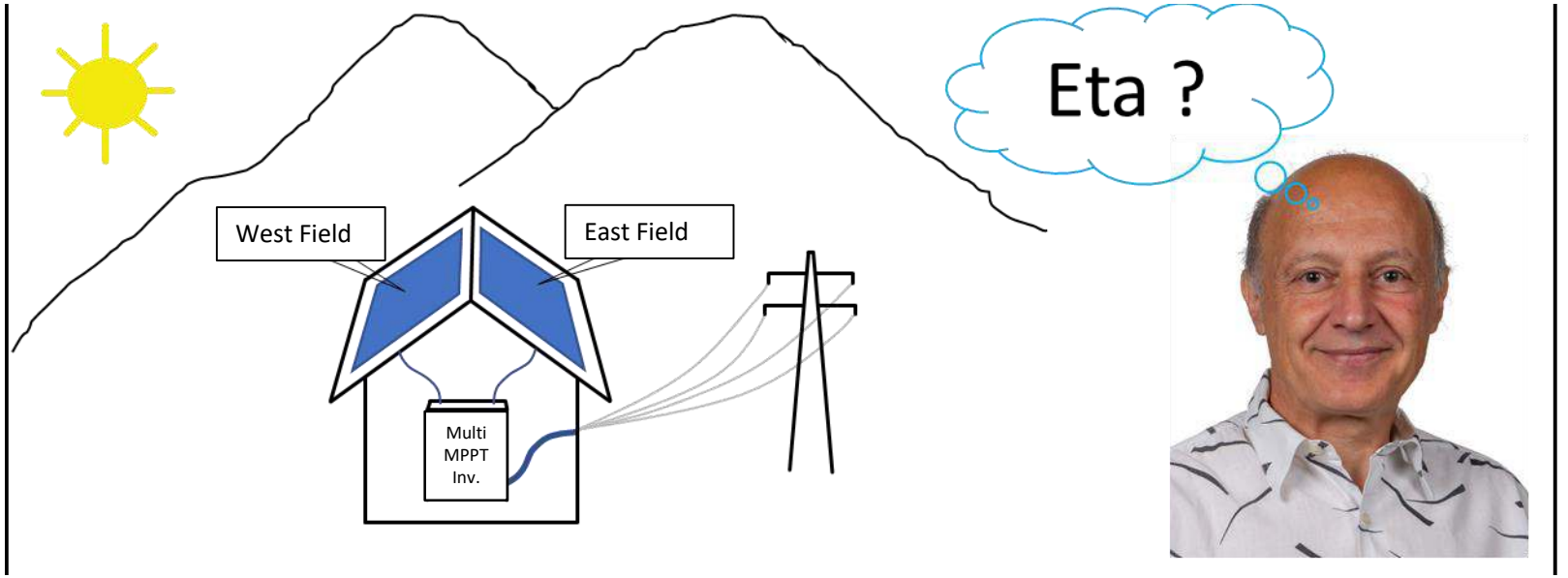


Measurement of the efficiency of multi-string inverters

Urs Muntwyler, Professor PV Laboratory Berner Fachhochschule (BFH-TI)

Task 13, 10. September 2020

MPP-Tracker with different power

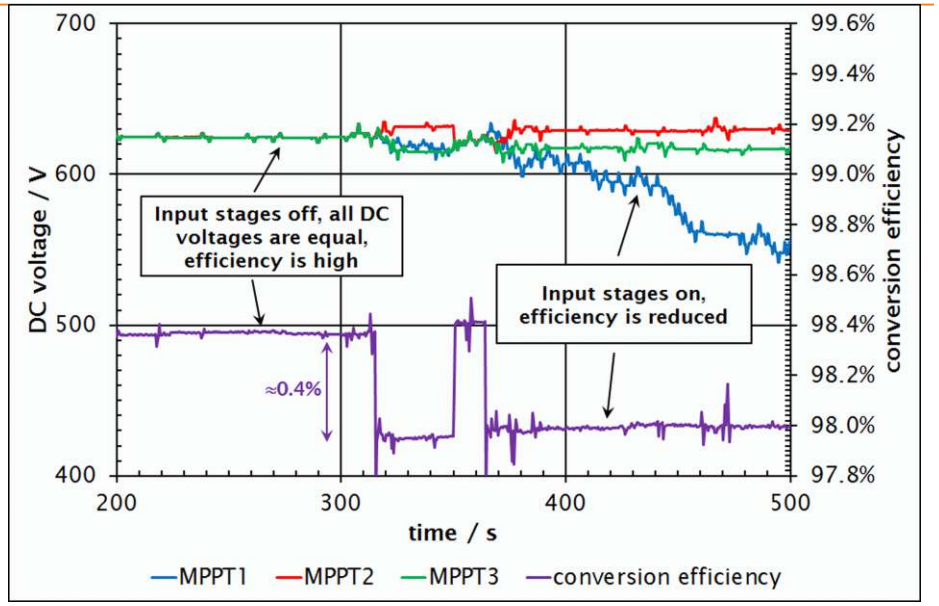
- PV installations with different PV fields can have different orientations and/or different DC nominal power.
- For such applications multi-MPPT PV inverters are very popular.
- Further examples are: east-west installations and facades on all the sides of sky scrapers. Such installations inject more constant power into the public grid and help to reduce the PV peak at noon.

Multi-String PV inverters on the new test facility KNS of the PV LAB BFH-TI. 6 kWp (left) and 20 kWp (right).

PV inverter test bench with accredidation

PV LAB got the accreditation of the PV inverter testbench for EN50530 (efficiency)/ EN61000 (emittance of line disturbances) and CISPR11/EN 55011 (radio emittance) after 5 years of preparation (effort: >sFr. 800'000.--)!

Multistring Inverter Test facility

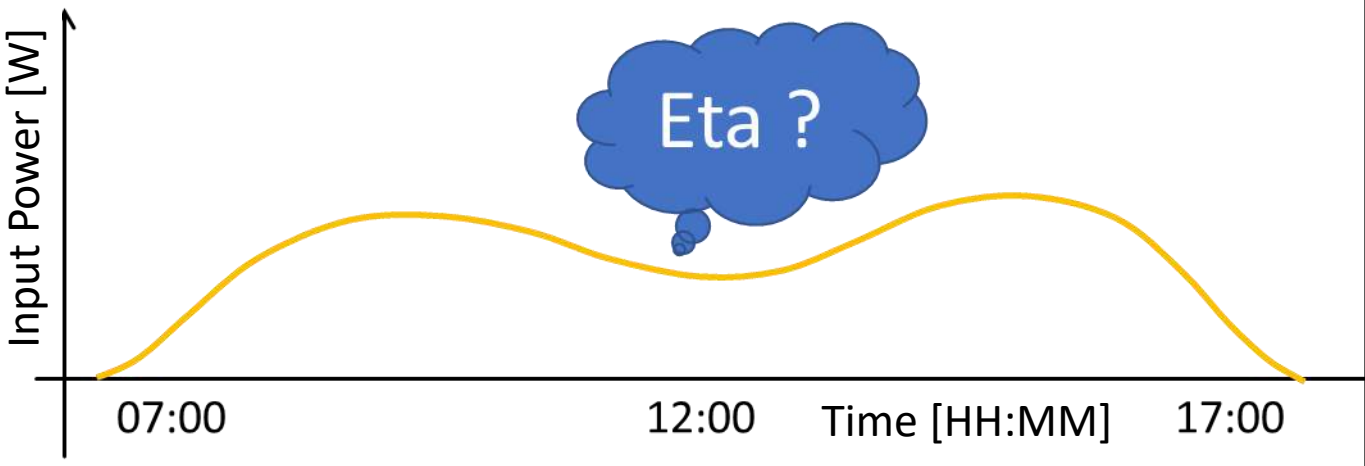


New test infrastructure (SFOE project) with 3 DC outputs up to 11.5 kWp each in the PV test laboratory of the BFH - TI in Burgdorf!

Measurements of multi string PV inverters with 3 different strings show some potential to improvements – which requirements should a test standard include for such measurements?

Efficiency of MPP-Trackers with different power

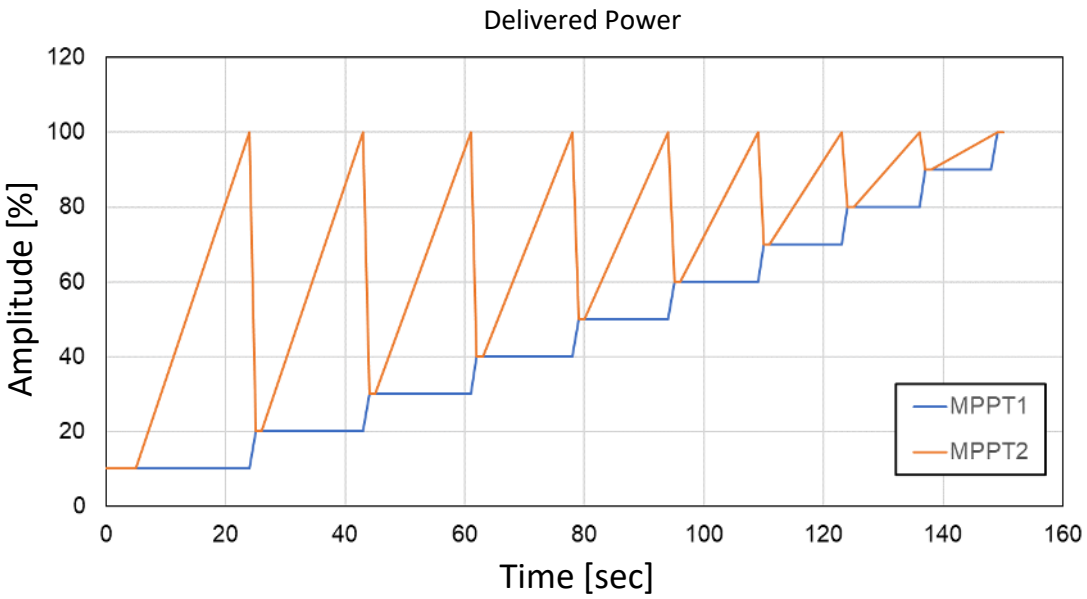
- Energy providers wish to have a constant and more distributed injection of the PV power so they don't need to reinforce their grids.
- East-west-oriented PV installations can help to reduce peaks in PV-production.



But the question is: what is the influence of the unequal DC power on the different MPPTs for the overall efficiency of the PV inverter?

Test profiles

- For the measurement of the inverter efficiencies we need an insolation profile which reflects the different situations. It should also allow to measure with an acceptable effort.
- The profile shouldn't disturb the tracking of the MPPs and the power changes must be slow enough to allow the inverter to stay in the MPP.
- The time changes would be adjusted to the tracking behaviour of the inverter.



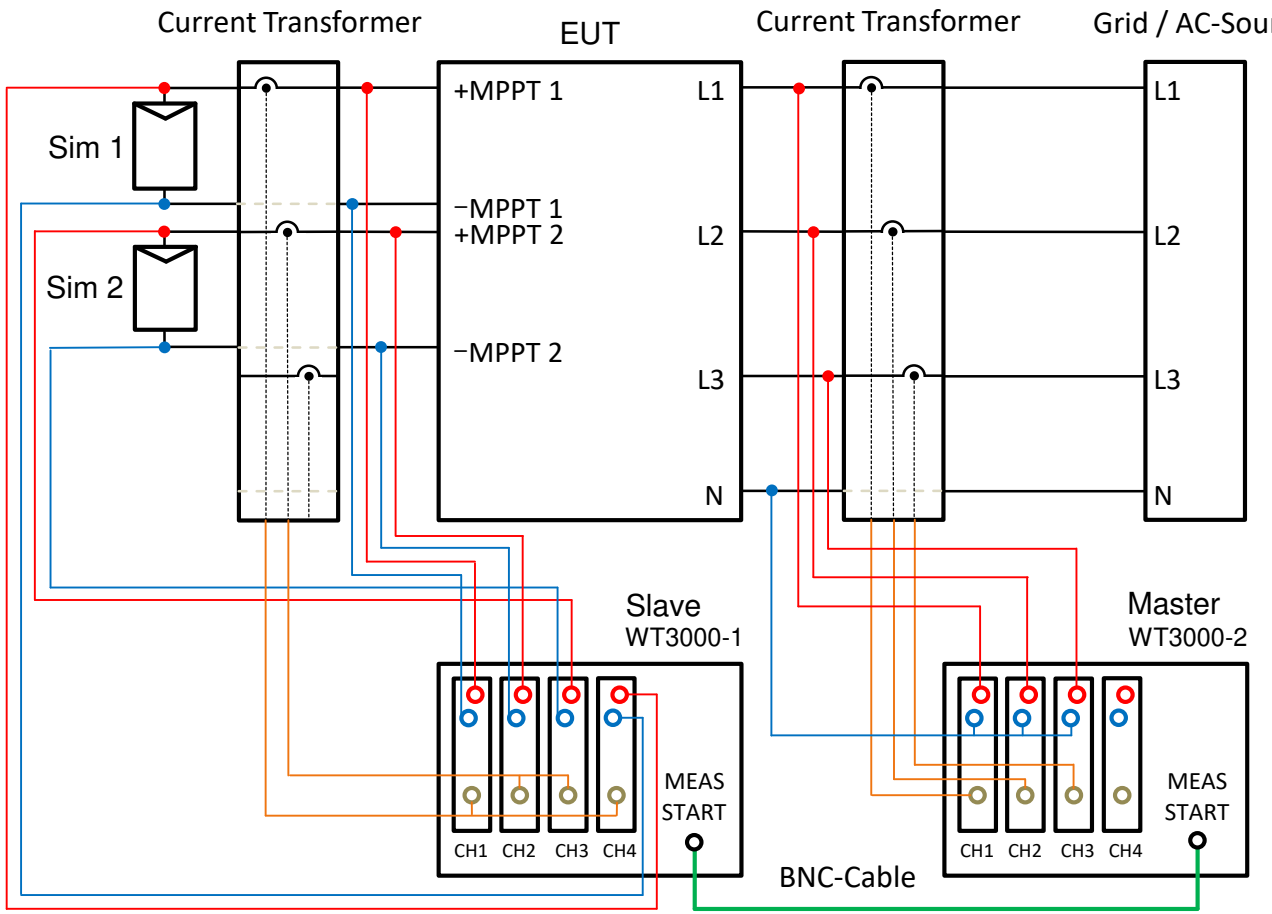
- The test profiles we choosed covers power contributions from 10 - 100%! It gives us a good overview on the behaviour of the inverter and the efficiencies in all working areas.

Measurement concept for 2 MPT's

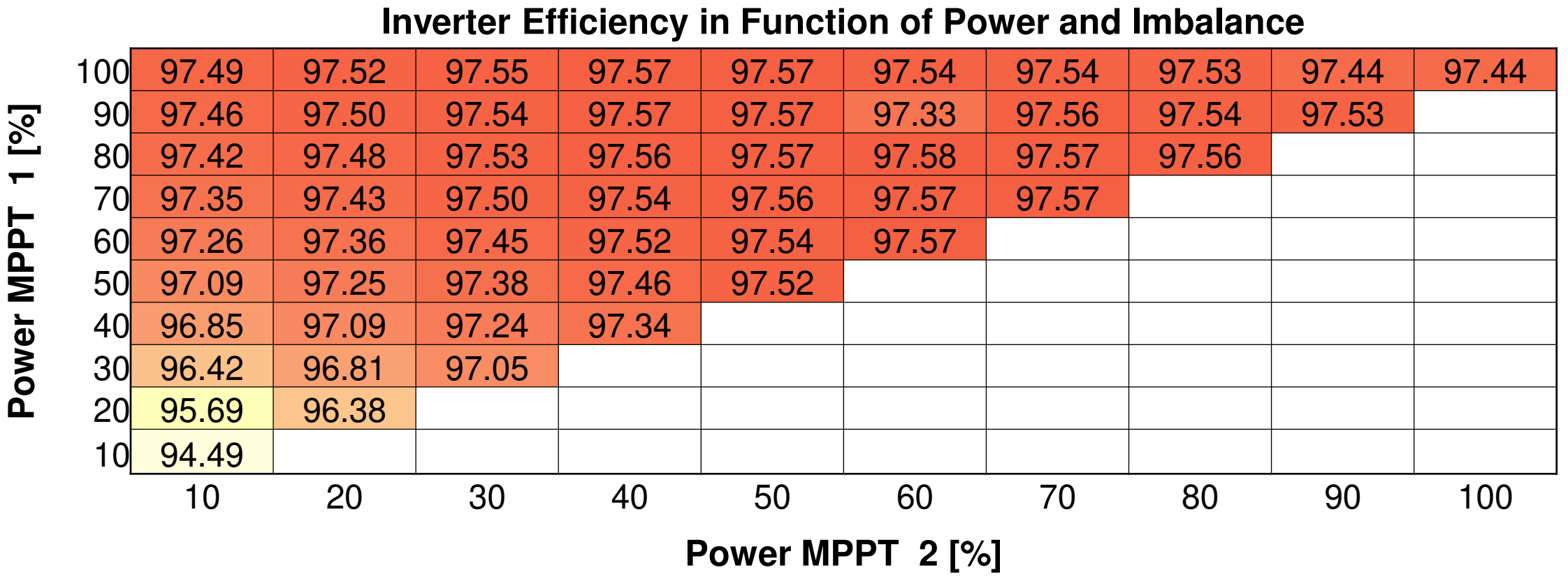
The measurement equipment for 2 MPPT tests. The device can cover up to 3 MPPT's.

The solargenerator simulator is linear, liquid cooled and therefore very quick and with very low electromagnetic disturbances.

For the measurement we used five different 6 kWp inverters with 2-3 MPP-Trackers.

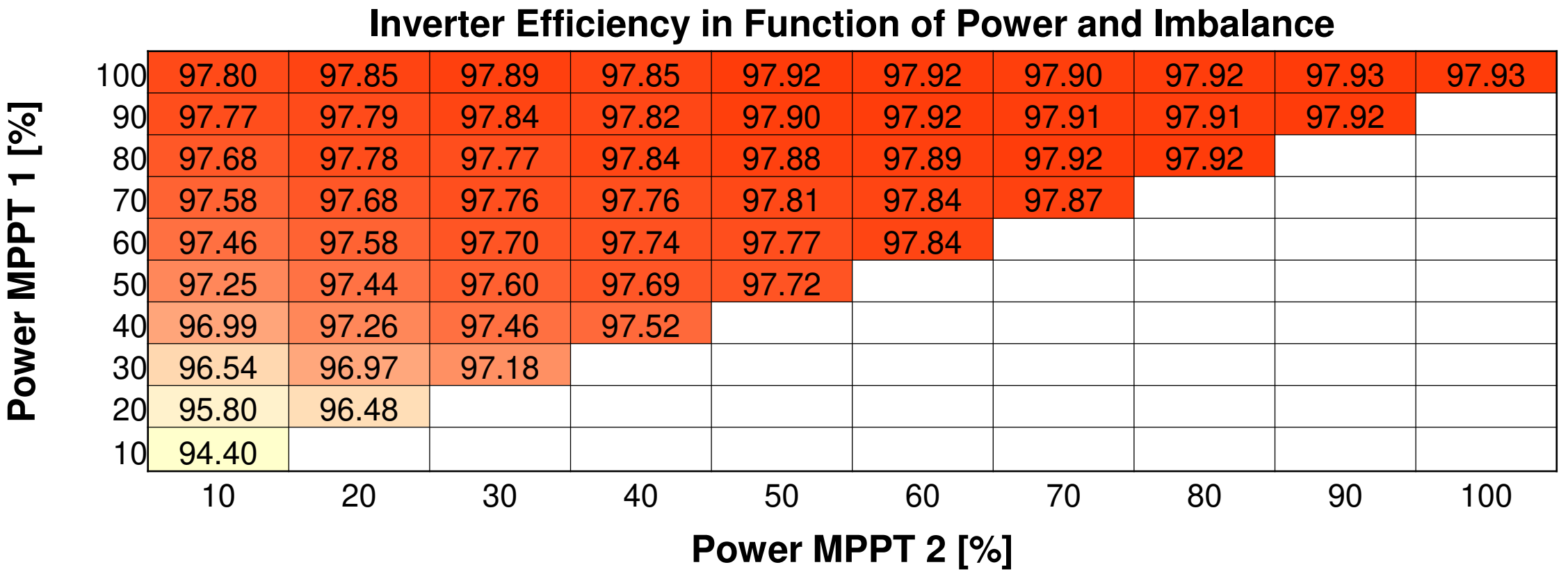


Efficiency of the SMA Model: STP 6.0-3AV-40

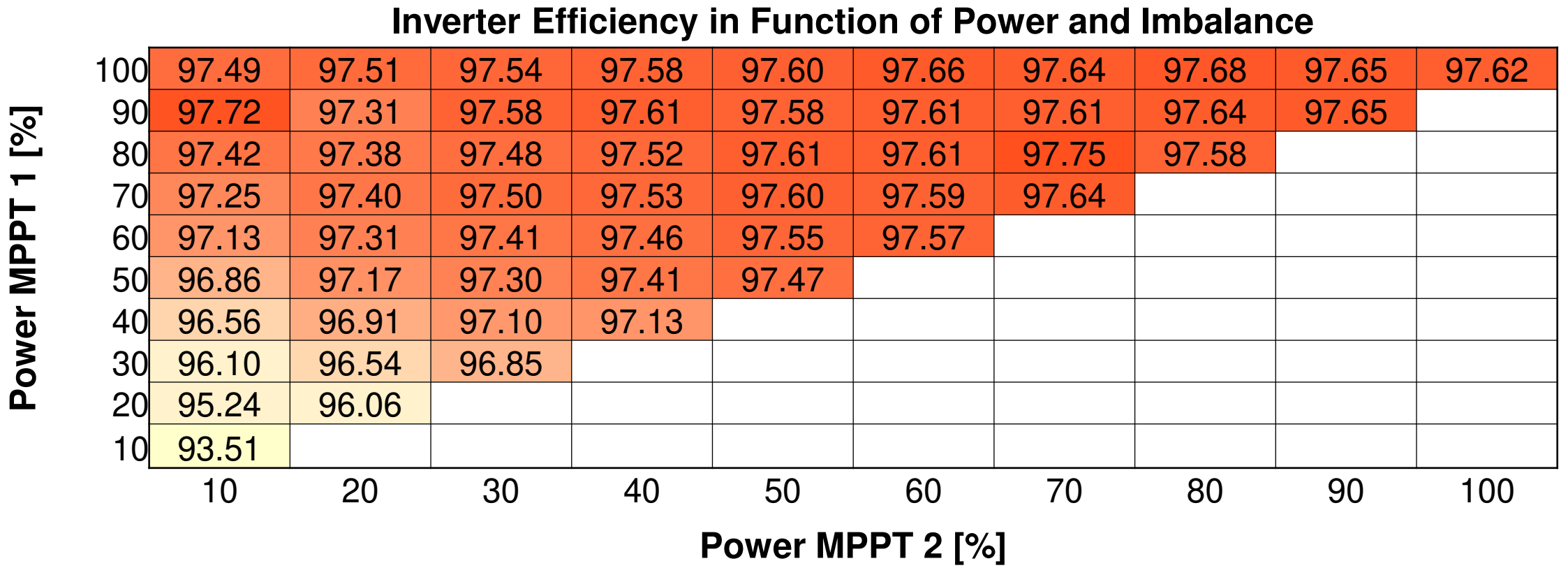


Power MPPT 1 [%] \ Power MPPT 2 [%]	10	20	30	40	50	60	70	80	90	100
100	97.49	97.52	97.55	97.57	97.57	97.54	97.54	97.53	97.44	97.44
90	97.46	97.50	97.54	97.57	97.57	97.33	97.56	97.54	97.53	
80	97.42	97.48	97.53	97.56	97.57	97.58	97.57	97.56		
70	97.35	97.43	97.50	97.54	97.56	97.57	97.57			
60	97.26	97.36	97.45	97.52	97.54	97.57				
50	97.09	97.25	97.38	97.46	97.52					
40	96.85	97.09	97.24	97.34						
30	96.42	96.81	97.05							
20	95.69	96.38								
10	94.49									

Efficiency of the Huawei SUN2000 6KTL-M0

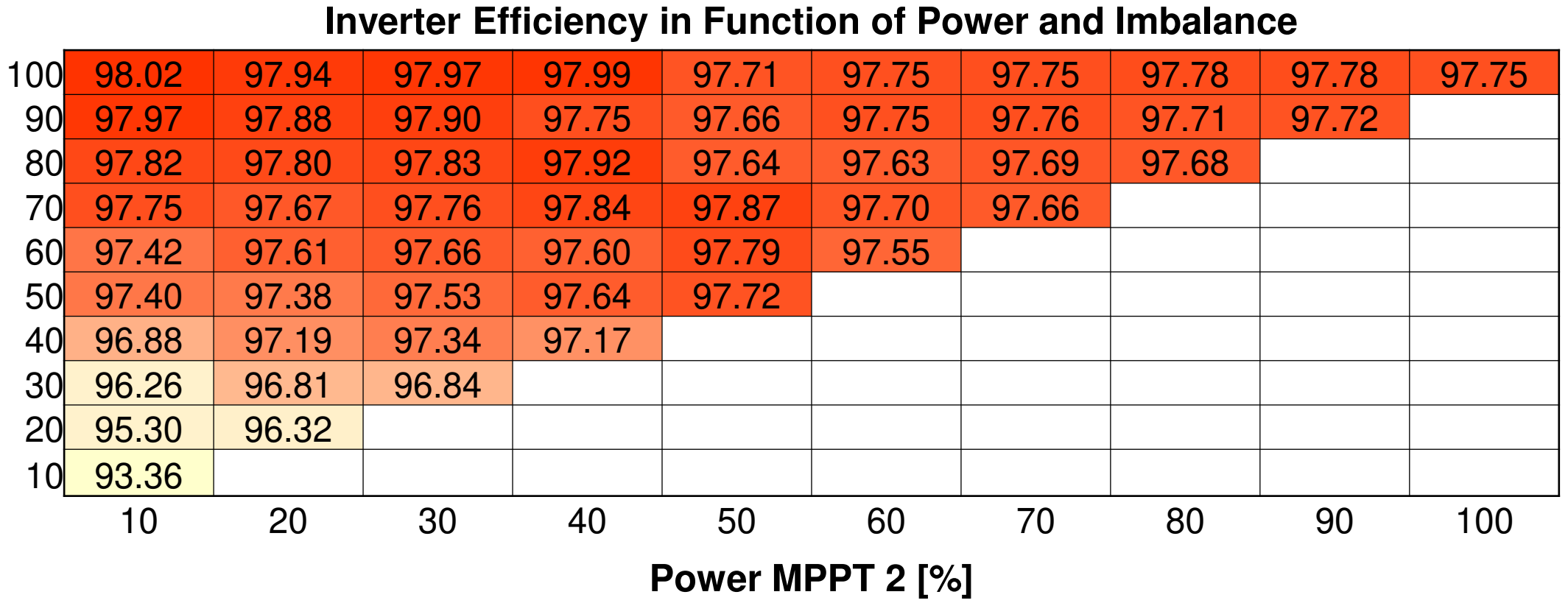


Efficiency of the Fronius Symo-6.0-3-M



Power MPPT 1 [%] \ Power MPPT 2 [%]	10	20	30	40	50	60	70	80	90	100
100	97.49	97.51	97.54	97.58	97.60	97.66	97.64	97.68	97.65	97.62
90	97.72	97.31	97.58	97.61	97.58	97.61	97.61	97.64	97.65	
80	97.42	97.38	97.48	97.52	97.61	97.61	97.75	97.58		
70	97.25	97.40	97.50	97.53	97.60	97.59	97.64			
60	97.13	97.31	97.41	97.46	97.55	97.57				
50	96.86	97.17	97.30	97.41	97.47					
40	96.56	96.91	97.10	97.13						
30	96.10	96.54	96.85							
20	95.24	96.06								
10	93.51									

Efficiency of the Delta RPI M6A



Power MPPT 1 [%] \ Power MPPT 2 [%]	10	20	30	40	50	60	70	80	90	100
100	98.02	97.94	97.97	97.99	97.71	97.75	97.75	97.78	97.78	97.75
90	97.97	97.88	97.90	97.75	97.66	97.75	97.76	97.71	97.72	
80	97.82	97.80	97.83	97.92	97.64	97.63	97.69	97.68		
70	97.75	97.67	97.76	97.84	97.87	97.70	97.66			
60	97.42	97.61	97.66	97.60	97.79	97.55				
50	97.40	97.38	97.53	97.64	97.72					
40	96.88	97.19	97.34	97.17						
30	96.26	96.81	96.84							
20	95.30	96.32								
10	93.36									

Efficiency of the Kostal Plenticore Plus 5.5

Inverter Efficiency in Function of Power and Imbalance

Power MPPT 1 [%] \ Power MPPT 2 [%]	10	20	30	40	50	60	70	80	90	100
100	96.44	96.54	96.58	96.68	96.72	96.78	96.80	96.86	96.92	96.93
90	96.39	96.47	96.56	96.60	96.68	96.68	96.78	96.79	96.84	
80	96.27	96.32	96.46	96.53	96.59	96.65	96.72	96.79		
70	96.09	96.21	96.38	96.42	96.51	96.65	96.70			
60	95.85	96.01	96.25	96.37	96.47	96.52				
50	95.55	95.61	96.08	96.25	96.40					
40	95.18	95.56	95.93	96.07						
30	94.69	95.12	95.61							
20	93.97	94.65								
10	93.04									

Power MPPT3 = 20%

Inverter Efficiency in Function of Power and Imbalance

Power MPPT 1 [%] \ Power MPPT 2 [%]	10	20	30	40	50	60	70	80	90	100
100	96.64	96.77	96.80	96.79	96.77	96.86	96.89	96.89	96.90	96.90
90	96.65	96.66	96.76	96.78	96.75	96.83	96.86	96.89	96.94	
80	96.64	96.59	96.68	96.73	96.69	96.78	96.84	96.87		
70	96.45	96.52	96.66	96.71	96.68	96.76	96.86			
60	96.38	96.51	96.57	96.64	96.61	96.63				
50	96.23	96.44	96.50	96.57	96.60					
40	96.02	96.28	96.41	96.47						
30	95.90	96.13	96.23							
20	95.72	95.81								
10	95.34									

Power MPPT3 = 50%

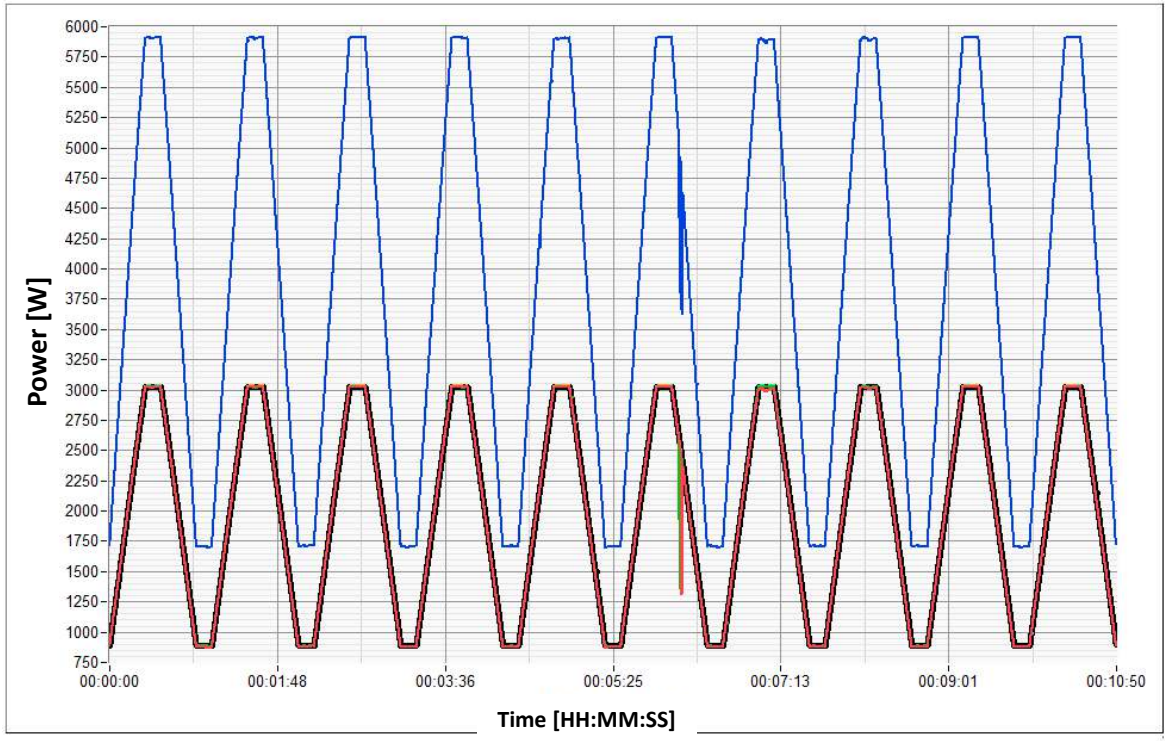
Inverter Efficiency in Function of Power and Imbalance

Power MPPT 1 [%] \ Power MPPT 2 [%]	10	20	30	40	50	60	70	80	90	100
100	96.73	96.76	96.81	96.84	96.90	96.89	96.88	96.97	96.93	96.93
90	96.75	96.69	96.78	96.80	96.85	96.91	96.87	96.93	96.95	
80	96.69	96.69	96.77	96.81	96.85	96.87	96.87	96.91		
70	96.61	96.60	96.71	96.77	96.80	96.89	96.88			
60	96.56	96.51	96.64	96.77	96.73	96.84				
50	96.52	96.49	96.58	96.73	96.79					
40	96.48	96.45	96.55	96.71						
30	96.34	96.34	96.45							
20	96.25	96.26								
10	96.10									

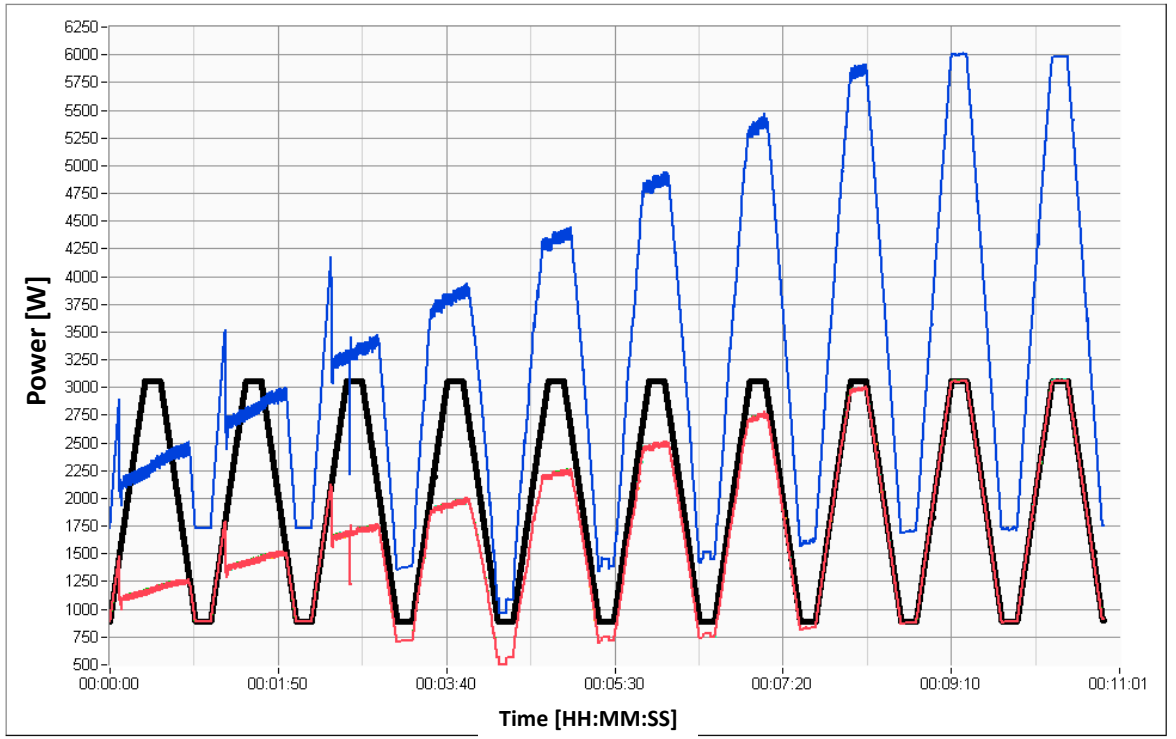
Power MPPT3 = 80%

Dynamic behavioural

Inverter A



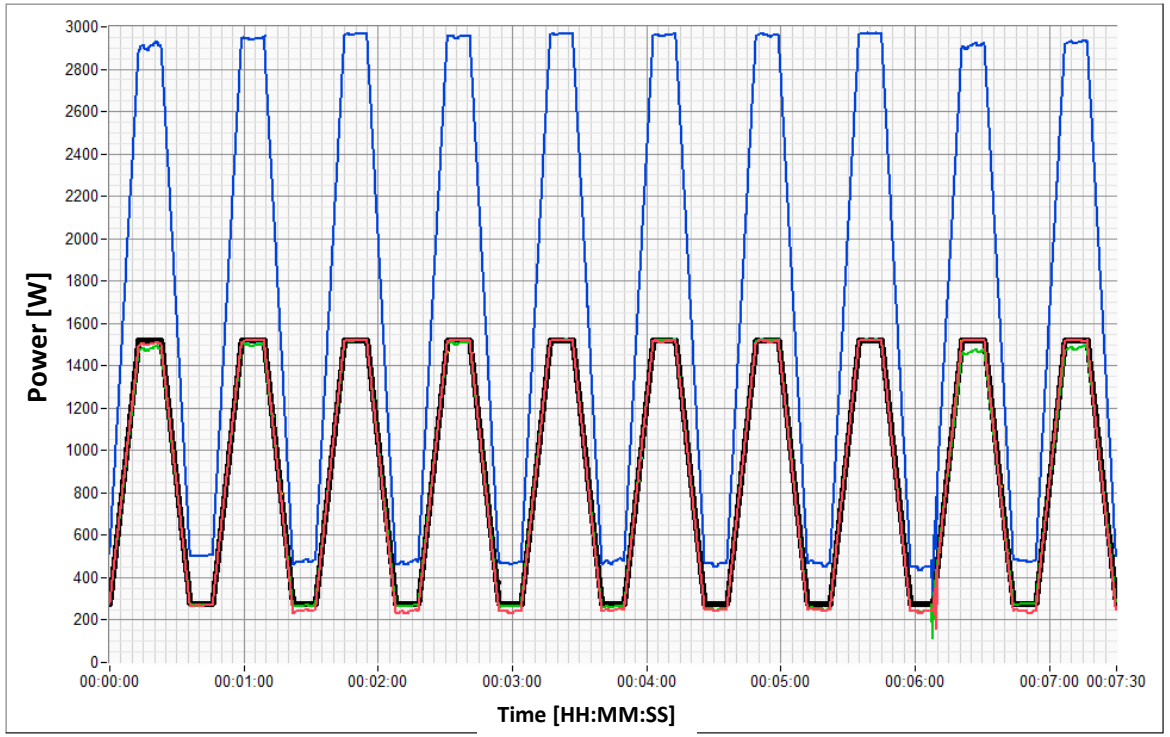
Inverter B



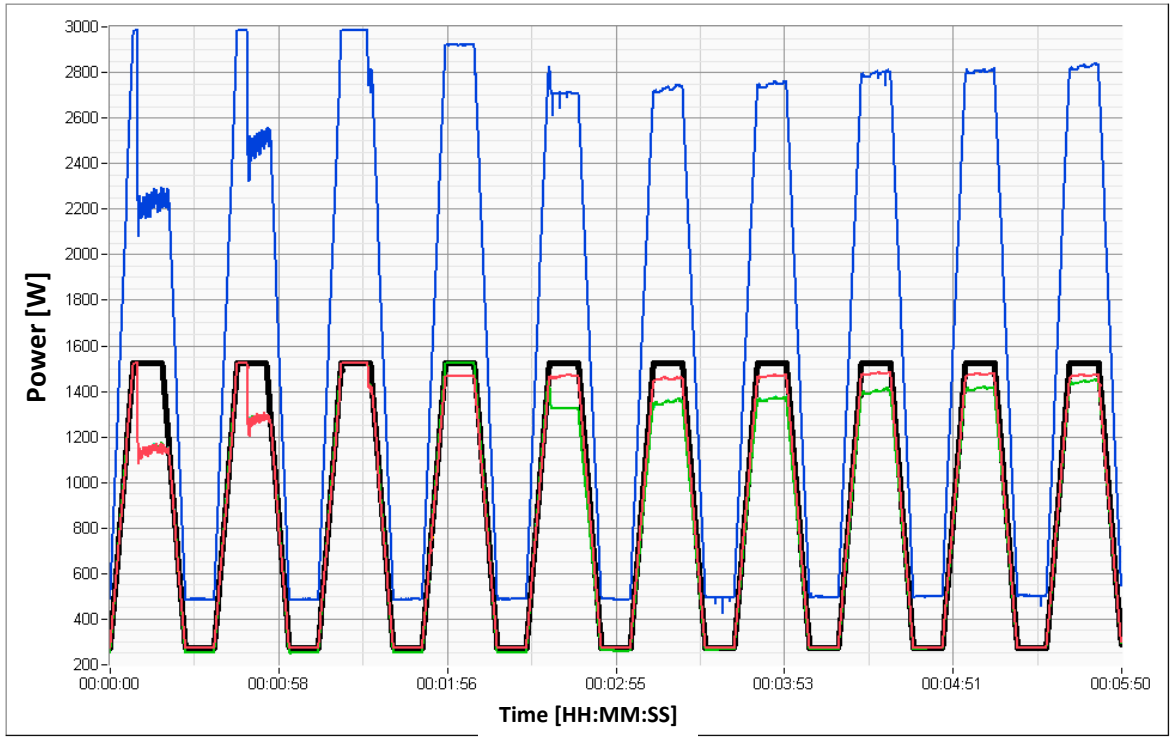
Fast Power Changes → Inverter B can't track the MPP properly

Dynamic behavioural

Inverter A



Inverter B



Fast Power Changes → Inverter B can't track the MPP properly

Final remarks

- The five multi-string 6 kWp PV inverters had a good efficency behaviour.
- The dynamic behaviour was different – some inverters have room for improvements.
- Since multi-string inverters have a great success on the market, a test standard and therefore recommendations for the best use of such systems would be helpful for the installers and the users.
- The manuals of PV inverters should inform the user about the applicable range of power differences between the strings and the dynamic behaviour of the MPPT's.
- The PV laboratory at the BFH is looking for contributions to such a discussion.

Urs Muntwyler/ Luciano Borgna – Task 13
E-mail: urs.Muntwyler@bfh.ch