Determination and evaluation of frequency in power supply networks

Effects of grid-side interference

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VDE FNN

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List of Abbreviations

ADC ..... *Analogue-to-digital converter*
AR ..... *Automatic reclosing*
CB ..... *circuit-breaker*
CBLS ..... *Contingency Based Load Shedding*
DFT ..... *Discrete Fourier Transform*
ENTSO-E ..... *European Network of Transmission System Operators*
FFT ..... *Fast-Fourier-Transformation*
FIR ..... *Finite Impulse Response*
IIR ..... *Infinite Impulse Response*
LSE ..... *Least Square Estimation*
NC ER ..... *Network Code Electricity Emergency and Restoration*
NDZ ..... *Non-Detection-Zone*
PLL ..... *Phase-Locked-Loop*
PMU ..... *Phasor Measurement Unit*
RE ..... *Renewable Energy*
ROCOF ..... *Rate of change of frequency*
SFR ..... *Simplified-Frequency-Response*
THD ..... *Total Harmonic Distortion*
UFLS ..... *Underfrequency load shedding*

List of Formulas

$\mathrm{d}f/\mathrm{d}t$	Frequency change (quasi-steady)
f	Operating frequency, momentary value
f_{nenn}	Nominal frequency 50 Hz, or rated frequency f_r
$f_<$	Setting value of the underfrequency protection
Δf	Amount of the required accuracy without disturbance variables: The underfrequency protection does reliably not respond at $f > (f_< + \Delta f)$, at $f < (f_< - \Delta f)$ it responds if there are no disturbances.
Δf_{ob}	Amount of the required accuracy for tests for unwanted operation with disturbance variables: The underfrequency protection will reliably not respond at $f > (f_< + \Delta f_{\mathrm{ob}})$ if disturbances are present.
Δf_{un}	Amount of required accuracy for tests for failure to operate of protection with disturbance variables: The underfrequency protection responds reliably at $f > (f_< + \Delta f_{\mathrm{un}})$ when disturbances are present.
H	Equivalent inertia constant of all synchronous generating units
ΔP	Change in active power ($P_{\mathrm{Verbrauch}} - P_{\mathrm{Erzeugung}}$)
S_{nenn}	Nominal apparent power of the machines
t_{AFi}	Tripping time of the underfrequency protection at the i test. If ramps are used, then the tripping time is considered to be the time when the pickup value is first undershot until the trip contact of the protection device is closed.
t_{AFmmax}	Maximum trip time with disturbances Maximum value of all measurements with disturbances
t_{AFomax}	Maximum trip time without disturbances Maximum value of all measurements without disturbances
t_{nach}	Time period during which no unwanted operation may occur
t_{vor}	Duration of pre-fault voltage during tests
U_{B}	The voltage value that has to be undershot for the underfrequency protection to be blocked.

Disclaimer: This document follows German notation standards concerning decimal separators and the following symbols:

- *U equals voltage V*
- *index 'nenn' equals 'nom' for nominal values*
- *L1/L2/L3 equals A/B/C for line indication*

Foreword

The network frequency is an important quantity for robust control and fault detection in electrical networks. However, in rapidly changing (transient) network conditions, the network frequency is usually not clearly definable and a compromise has to be found between a very accurate and a very fast measurement.

This FNN Note describes the relationships between measurement duration and measurement accuracy according to the current state of knowledge and provides an overview of different measurement methods and their use cases. The focus is mainly on grid protection and the Note is consequently addressed to grid operators, manufacturers and users. It replaces Version 1 of the FNN Note "Determination and evaluation of the power frequency - effects of line-side disturbances" from 2017. The chapters have been reorganised according to functions and ranges of application and expanded thematically.

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