TECHNICAL REPORT FOR INTERNAL PROJECT

Client	**:**	**Griffith University**
Client contact	**:**	**Prof Brendan Mackey**
Scope of report	**:**	**Performance and safety screening of Microprocessor-based inverter**
Testing unit	**:**	**Microprocessor based inverter**
Testing unit received on	**:**	**01 December, 2015**
Test performed on	**:**	**03 December, 2015**
Date of issue	**:**	
Contributors	**:**	o **Dr. Jahangir Hossain (Team Lead)** o **Prof. Junwei Lu** o **Dr. Boyuan Zhu** o **Mr. F. H. M. Rafi** o **Mr. Md Shamiur Rahman** o **Mr. Seyedfoad Taghizadeh**

Prof Brendan Mackey is the project director for the research project entitled "Evaluating the re-building of a Climate resilient Enkatalie, Vanuatu". The testing team were requested by Prof Mackey to analyse the technical performance of the LEDTEK 'Mini Power System' or 'MPS' - also referred to in this report as a 'mini mobile power supply unit' or a 'microprocessor based inverter' - and provide a report summarising the approach and results, along with any recommendations. Note that this is a technical report which presents the result only from testing of technical performance of the mobile power system under a limited range of conditions. It is not a standard test certificate.

Introduction:

The primary objective of this technical report is to measure the performance and safety screening of the microprocessor based inverter under a number of household loads. The sample testing unit has been tested autonomously under the household loads described in the results section of this report. Battery performance has been tested on a timely basis. The electromagnetic compatibility (EMC) test has been performed in order to measure safety based on the EN55022 (2006) / CISPR22 standards. The main purposes of this testing are to examine: (i) the safety aspect of the unit in relation to Australian standards prior to it being submitted by the manufacturer to SAA for certification; (ii) amperage requirements to meet the specification of the unit supplied; (iii) multi input capabilities of the MPS unit; (iv) control of input and output solar and wind etc.; (v) the ability of the battery to charge while supplying load to run appliances given the availability of natural resources like solar and wind; and (vi) the ability to switch over to mains on over load and revert back.

PLEASE NOTE while Griffith University has taken care to ensure the measurements specified in the report are accurate at the time of recording, Griffith University does not guarantee the recordings will be duplicated in any future testing. This report does not constitute and must not be used as an endorsement of the sample testing unit. Griffith University makes no representations that the sample testing unit, nor any product derived from the sample testing unit, is suitable for your use or for any particular purpose, that it does not infringe the intellectual property rights of any third party or that it complies with any applicable laws. This report does not constitute legal, compliance or financial advice and you should consult your own legal, accounting and other advisors before making any decisions about use or potential use of any related product.

Sample testing unit:

The test system is a 5000 W charger composed of a 4.8 kW 240 VAC inverter and a 48 V 200 Ah battery array, all housed in a lockable mobile 19'' rack cabinet.

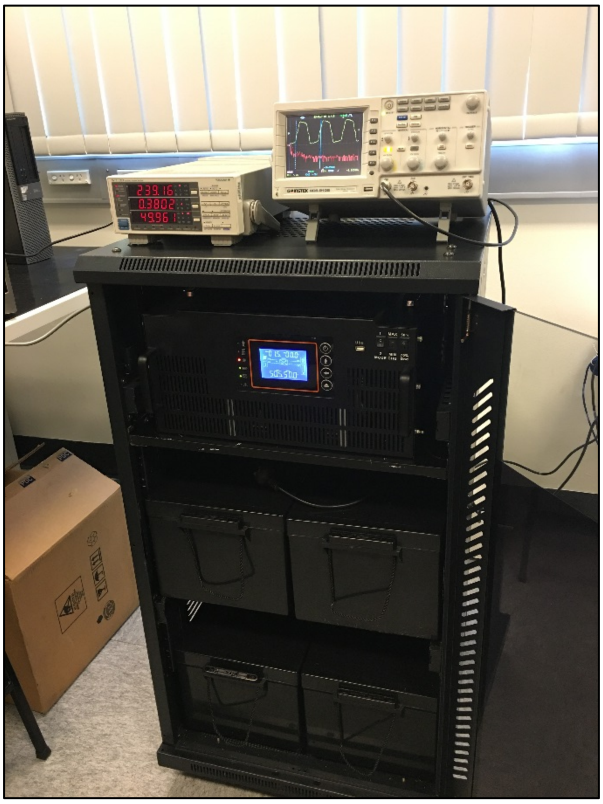


Fig. 1: Sample MPS unit

Test results:

The system has been tested autonomously with variable household loads e.g. oil heater, microwave oven, air conditioner, computer, electric frypan and combination of oil heater and air conditioner. Throughout the load testing battery performance of the system has been observed and electromagnetic compatibility (EMC) test has been performed to observe the emitted electromagnetic radiation from the system. The summary of the test is included in the following Table.

Test Summary

(i) Australian safety standards	(ii) amperage requirements	(iii) multi input capabilities	(iv) control of input and output	(v) charge the battery while suppling load	(v) switch over to mains on over load
It is recommended to include earthing connections and submit the MPS to SAA for certification	20 A	4 inputs (solar, wind, hydro and conventional generator) and a single output	Maximum power point tracking control (MPPT)	The MPS can charge the battery while supplying power	The MPS can switch to main power supply if it is available when over loaded.

MPS unit working during grid connected mode. No PV and Battery supply.

With PV connected and battery is supplying the load

From the test it was found that the data obtained from the measurement matches with the nameplate ratings. The MPS has 4 inputs i.e., the battery can be charged from either a single or combinations of output power from photovoltaic (PV) unit, wind generator, hydro or conventional coal or diesel type synchronous generator.

The MPS has maximum power point tracking (MPPT) control which ensures possible maximum output power for any operating conditions. It can switch the load to main supply (if available) when the battery is flat (completely discharged). It can also supply power to load while it is charging.

The MPS provided for testing came with an internal earth for connection to grid power. In the case of an "off grid" installation, the MPS needs to be grounded with an earth stake that complies with the SA&NZA Standards.

A neutral point represents a reference point within an electrical distribution system. The Conductors connected to this reference point (Neutral) should, normally, be non-current carrying conductors, sized to handle momentary faults (short circuits) occurring in electrical equipment. However, with the introduction of non-linear loads, such as computers, electronic lighting, television, refrigerators and other switch-mode power conversion equipment, the requirements for the neutral conductor has increased. A ground represents an electrical path, normally designed to carry fault current when an insulation breakdown occurs within electrical equipment.

The details of the performance of the unit with different types of load are mentioned below.

Load Testing:

Load test: 01

Load Type (Oil Heater)								
	Load Voltage (V)	Load Current (A)	Power (kW)	Reactive Power (kVAR)	Power Factor	Frequency (Hz)	Battery Voltage (V)	Battery Temperature (˚C)
Griffith Power Meter	238.1	3.732	0.8	0	1	49.96	50.6	33
Testing Unit	239	3.6	0.8	0	1	50	50.6	34

Observations:

The test results show that the MPS unit provides almost rated constant voltage (around 240 V) and constant frequency (around 50 Hz) which is important for the reliable and healthy operation of connected loads, for example, refrigerator, light, and fan. Wave shape is not distorted i.e., it can ensure the required power quality and losses will be minimum. The nominal supply voltage for the low voltage network is 240 Volts, phase to neutral, and 415 Volts phase to phase with a tolerance of 6% [1-3]. Grid connected inverters and grid protection devices shall be capable of operation within these parameters. The AEMC (Australian Electricity Market standards state that "*The frequency operating standards require that, during periods when there are no contingency events or load events, the frequency be maintained within the normal operating frequency band (49.85 Hz to 50.15 Hz) for 99% of the time, with larger deviations permitted within the normal operating frequency excursion band (49.75 Hz to 50.25 Hz) for no more than 1% of the time* [1-3]". Power factor has been kept constant (~ 1) due to no reactive power consumption by the load. The measurements given by the power meter of the Griffith University and the testing unit were approximately the same. The cooling fan was off as it did not exceed the allowable temperature.

Load test: 02

Load Type (Microwave Oven)								
	Load Voltage (V)	Load Current (A)	Power (kW)	Reactive Power (kVAR)	Power Factor	Frequency (Hz)	Battery Voltage (V)	Battery Temperature (˚C)
Griffith Power Meter	239.9	6.47	1.36	0.68	0.88	49.9	50.2	35

Observations: Regulated magnitude of the output voltage (nearly 240 V) and acceptable voltage wave shape (nearly sinusoidal) are obtained with RL (resistive-inductive) type load. Output frequency (50 Hz) has been well regulated by the system. Power factor was less than unity due to reactive power consumption by the load. The cooling fan was on. It can be concluded that the MPS provides acceptable performance for RL type load which requires both active and reactive powers.

Load test: 03

Load Type (Air Conditioner)								
	Load Voltage (V)	Load Current (A)	Power (kW)	Reactive Power (kVAR)	Power Factor	Frequency (Hz)	Battery Voltage (V)	Battery Temperature (˚C)
Low Fan (LF)	239.05	0.37	0.09	0.0046	0.99	49.96	50.5	43
High Fan (HF)	239.05	0.424	0.1	0.02	0.98	49.96	50.4	43
Low Cooling (LC)	239.05	1.81	0.403	0.15	0.93	49.96	50.9	43
High Cooling (HC)	239.05	1.95	0.43	0.157	0.94	49.96	50.9	42

Observations: Similar performance as mentioned above in terms of the magnitude of the output voltage and acceptable voltage wave shape is also obtained with an air conditioner load. Output frequency has been well regulated by the system. Power factor was less than unity due to reactive power consumption by the load. Different operational modes of the air conditioner (i.e. LF, HF, LC and HC) consumed different levels of power which did not affect the performance of the system.

Load Test: 04

Load Type (Computer)								
	Load Voltage (V)	Load Current (A)	Power (kW)	Reactive Power (kVAR)	Power Factor	Frequency (Hz)	Battery Voltage (V)	Battery Temperature (˚C)
Griffith Power Meter	239.5	0.3	0.035	0.06	0.45	49.96	50.2	33

Observations: Acceptable performance is obtained with the light load (0.3 A) as well. The MPS did not produce higher voltage when operated with the lighter load. Higher voltage can reduce the performance and life time of the connected load. Normally, if higher voltage occurs which is higher than rated voltage (240 V-single phase) then the life time of the load can be reduced. However, this did not occur when we tested the MPS unit.

Load Test: 05

Load Type (Electric Fry pan)								
	Load Voltage (V)	Load Current (A)	Power (kW)	Reactive Power (kVAR)	Power Factor	Frequency (Hz)	Battery Voltage (V)	Battery Temperature (˚C)

Griffith Power Meter	239.5	5	2.2	0	0.99	49.96	50.2	33

Observations: The test results showed an acceptable constant output voltage and voltage wave shape with the comparatively higher resistive load (5A). Output frequency is also almost 50 Hz (49.96 Hz). The power factor was kept constant (~ 1) due to no reactive power consumption by the load. It is evident that the MPS provides rated voltage and frequency with both lighter and comparatively higher load.

Load Test: 06

Load Type (Combined Load : Air Conditioner + Oil Heater)								
	Load Voltage (V)	Load Current (A)	Power (kW)	Reactive Power (kVAR)	Power Factor	Frequency (Hz)	Battery Voltage (V)	Battery Temperature (˚C)
Low Fan	239.5	6.5	1.56	0.0046	0.98	49.96	50.2	33
High Fan	239.5	7.7	1.84	0.02	0.98	49.96	50.2	33
Low Cooling	239.5	7.7	1.84	0.15	0.98	49.96	50.2	33
High Cooling	239.5	6.4	1.53	0.157	0.98	49.96	50.2	33

Observations: The similar performance in terms of voltage and frequency magnitudes, and wave shapes were found with the combinations of two loads, i.e., air conditioner and oil heater. Output frequency was well regulated by the system. Power factor was less than unity due to reactive power consumption by the load. Different operational modes of the air conditioner (i.e., LF, HF, LC and HC) consumed different levels of power but these did not affect the performance of the system. The cooling fan of the testing unit starts when the load consumes more than 5 A; which is approximately 1.2 kW.

From the testing, average household load consumption pattern and average household active and reactive power consumption were obtained as illustrated in Fig. 2 and Fig. 3.

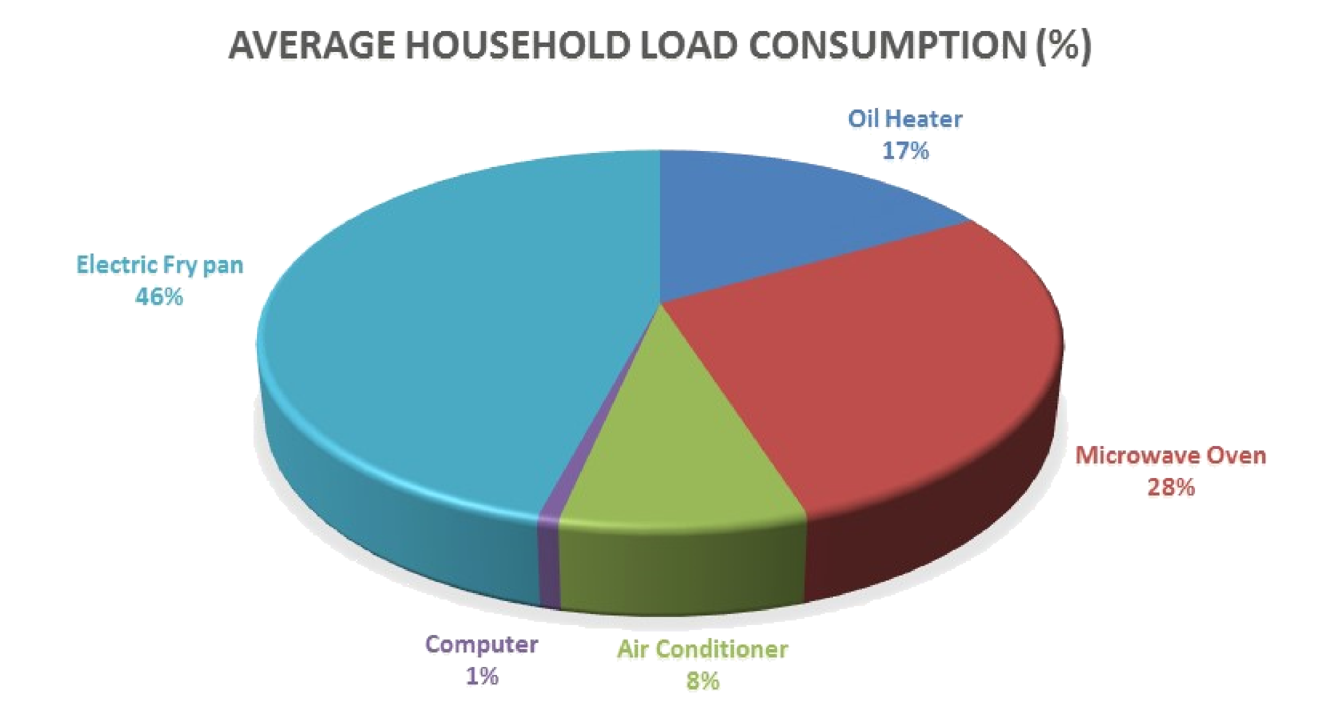
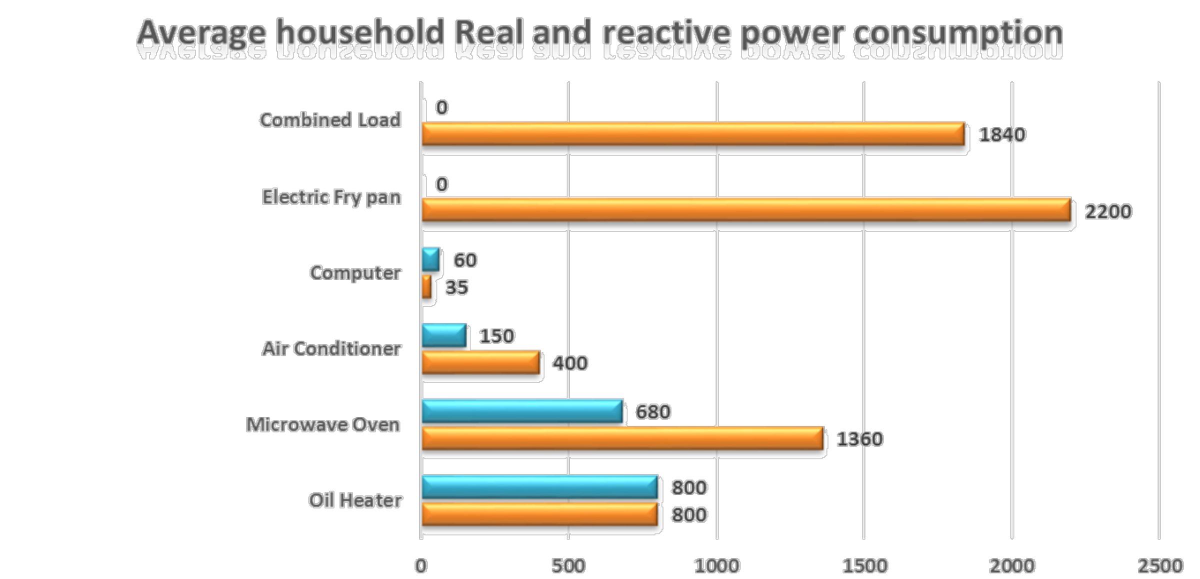


Fig. 2: Average household load consumption pattern



	Oil Heater	Microwave Oven	Air Conditioner	Computer	Electric Fry pan	Combined Load
Average Reactive Power Consumption in VAR	800	680	150	60	0	0
Average Real Power Consumption in W	800	1360	400	35	2200	1840

Fig. 3: Average household Real and reactive power consumption

Battery performance testing:

The system was tested for thirty minutes with combined load connected to it. The loads used in the testing were the air conditioner and the oil heater. Battery voltage and temperatures were measured with ten minute interval. A linear relationship of battery voltage with the temperature drop was observed. The findings are illustrated in Fig. 4.

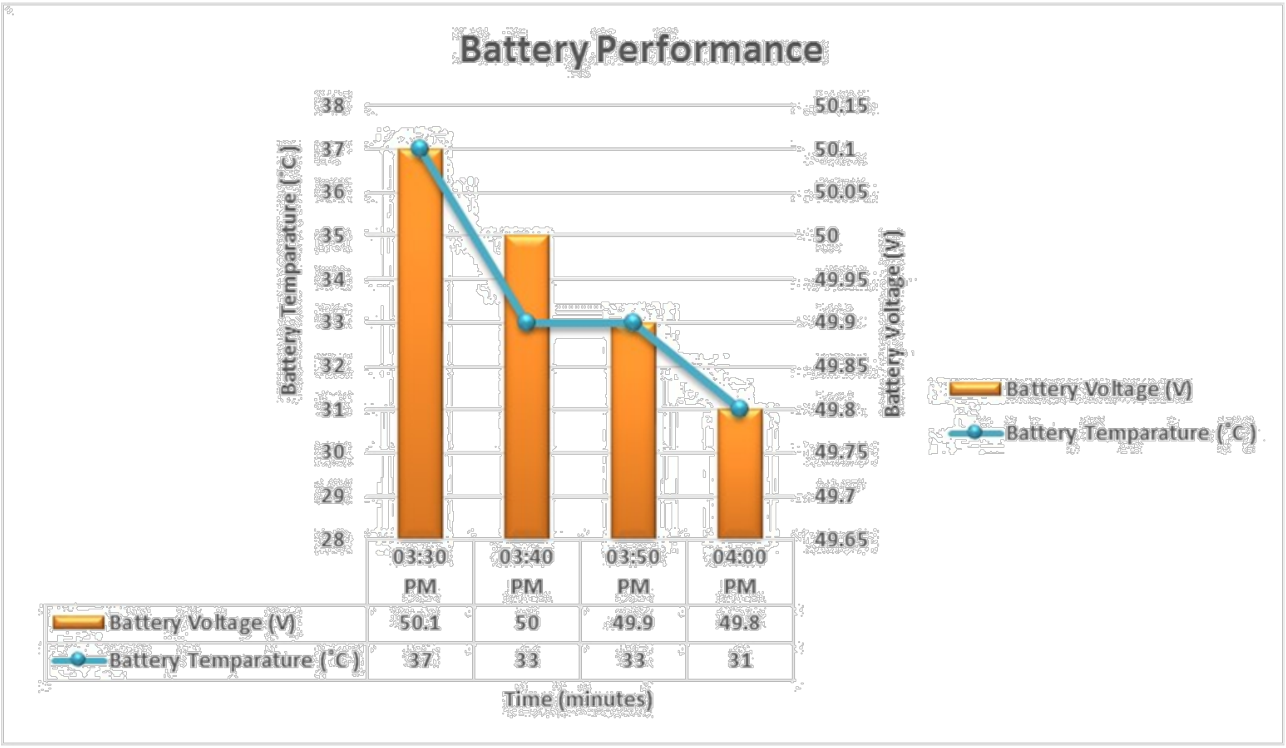


Fig. 4: Battery array performance testing

Voltage Wave shape:

The voltage waveform of the system generated voltage generated was observed and provided in Fig. 5.

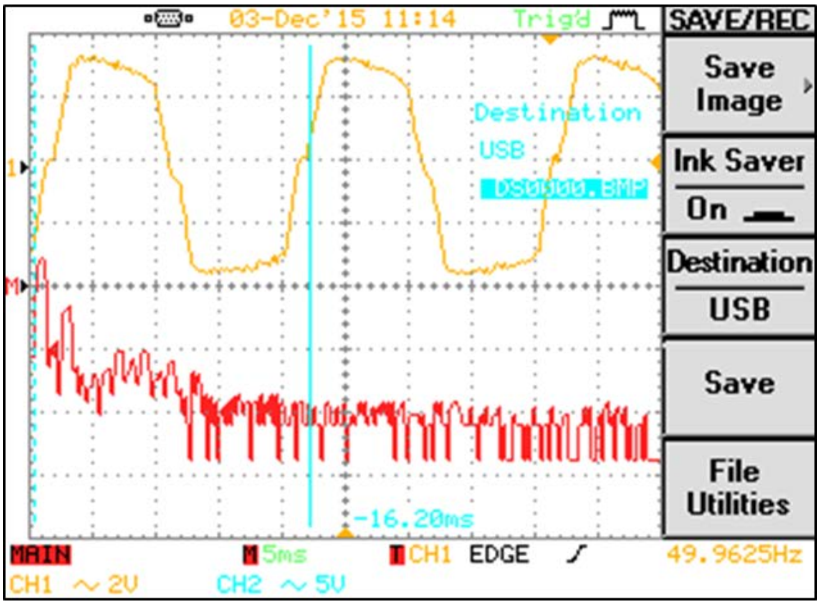


Fig. 5: Voltage wave shape during the operation (orange line) and harmonic contents (red line)

Electromagnetic compatibility (EMC) testing:

The EMC conducted and radiated emission were tested within the full range between 150 kHz and 30 MHz according to the EN55022 (2006) / CISPR22 standard [4] but no ground plane was used as the setup is for baseline test only. Rohde & Schwartz Hameg HM6050-2 line impedance stabilisation network (LISN) and Rohde & Schwartz Hameg HMS3000 spectrum analyser were used for conducted emission test. As shown in Fig. 6, background measurement of charger output is under -55dBm which is acceptable for the general power usage. Additional Rohde & Schwartz Hameg HZ540 toolkits were connected for investigation of RF electromagnetic fields. Results show no evidence of obvious radiation.

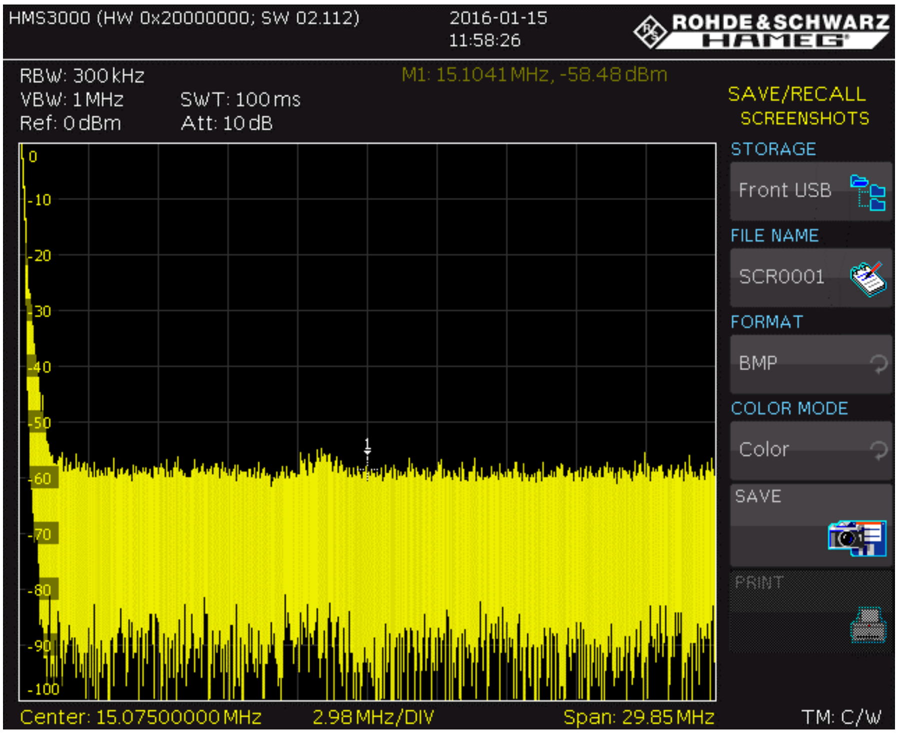


Fig. 6: Background emissions measurement 150 kHz – 30 MHz

Recommendations:

- Inverters can present a hazard when operated without an earth connection. Therefore, as explained earlier, In the case of an "off grid" installation (i.e., when the MPS is being installed in a building that is not connected to a public/private utility power grid) the MPS will need to be grounded with an earth stake that complies with the SA&NZA Standards.
- We understand that the villages in Tanna Island, Vanuatu where the MPS are being installed are all "off-grid" and therefore an earth connection will be essential.
- The MPS needs a certificate of compliance from Aus-Test compliance testing laboratories (SA). It cannot be used in Australia before completing this compliance test.

References:

1. Australian standard (AS 4777-2005), Grid Connection of Energy Systems via Inverters - Australian Government.
2. Electricity Regulation 2006, Queensland
3. The Australian PV Association, The PV integration and Australian distribution network, 2007, www.apva.org.au.
4. AS/NZS CISPR 22:2006, AS/NZS CISPR 22:2006 , Australian/New Zealand Standard Information technology equipment—Radio disturbance characteristics—Limits and methods of measurement.

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