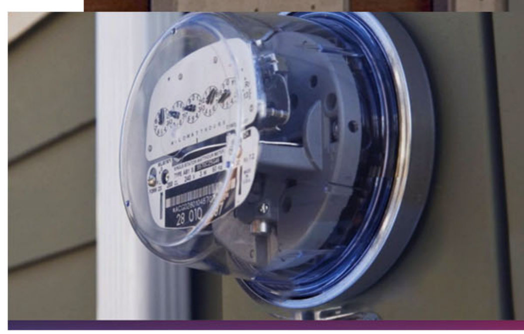
SAVANT POWER

CIGRE 2021 GRID OF THE FUTURE SYMPOSIUM

HARMONIC ANALYSIS OF RESIDENTIAL MICROGRID OPERATING ON/OFF GRID WITH NON-LINEAR LOADS

Smart Homes Operating as a *Microgrids*



Smart Home Operating as a Microgrid

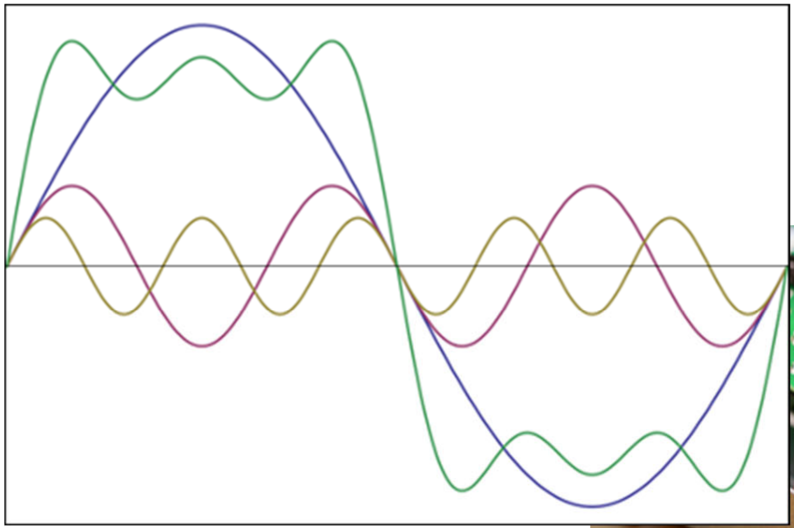
✓ Ensure the microgrid is resilient during both grid-connected and islanded operation.

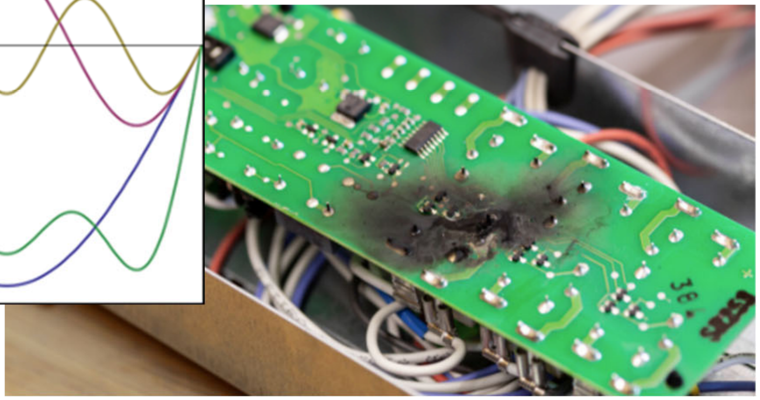
✓ Key component often overlooked in low voltage residential space is power quality.
- DER/microgrid control technology
- Load types: non-linear loads. Non-linear loads, such as switch mode power supplies, LED lighting and rotary converters, are not only common in a typical smart home, but can make up most of the load profile.

Power Quality

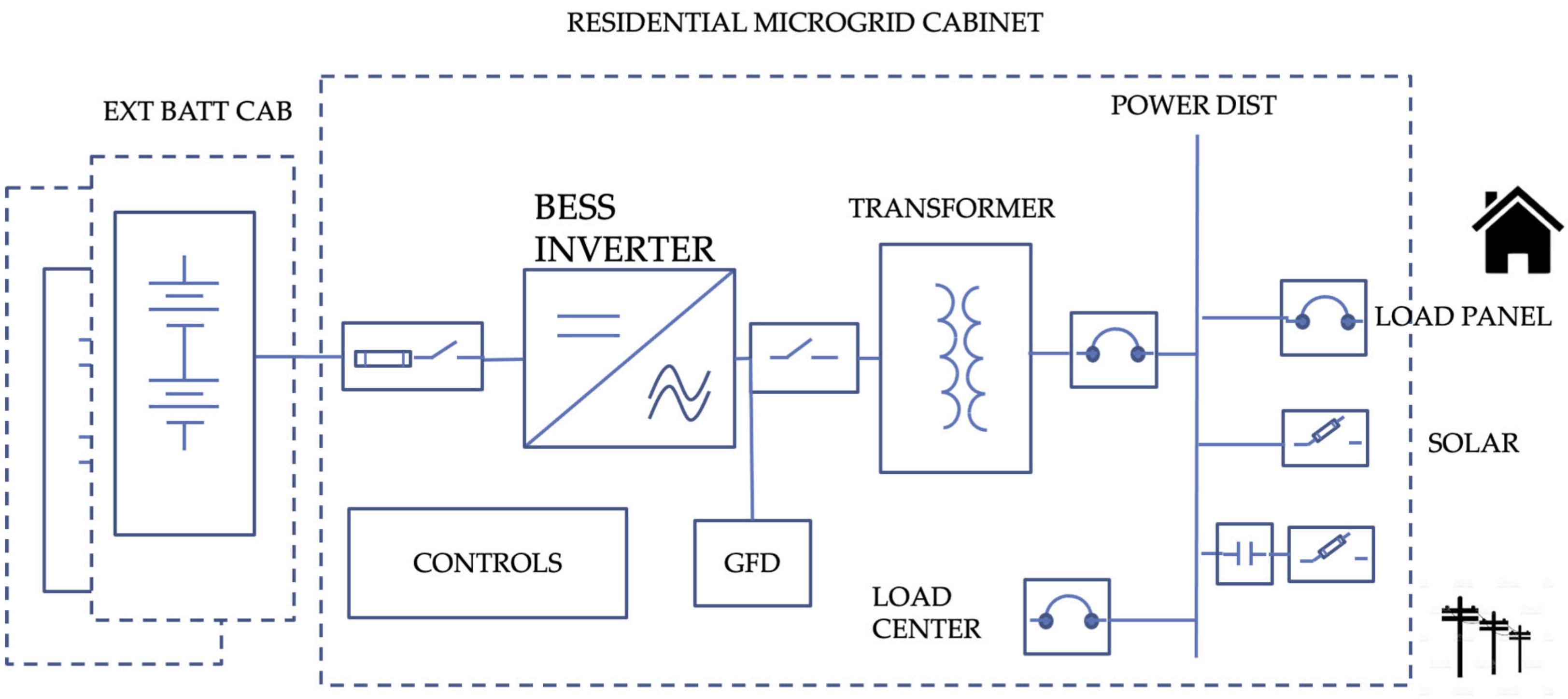
Harmonics

IEEE Std 519

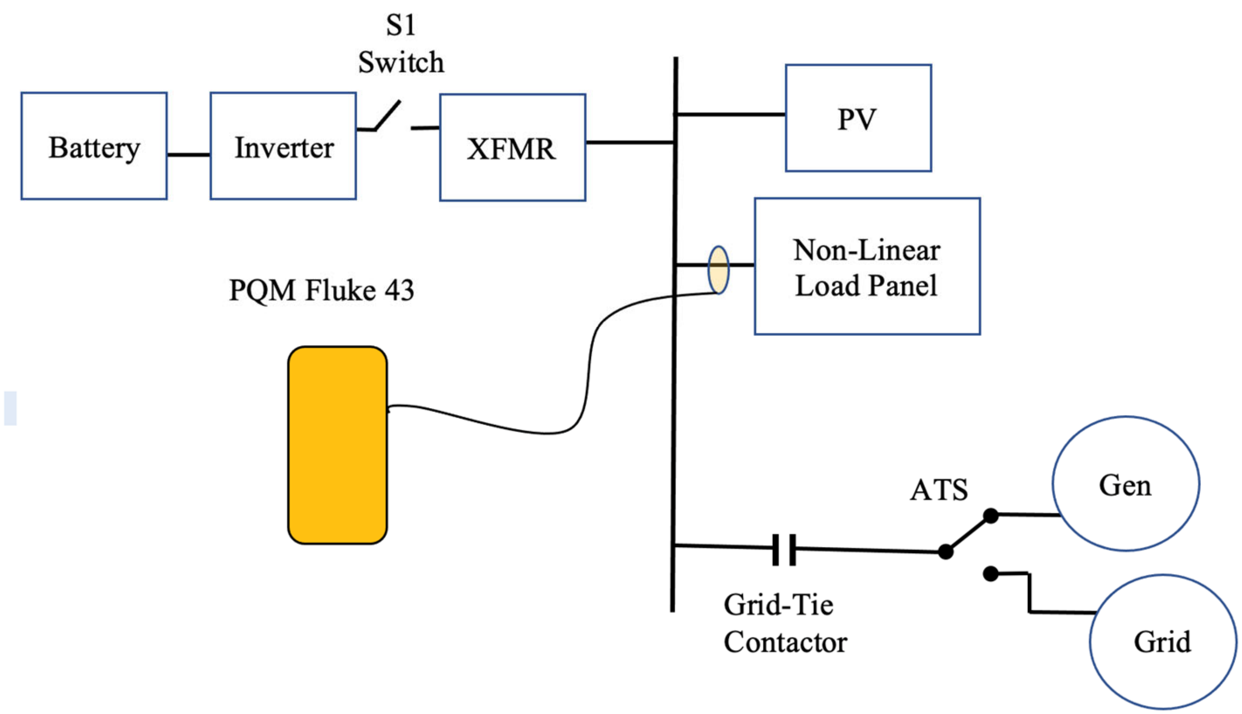




Residential Microgrid Example Topology



240VAC / 600A Lab Test Fixture



LAB TEST PROCEDURE

1. **Grid Only:** Take Current THD measurements with DER unit off (S1 OPEN, Grid-Tie Contactor CLOSED)
2. **Grid + DER:** Take Current THD measurements with DER unit running (S1 CLOSED, Grid-Tie Contactor CLOSED)
3. **DER Only:** Take Current THD measurements with DER Grid Forming (S1 CLOSED, Grid-Tie Contactor OPEN)

LAB TEST RESULTS

System Configuration	Line Current	THD (Current)	3rd (Current)	5th (Current)	7th (Current)
Grid Only	(L1) 50 A (L2) 59 A	(L1) 10.2% (L2) 11.0%	(L1) 8.5% (L2) 9.4%	(L1) 2.3% (L2) 1.5%	(L1) 4.3% (L2) 3.2%
Grid + DER	(L1) 50 A (L2) 59 A	(L1) 8.4% (L2) 10.4%	(L1) 7.1% (L2) 8.7%	(L1) 2.4% (L2) 3.4%	(L1) 3.8% (L2) 3.6%
DER Only	(L1) 42A (L2) 51A	(L1) 15.0% (L2) 15.7%	(L1) 13.0% (L2) 15.4%	(L1) 5.1% (L2) 3.2%	(L1) 2.6% (L2) 1.1%

Table 1 – Current THD Results

CALCULATE TDD PROCEDURE

a) *Lab Grid Short Circuit Current*

$$Isc = \frac{100KVA}{240V} \times \frac{1}{5\%} = 8.33kA$$

Transformer %Z = 5% and infinite bus from utility.

b) *DER Short Circuit Current*

$$Isc = \frac{100KW}{240V} \times 1.4\ p.u = 0.583kA$$

DER inverter short circuit output is 1.4p.u.

c) *Short Circuit Ratios (SCR)*

Grid = $\frac{8333}{400} = 21$

DER = $\frac{583}{400} = 1.5$

Note: Maximum Load current was set to 400A. If the maximum demand current at each residence is lower or higher, this SCR could force the TDD requirement into another category.

IEEE Std. 519

Table 2—Current distortion limits for systems rated 120 V through 69 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{SC}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	TDD
$< 20^c$	4.0	2.0	1.5	0.6	0.3	5.0
$20 < 50$	7.0	3.5	2.5	1.0	0.5	8.0
$50 < 100$	10.0	4.5	4.0	1.5	0.7	12.0
$100 < 1000$	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

[a]Even harmonics are limited to 25% of the odd harmonic limits above.

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.

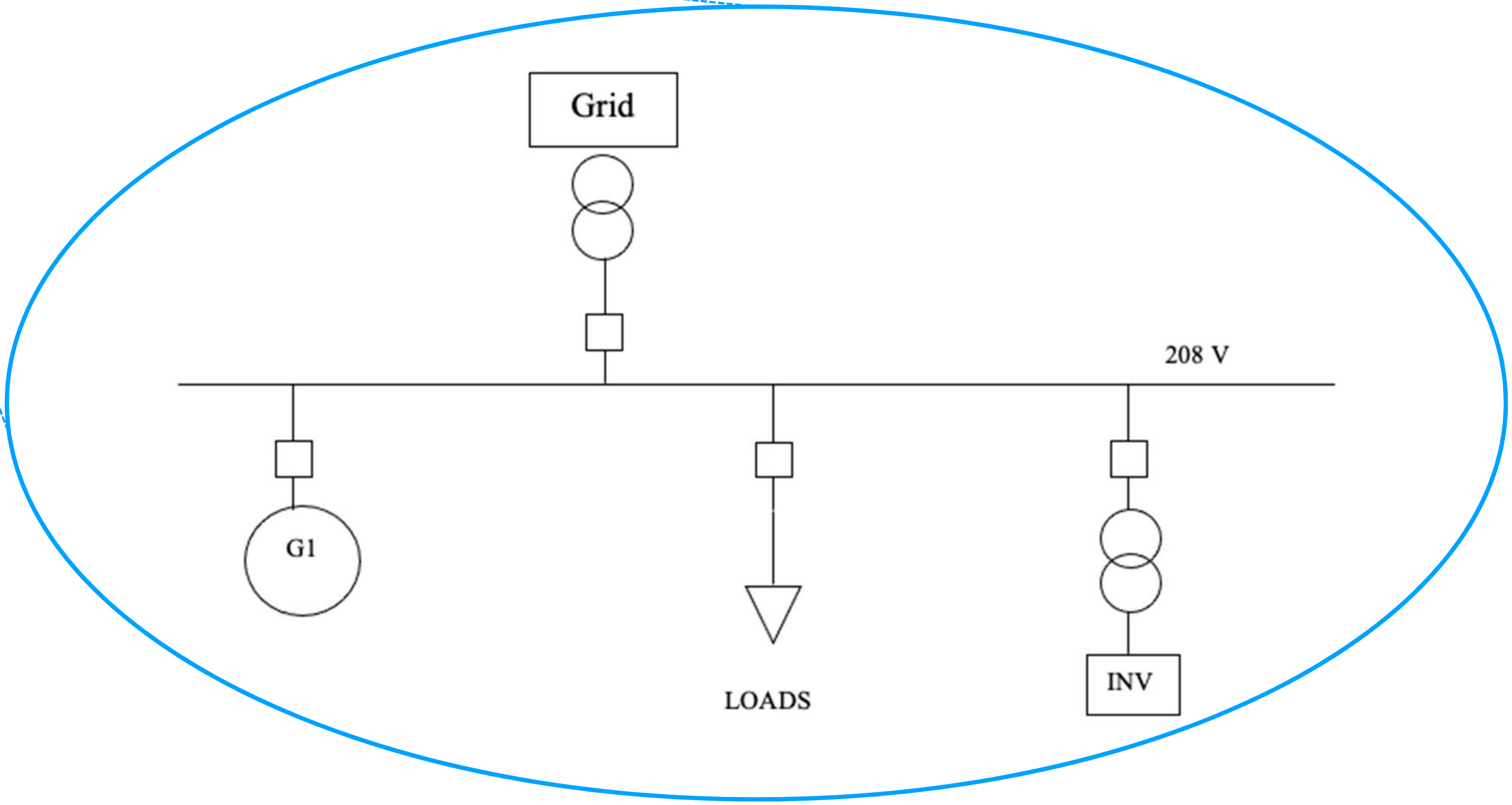
where

I_{sc} = maximum short-circuit current at PCC

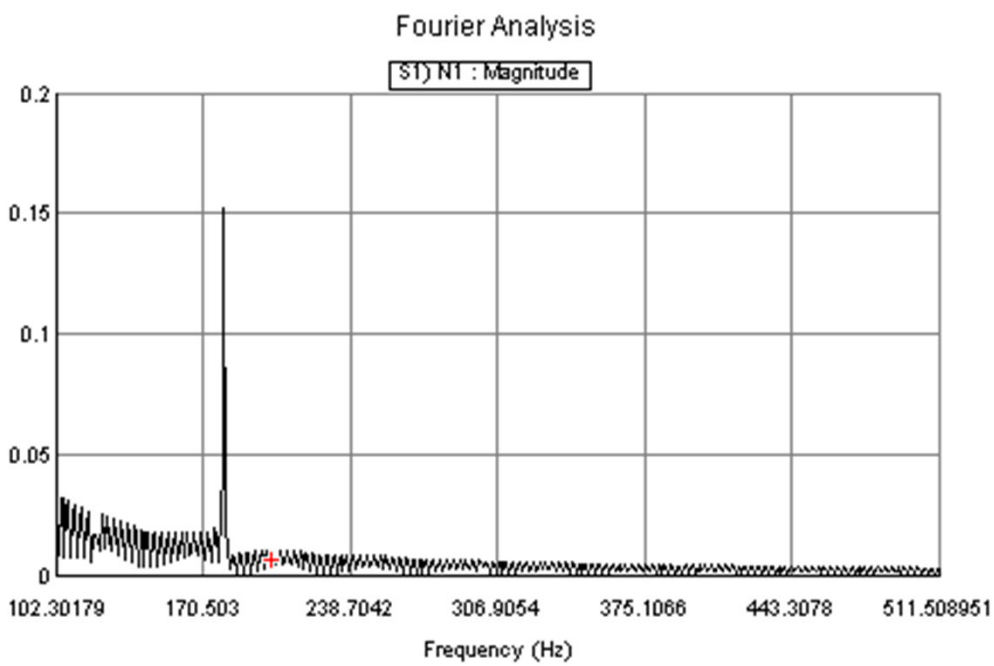
I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

Figure 2 – IEEE519 Table 2 Current Distortion Limits [1]

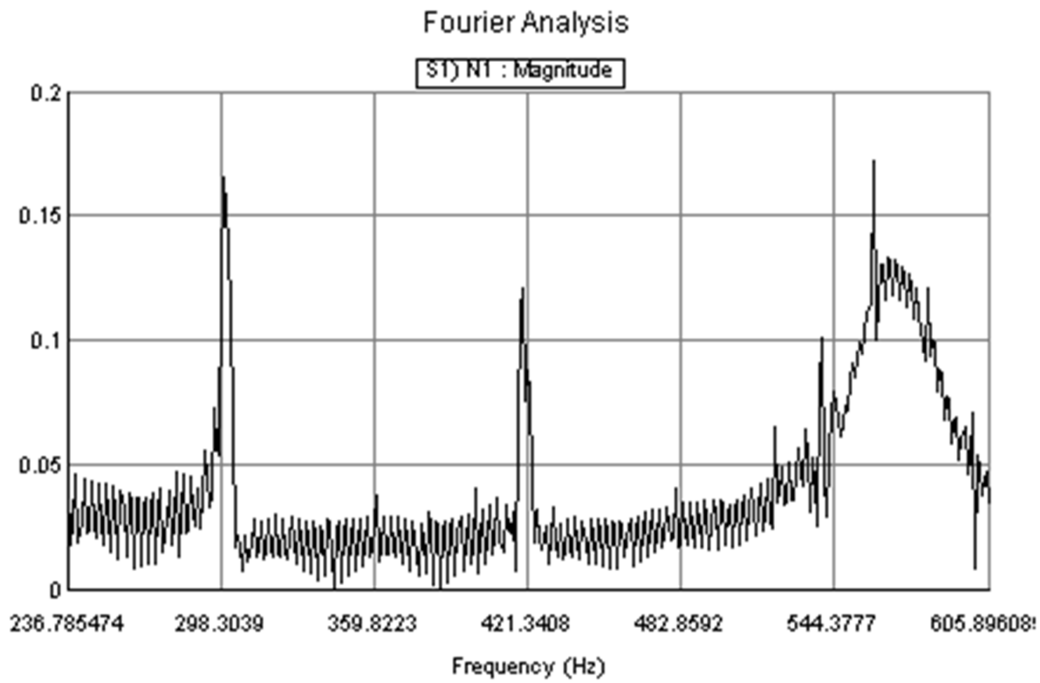
RTDS Test Case



Grid + Gen + Inverter



Inverter Only



Conclusion

- Due to the changes in the nominal load/short circuit current ratios in both modes the microgrid should be modelled, if possible, and measured with accurate power quality equipment.

- Inverter-based DERs inherently do not have large short circuit capability and active filters are not common in single phase or residential applications, mitigating power system harmonics can be a challenge.

- Proper power distribution planning and applying as needed passive solutions such a line filters are a couple key tools to help address these challenges.

- With a sound approach and the right tools, a residential microgrid with non-linear loads can operate with acceptable power quality.

References

- IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems, IEEE Standard 519-2014

- T. Hoevenaars, K. LeDoux, M. Colosino "Interpreting IEEE 519 and Meeting it Harmonic Limits in VFD Applications" IEEE, Paper No. PCIC-2003-15, 2003