The System for Distributed Energy Resource Testing According to the IEEE 1547-2018

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Abstract

Distributed energy resources (DER) are response to an increasing demand for clean and renewable energy. The DER is usually integrated within existing power grid, referred as electric power system (EPS). The IEEE 1547-2018 standard imposes specifications for interconnection and interoperability of DERs within EPS. In this proceedings, the system for testing and validation of DERs in accordance with the IEEE 1547-2018 standard, implemented using virtual instrumentation paradigm will be presented.

Introduction

In the last decade, installations of grid-connected renewable energy source systems are increasing due to several advantages over stand-alone systems. Those systems are usually referred as distributed energy resources (DER). An implementation of one DER is enabled by means of power converters, implemented using power electronics and control software. Therefore, DERs must meet voltage and current quality criteria, and fulfill appropriate requirements for integration into the power distribution grid.

The IEEE 1547-2018 standard prescribes power quality issues, which can be classified into four categories: reactive power capability and voltage/power control requirements, limitations of voltage fluctuations – flicker, DC current injection limit and current distortion limitations.

Methodology

In order to facilitate DER validation and testing, a unique, integrated validation system is developed. The system is based on virtual instrumentation paradigm, capable of performing all measurements according to IEEE 1547-2018 standard. It consists of acquisition device for voltage/current acquisition (Figure 1) and virtual instrument for analysis, data presentation and reporting (Figure 2).

The acquisition device comprises of a connection circuit with current sensors, acquisition modules and data interface.

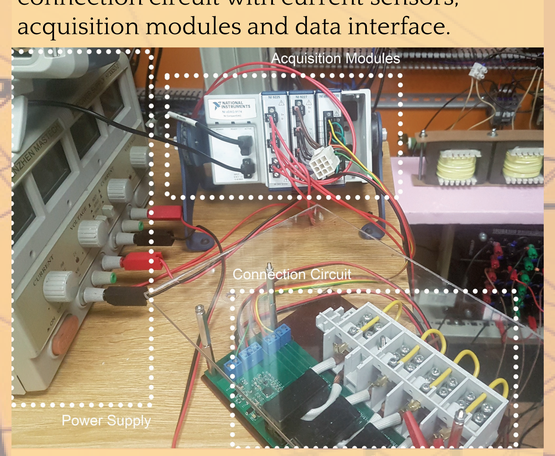
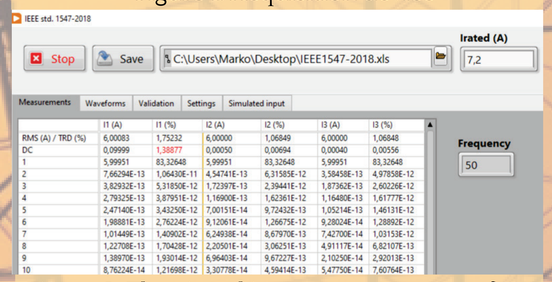


Figure 1. Acquisition device



	I1 (A)	I1 (%)	I2 (A)	I2 (%)	I3 (A)	I3 (%)
RMS (A) / TRD (%)	6,00083	1,75232	6,00000	1,06849	6,00000	1,06848
DC	0,09999	1,38877	0,00050	0,00694	0,00040	0,00556
1	5,99951	83,32648	5,99951	83,32648	5,99951	83,32648
2	7,66294E-13	1,06430E-11	4,54741E-13	6,31585E-12	3,58458E-13	4,97858E-12
3	3,82932E-13	5,31850E-12	1,72397E-13	2,39441E-12	1,87362E-13	2,60226E-12
4	2,79325E-13	3,87951E-12	1,16900E-13	1,62361E-12	1,16480E-13	1,61777E-12
5	2,47140E-13	3,43250E-12	7,00151E-14	9,72432E-13	1,05214E-13	1,46131E-12
6	1,98881E-13	2,76224E-12	9,12061E-14	1,26675E-12	9,28024E-14	1,28892E-12
7	1,01449E-13	1,40902E-12	6,24938E-14	8,67970E-13	7,42700E-14	1,03153E-12
8	1,22708E-13	1,70428E-12	2,20501E-14	3,06251E-13	4,91117E-14	6,82107E-13
9	1,38970E-13	1,93014E-12	6,96403E-14	9,67227E-13	2,10250E-14	2,92013E-13
10	8,76224E-14	1,21698E-12	3,30778E-14	4,59414E-13	5,47750E-14	7,60764E-13

Figure 2. The virtual instrument user interface showing DC injection and current harmonics

Results

Intensive laboratory measurements were performed on a laboratory prototype of a microgrid with several single-phase and three-phase grid inverters, some of which are commercial and others are purpose-built devices for testing new control algorithms. Grid inverters are powered from programmable DC sources IT6000C, which can emulate the characteristics of solar panels and batteries.

As an illustration, Figure 3 shows results of measuring the spectrum of the mains current I_2. The measured results are for an inverter with 7.2A nominal current and with active power equal to 80% rated value.

The waveforms of output voltages are shown in Figure 4.

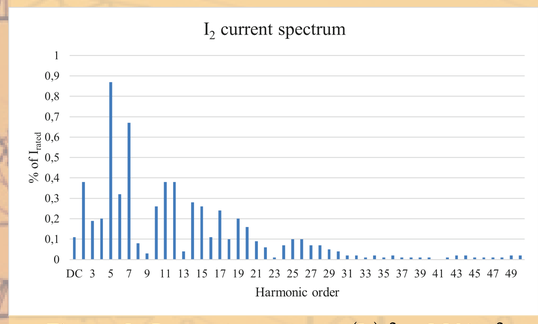


Figure 3. Current spectrum (I_2) for 80% of nominal load

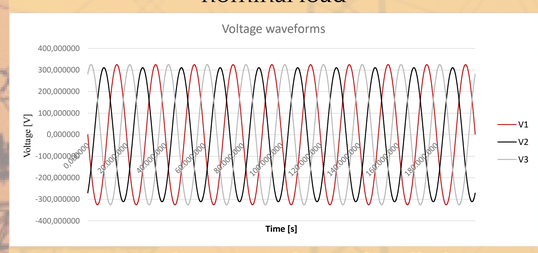


Figure 4. Voltage waveforms for all phases

Conclusion

For the purpose of this research, the testing of implemented microgrid according to IEEE1547-2018 standard current distortion limitation and DC current injection is performed. The results The measured values are compared with reference instrument.

The validation results regarding DC current injection, harmonic components and total rate of distortion (TRD) for all phases, for 80% of maximum rated current are shown in Table 1. Measured results show that microgrid under testing satisfies all IEEE 1547-2018 requirements regarding current distortions.

In further development, other aspect of IEEE 1547-2018 standard, such as limitation of voltage fluctuations, will be incorporated.

Table 1. Validation results for microgrid under testing (80% of rated load)

	I1(A)	I1(%)	I2(A)	I2(%)	I3(A)	I3(%)		I1(A)	I1(%)	I2(A)	I2(%)	I3(A)	I3(%)
TRD		1.74		2.97		3							
DC	0.03	0.38	0.01	0.11	0.03	0.44	26	0	0.02	0.01	0.1	0.01	0.08
2	0.03	0.35	0.03	0.38	0.02	0.32	27	0	0.01	0	0.07	0.01	0.08
3	0.02	0.34	0.01	0.19	0.01	0.15	28	0.01	0.08	0.01	0.07	0.01	0.13
4	0.01	0.13	0.01	0.2	0.02	0.28	29	0	0.01	0	0.05	0	0.06
5	0.03	0.44	0.06	0.87	0.07	0.94	30	0	0.04	0	0.04	0	0.03
6	0.03	0.38	0.02	0.32	0.05	0.68	31	0	0.02	0	0.02	0	0.05
7	0.04	0.62	0.05	0.67	0.05	0.71	32	0	0.03	0	0.02	0	0.04
8	0.01	0.07	0.01	0.08	0.01	0.16	33	0	0.02	0	0.01	0	0.05
9	0.01	0.07	0	0.03	0.01	0.11	34	0	0.04	0	0.02	0	0.04
10	0.02	0.21	0.02	0.26	0.03	0.46	35	0	0.02	0	0.01	0	0.03
11	0.02	0.26	0.03	0.38	0.04	0.57	36	0	0.02	0	0.02	0	0.02
12	0.04	0.5	0.03	0.38	0.05	0.7	37	0	0.02	0	0.01	0	0.03
13	0.03	0.38	0	0.04	0.03	0.41	38	0	0.03	0	0.01	0	0.01
14	0.05	0.63	0.02	0.28	0.05	0.73	39	0	0.02	0	0.01	0	0.02
15	0.02	0.21	0.02	0.26	0.03	0.4	40	0	0.03	0	0.01	0	0.02
16	0.03	0.43	0.01	0.11	0.03	0.46	41	0	0.01	0	0	0	0.02
17	0.01	0.1	0.02	0.24	0.02	0.34	42	0	0.01	0	0.01	0	0.01
18	0.02	0.29	0.01	0.1	0.02	0.23	43	0	0.02	0	0.02	0	0.02
19	0.04	0.54	0.01	0.2	0.05	0.73	44	0	0.02	0	0.02	0	0.01
20	0	0.02	0.01	0.16	0.01	0.14	45	0	0.01	0	0.01	0	0.02
21	0.01	0.21	0.01	0.09	0.02	0.27	46	0	0.01	0	0.01	0	0.01
22	0	0.02	0	0.06	0	0.04	47	0	0.01	0	0.01	0	0.01
23	0.01	0.1	0	0.01	0.01	0.13	48	0	0	0	0.01	0	0
24	0	0.02	0.01	0.07	0.01	0.1	49	0	0.02	0	0.02	0	0.01
25	0.01	0.13	0.01	0.1	0.01	0.17	50	0	0	0	0.02	0	0.01

Acknowledgements

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