HACETTEPE UNIVERSITY

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

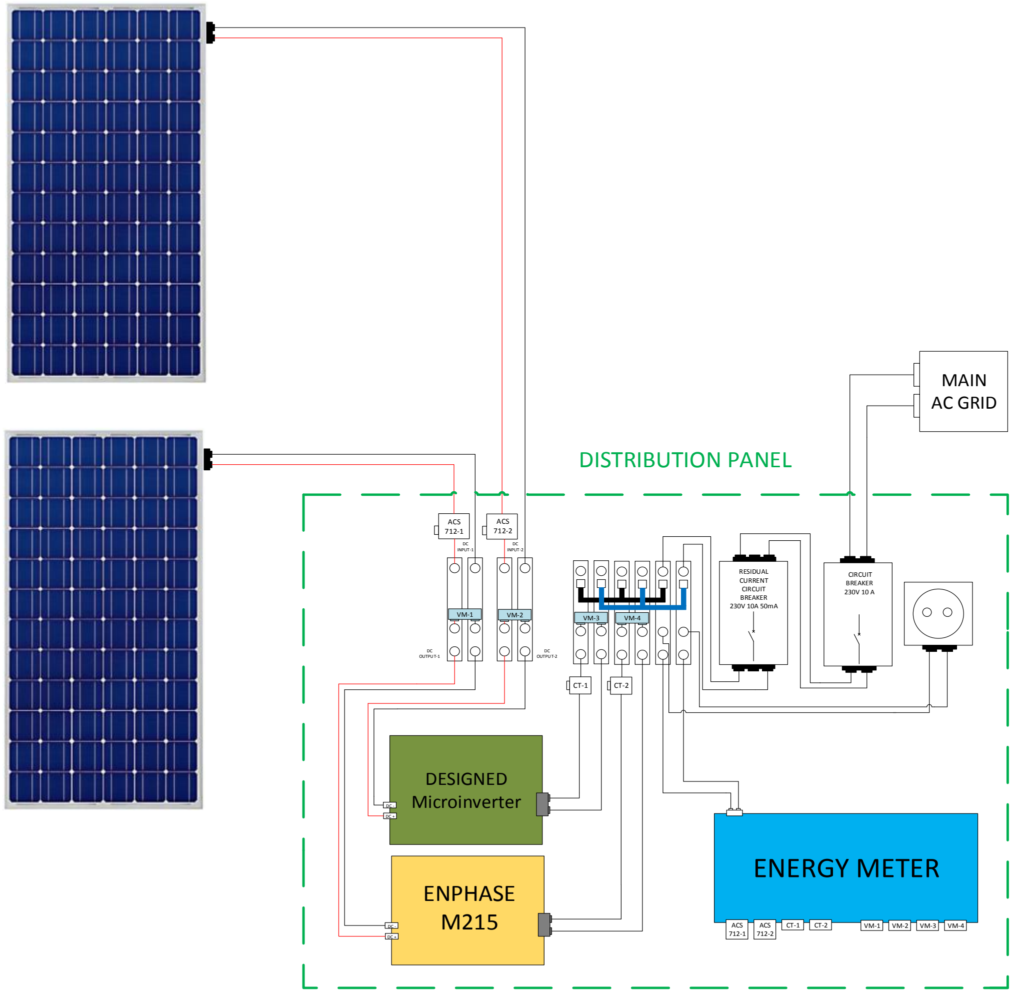
A Proposed Micro inverter Performance Test Set-up under Real-Time Operation

Gürkan GÖK

Advisor:
Prof. Dr. Uğur BAYSAL

SUMMARY

2. Test-Setup and Reference System
2.1 Electrification of Test-Setup



2.2. Decision of Reference Micro Inverter

- High Efficiency Performance
- Reasonable Price,
- If possible, The Reactive Power Support to the Grid

INPUT DATA (DC)	M215-60-2LL-S22-IG / S23-IG / S24-IG	
Recommended input power (STC)	190 - 270 W	
Maximum input DC voltage	48 V	
Peak power tracking voltage	27 V - 39 V	
Operating range	16 V - 48 V	
Min/Max start voltage	22 V / 48 V	
Max DC short circuit current	15 A	
Max input current	10 A	
OUTPUT DATA (AC)	**@208 VAC**	**@240 VAC**
Peak output power	225 W	225 W
Rated (continuous) output power	215 W	215 W
Nominal output current	1.1 A (A rms at nominal duration)	0.9 A (A rms at nominal duration)
Nominal voltage/range	208 V / 183-229 V	240 V / 211-264 V
Nominal frequency/range	60.0 / 57-61 Hz	60.0 / 57-61 Hz
Extended frequency range*	57-62.5 Hz	57-62.5 Hz
Power factor	>0.95	>0.95
Maximum units per 20 A branch circuit	25 (three phase)	17 (single phase)
Maximum output fault current	850 mA rms for 6 cycles	850 mA rms for 6 cycles
EFFICIENCY		
CEC weighted efficiency, 240 VAC	96.5%	
CEC weighted efficiency, 208 VAC	96.5%	
Peak inverter efficiency	96.5%	
Static MPPT efficiency (weighted, reference EN50530)	99.4 %	
Night time power consumption	65 mW max	

2.3 Installed Base

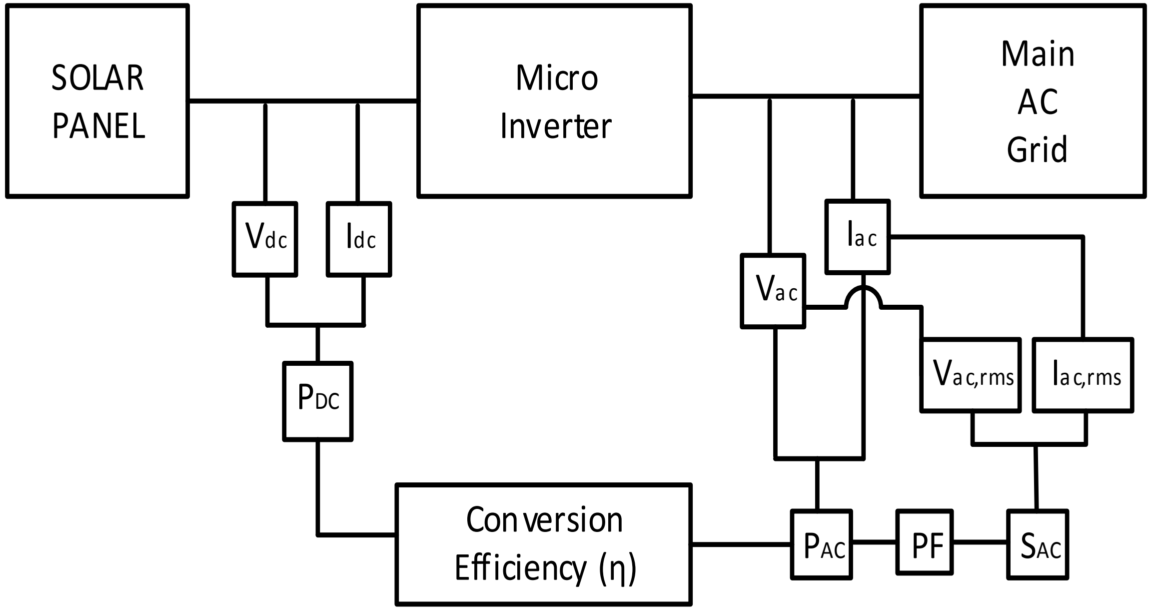
- Inclination of Solar Panel 32°
- Solar Panel Power: 230 Watt

2. Why do we need a custom design power meter?

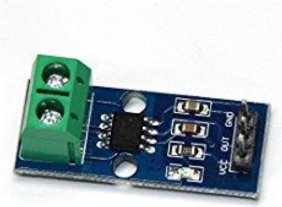
- To observe Overall System Efficiency
- DC Side Power Measurement
- AC Side Power Measurement
- Power Factor Calculation
- Reactive Power Observation
- Logging the Information
- Real Time Observation ability
- Two different System Tracking Instanteneously

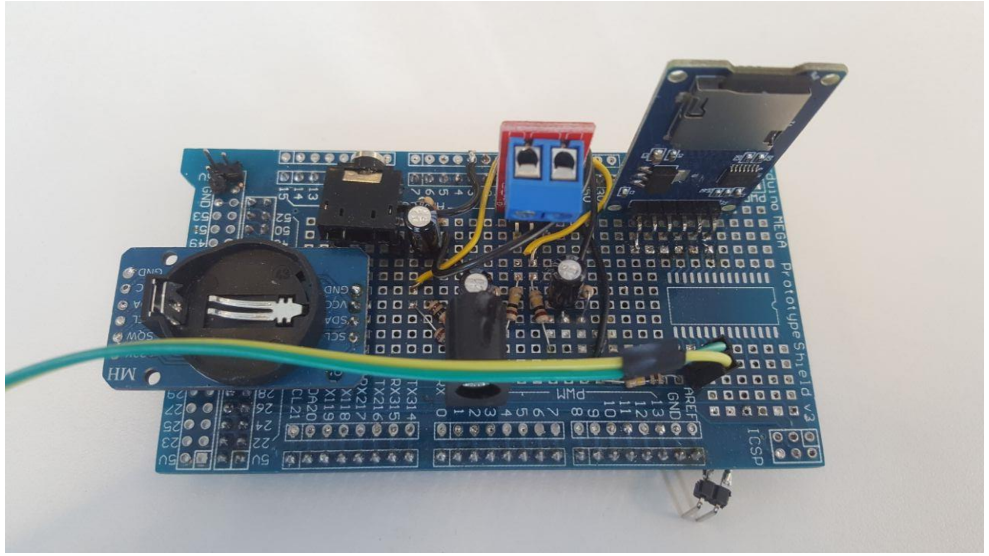
3. Power Meter Design

- Flow Chart of Power Meter



3.1. Modules of Power Meter





3.2. AC Voltage and Current Measurement

- AC Voltage Measurement:12 V AC-AC Transformer 15VA (Tolerance: 1%)
- AC Current Measurement: Split-Core Transformer 30A/1V (Tolerance: 3%)
- RMS Current and RMS Voltage

$$U_{rms} = \sqrt{\frac{\sum_{n=0}^{N-1} u^2(n)}{N}} \qquad I_{rms} = \sqrt{\frac{\sum_{n=0}^{N-1} i^2(n)}{N}}$$

- Instantaneous Power, Apparant Power and Power Factor Calculations

3.3. DC Voltage and Current Measurement

- DC Voltage Measurement: Resistive(Axial-lead) Voltage Divider (Tolerance: 5%)
- DC Current Measurement: ACS 712 Current Sensing Module (Tolerance: 0.1%)

3.4. Calibration of Power Meter

Challenges:

- Low Power Measurement
- Low level sensitive Equipment

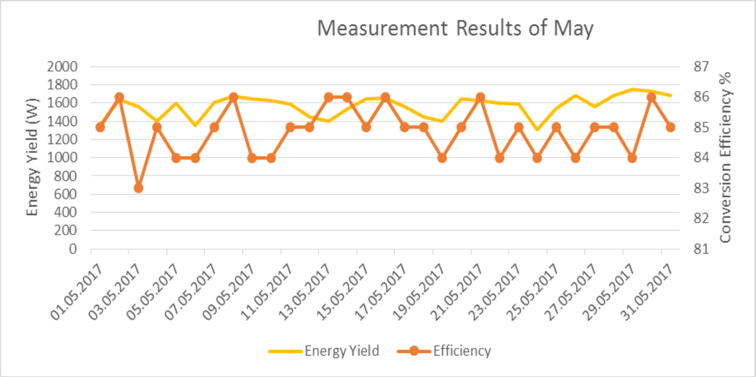
Solution:

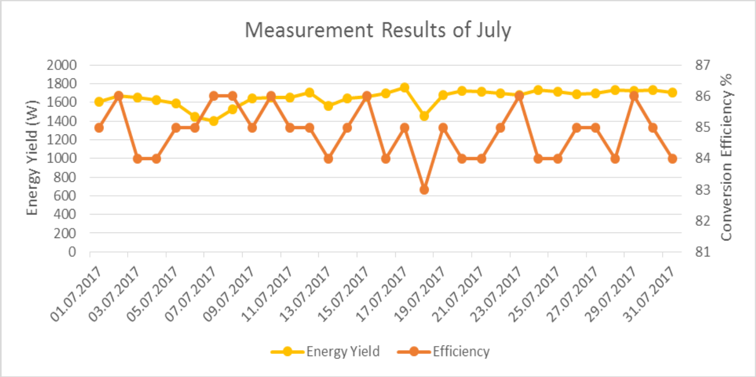
- Different Calibration Values for Different Power Ranges
- 1.15% power measurement sensitivity achivement
- Calibration Devices:
  - Fluke 43B Single Phase Power Analyzer
  - Rigol DS 1054Z Osciloscope
  - UNI-T 203 Digital Clamp Multimeter

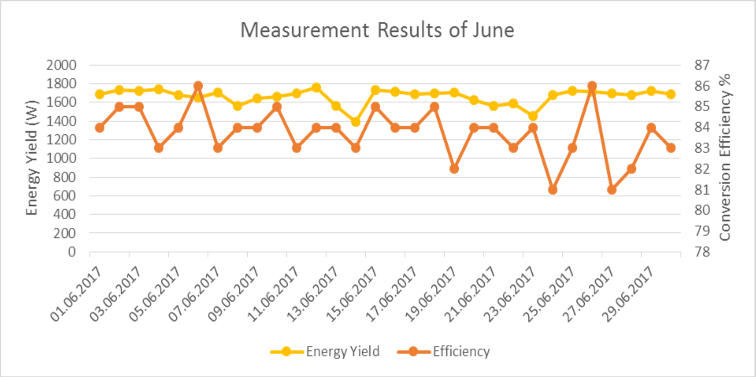
HACETTEPE UNIVERSITY

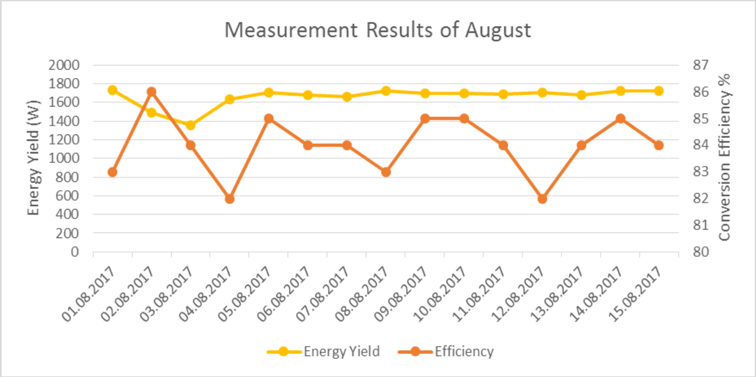
4. Comprasion of Enphase Micro inverter Real-Time Results

- Performance test result of Enphase M215
  - MPPT Performance
  - Real-Time Environmental Conditions(Temperature, Moisture)



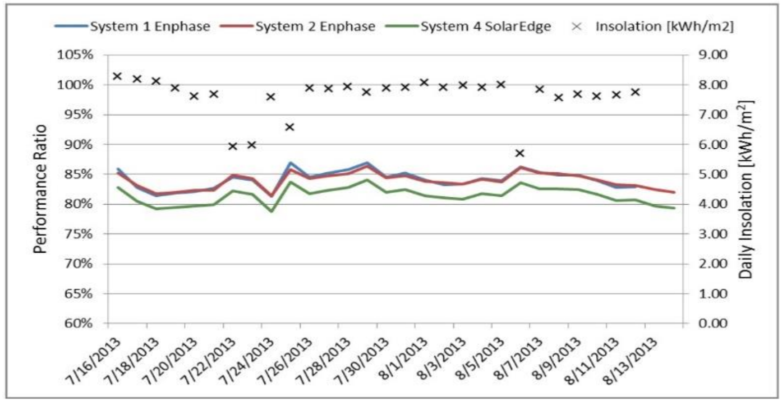






5. Reference Measurement Comprasions

- PVEL Performance test result of Enphase M215 and SolarEdge

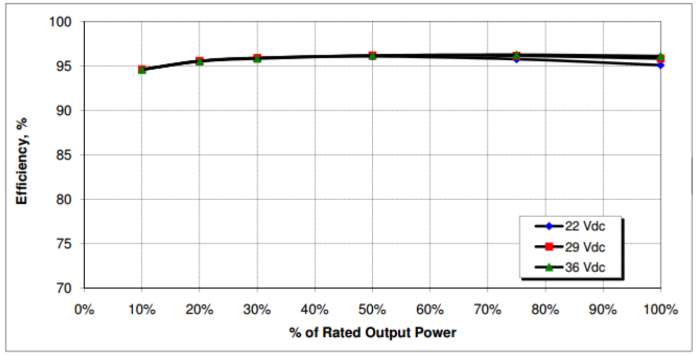


- Performance test result of Enphase M215 based on CEC

Vmin: 22 Vdc Vnom: 29 Vdc Vmax: 36 Vdc

Input Voltage (Vdc)		Power Level (%; kW) 10% 0.02	20% 0.04	30% 0.06	50% 0.11	75% 0.16	100% 0.22	Wtd
Vmin	22	94.6	95.5	95.9	96.1	95.7	95.1	95.7
Vnom	29	94.6	95.5	95.9	96.2	96.1	95.8	96.0
Vmax	36	94.6	95.5	95.8	96.1	96.2	96.1	96.1

CEC Efficiency = 96.0%



6. Conclusion

- Measurement technique for a micro inverter with reactive power support to the grid
- The compliance of testing a gird-tied micro inverter has been shown.
- Characteristic of a micro inverter under real conditions has been emphasized by comparing the performance results with reference reports.
- Moreover, an energy meter design for low power density devices is presented.
- The critical software calibration of a power meter with low level sensitive equipment is described.

7. References

[1] (2004). [Online].

Available:http://www.erec.org/media/publications/2040-scenario.html

[2] M. Donovan, J. Forrest, and N. Jacobson, "Engineering Report Energy Yield Evaluation at PVUSA Enphase and SolarEdge Side-by-Side," PV Evaluation Labs, Sep. 2013.

[3] S. Jiang, D. Cao, Y. Li, and F. Z. Peng, "Grid-connected boost-half-bridge photovoltaic micro inverter system using repetitive current control and maximum power point tracking," IEEE Trans. Power Electron., vol. 27, no. 11, pp. 4711–4722, Nov. 2012.

[4] Z. Liang, R. Guo, J. Li, and A. Q. Huang, "A high-efficiency PV module integrated DC/DC converter for PV energy harvest in FREEDM system," *IEEE Trans. Power Electron.*, vol. 26, no. 3, pp. 897–909, Mar. 2011.

[5] C. Prapanavarat, M. Barnes, and N. Jenkins, "Investigation of the performance of a photovoltaic AC module," *IEE Proc. Gener., Trans. Distrib.*, vol. 149, no. 4, pp. 472–478, Jul. 2002.

[6] T. Shimizu and S. Suzuki, "Control of a high efficiency PV inverter with power decoupling function," in *Proc. IEEE Int. Conf. Power Electron. ECCE Asia*, 2011, pp. 1533–1539.

[7] (2017). [Online]. Available:

http://www.enphase.com/sites/default/files/M215_DS_EN_60Hz.pdf

[8] (2017). [Online].

Available:http://www.plurawatt.com/files/Modeller/ing/Plurawatt_AC_Panel_EN.pdf

THANK YOU!

?