DEVELOPMENT OF TRANSITIONAL METHODS

Determination of the Efficiency of Inverters

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Inverters

Proposed **functional parameter:**

> *"1 kWh of AC power output from a reference photovoltaic system (excluding the efficiency of the inverter) under predefined climatic and installation conditions for 1 year and assuming a service life of 10 years".*

Model the performance of the inverter

- DC to AC conversion efficiency

- Efficiency MPP tracking: static and dynamic

IEC 61683 Photovoltaic systems – Power conditioners- Procedure for measuring efficiency

- Second edition under development (Jan 2020)

- Applicable to stand-alone and utility-interactive PV systems

- **Efficiency** calculated from direct measurement of input and output power at various levels of rated power

Total load, % of rated VA	5	10	25	50	75	100	120
Grid-connected		✓	✓	✓	✓	✓	✓
Stand-alone	✓	✓	✓	✓	✓	✓	✓

The resulting data shall be presented in tabular form and may also be presented graphically

IEC 61683 Photovoltaic systems – Power conditioners- Procedure for measuring efficiency

- **Weighted average efficiency**: $\sum k_i \cdot h_I$

  Weighting factors, k_i, depend on the inverter type

  - Grid-connected: regional irradiance duration curve
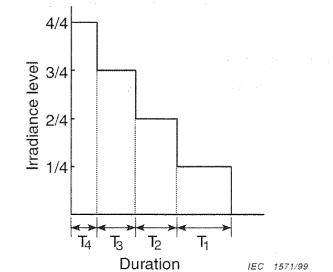
  - Stand-alone: load duration curve

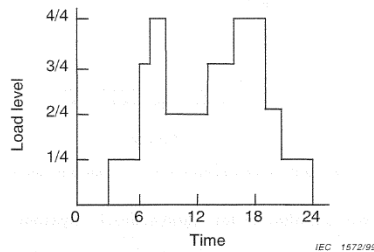Figure C.1 – An example of an irradiance duration curve
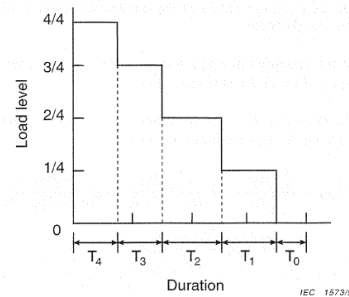

Figure C.2 – An example of a load profile

Figure C.3 – An example of a load duration curve

European Commission

EN 50530 Overall efficiency of grid connected inverters

- Current state: withdrawn

- Procedure for measuring the efficiency of the static and dynamic Maximum Power Point Tracking (MPPT)

- **Overall efficiency** calculated from static MPPT and the conversion efficiency from IEC 61683 with additional measurements.

$$P_{AC} = h_{conv} \; P_{DC} = h_{conv} \; h_{MPPT} \; P_{MPP}$$

Total load, % of rated VA	5	10	20	25	30	50	75	100	120
Grid-connected	✓	✓	✓	✓	✓	✓	✓	✓	✓

European Commission

EN 50530 Overall efficiency of grid connected inverters

Weighted MPPT and conversion efficiencies

- European Efficiency

$$h_{EUR} = 0.03\ h_{5\%} + 0.06\ h_{10\%} + 0.13\ h_{20\%} + 0.10\ h_{30\%} + 0.48\ h_{50\%} + 0.20\ h_{100\%}$$
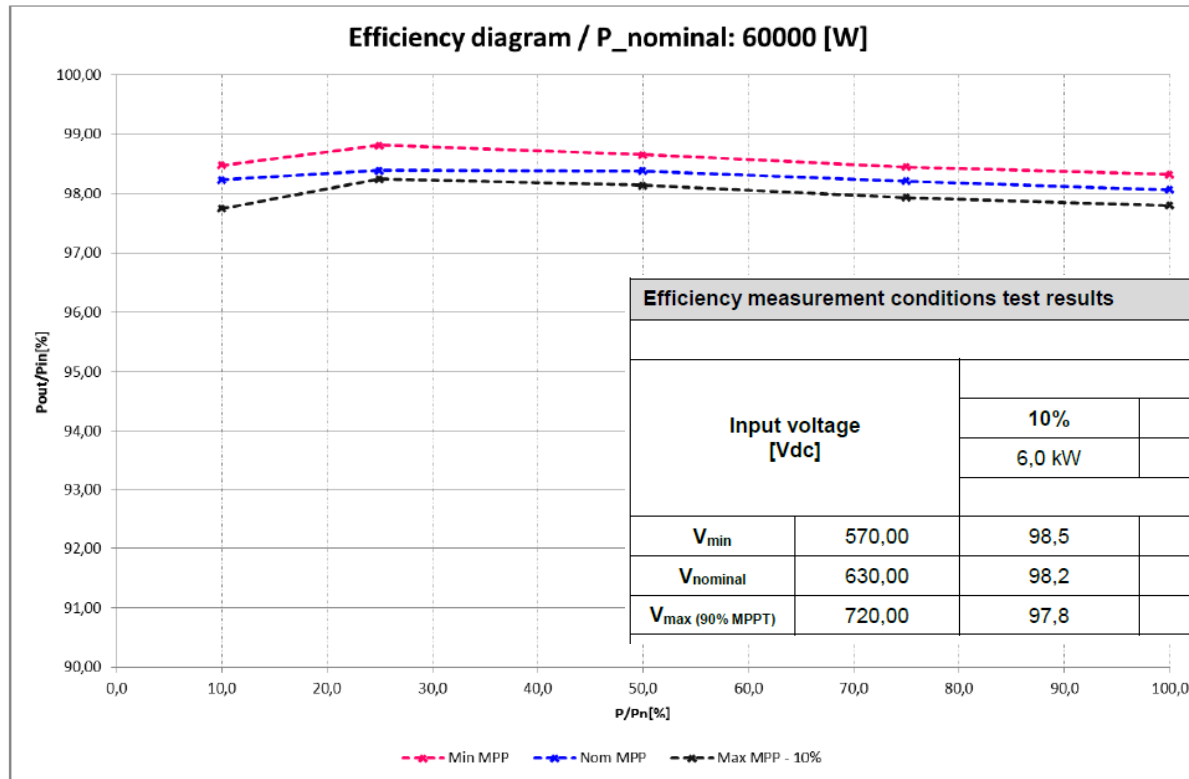
- CEC Efficiency (California Energy Commission)

$$h_{CEC} = 0.04\ h_{10\%} + 0.05\ h_{20\%} + 0.12\ h_{30\%} + 0.21\ h_{50\%} + 0.53\ h_{75\%} + 0.05\ h_{100\%}$$

h_i static MPPT efficiency at partial MPP power: MPP_i ($P_{MPP,PVS}/P_{DC,r}$)

$P_{MPP,PVS}$ Power provided by the power simulator
$P_{DC,r}$ Rated input power of the inverter

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Inverter information. Example

Efficiency diagram / P_nominal: 60000 [W]

IEC 61683

Efficiency measurement conditions test results

Input voltage [Vdc]		Power in [W] (nom. 60000W)				
		10%	25%	50%	75%	100%
		6,0 kW	15,0 kW	30,0 kW	45,0 kW	60,0 kW
		η in [%]				
Vmin	570,00	98,5	98,8	98,7	98,5	98,3
Vnominal	630,00	98,2	98,4	98,4	98,2	98,1
Vmax (90% MPPT)	720,00	97,8	98,3	98,1	97,9	97,8

STP 60-10

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Inverter datasheet. Examples

Input (DC)

Max. DC power (@ cos φ = 1)	1320 W	1850 W
Max. DC voltage	400 V	400 V
MPP voltage range	100 V – 320 V	147 V – 320 V
DC nominal voltage	120 V	180 V
Min. DC voltage / start voltage	100 V / 120 V	139 V / 180 V
Max. input current / per string	12.6 A / 12.6 A	12.6 A / 12.6 A
Number of MPP trackers / strings per MPP tracker	1 / 2	1 / 2

Output (AC)

AC nominal power (@ 230 V, 50 Hz)	1200 W	1550 W
Max. AC apparent power	1200 VA	1700 VA
Nominal AC voltage; range	220, 230, 240 V; 180 V – 265 V	220, 230, 240 V; 180 V – 265 V
AC grid frequency; range	50, 60 Hz; ± 4.5 Hz	50, 60 Hz; ± 4.5 Hz
Max. output current	6.1 A	8.6 A
Power factor (cos φ)	1	1
Phase conductors / connection phases	1 / 1	1 / 1

Efficiency

Max. efficiency / Euro-eta	92.1 % / 90.9 %	93.5 % / 91.8 %

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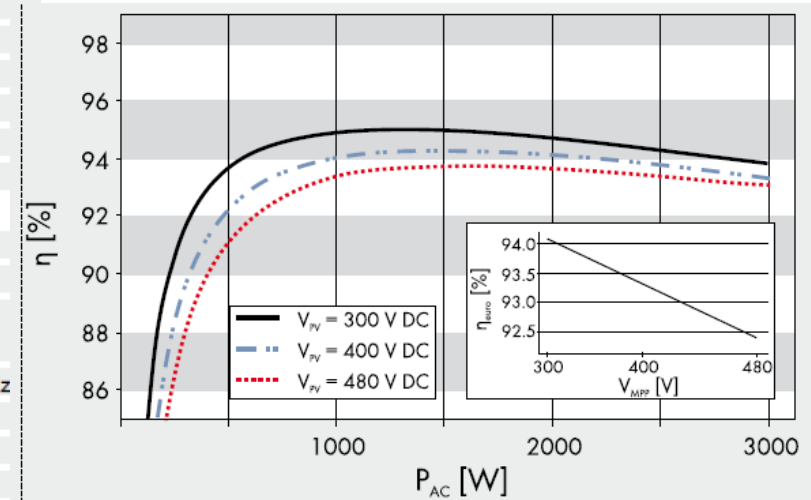
Inverter datasheet. Examples

Input (DC)	
Recommended PV array power range[1]	20.6 - 26.8 kW
Voltage range MPP[2]	560 - 820 V
Min. voltage for Pnom at rated Vac	560 V
Maximum voltage[3]	1,000 V
Maximum current[4]	37 A
Number of inputs	1
MPPT	1

Output (AC)	
Rated power	20 kW
Max. temperature at rated power[5]	55 °C
Maximum current	29 A
Rated voltage	400 V
Voltage range	187 - 528 V
Frecuency	50 / 60 Hz
Power Factor	1
Power Factor adjustable[6]	Yes. Smax=20 kVA; Qmax=20 kVAR
THD	<3%

General Information	
Refrigeration system	Forced ventilation
Air flow	200 m³/h
Stand-by consumption[7]	10 W
Consumption at night	1 W
Ambient temperature	-25 °C to 65 °C
Relative humidity (non-condensing)	0 - 100%
Protection class	IP65
Marking	CE

Efficiency	
Maximum efficiency	98.5%
Euroefficiency	98.3%

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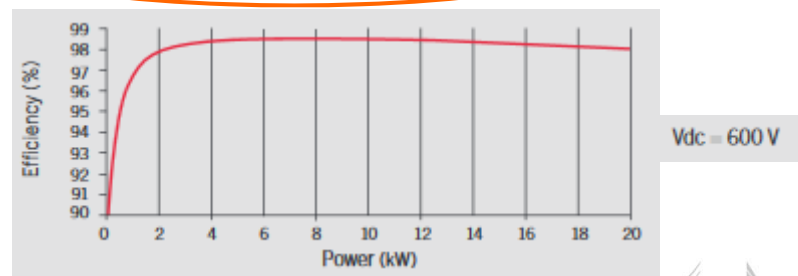
Conclusions

- There exist experimental methodologies to define the inverter's efficiency described in standards which are, however, at present under revision.

- Usefulness of having a single weighted average efficiency value or efficiency curves with several points.

- Interpolation methodology should be defined in order to apply the efficiency curves values.

- Possibility to define new weighted factors for the predefined climatic conditions mentioned in the functional parameter description.