65% to 75%	29
Figure 13 - Reduction to a partial load (from 90% to 55%) and a load increase back to 90%	29
Figure 14 - Model of a steam turbine with speed control.....	34
Figure 15 - Model of steam turbine with frequency-controlled power control (deviations from the steady state).....	34
Figure 16 - Simulation of electric power after a step change of the actual frequency by 125 mHz (operation on a large network).....	34
Figure 17 - Simulation of the frequency at a step load change (0.05 p.u.) (separate network operation)	35

Table of Tables

Table 1 - Dynamic requirements regarding primary control for the setting ranges of type 1 and type 2 PGM/PGCM.....	15
--	----