Electric Motor Systems
EMSA

Round Robin tests for converter losses (RR'C)

Conrad U. Brunner, Zurich

Workshop at Motor Summit, Zurich

13 November 2018

Agenda

time	program	speaker
13:30	Welcome to RR'C Workshop	Conrad U. Brunner
13:45	Introduction to UTP	Andrew Baghurst
14:00	Report of testing results, no 1	Andrew Baghurst
14:15	Report of testing results, no 2	Emmanuel Agamloh
14:30	Report of testing results, no 3	Andrea Vezzini
14:45	Coffee break	
15:00	Report of testing results, no 4	Sandie B. Nielsen
15:30	Results RR'C phase 1	Sandie B. Nielsen
16:00	Discussion of testing results and UTP	Martin Doppelbauer
16:15	Open discussion	all
16:45	Way forward: necessary changes in IEC 61800-9-2	Tim Schumann, all
17:00	Outlook, plan for RR'C phase 2	Andrea Vezzini
17:15	End of workshop	Conrad U. Brunner

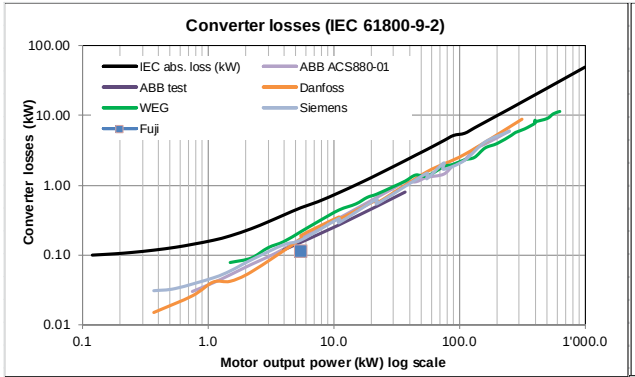
Background

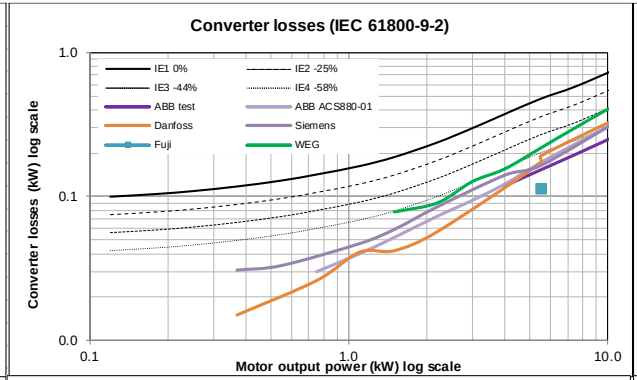
- IEC 61800-9-2, edition 1
  - published on 3 March 2017
  - unsatisfactory testing description
  - discussion on level of reference losses
  - no statistical evidence to set IE levels
- EEMODS 2017 in Rome IT:
  - launch of RR'C Task Force EMSA & WG18 on 6 September 2017
- Workshop at Motor Summit 2018
  - present and discuss intermediary results: Uniform Testing Protocol
- WG18 meeting: 19 - 21 February 2019 in Melbourne, Australia
  - present final report phase 1
  - launch of phase 2

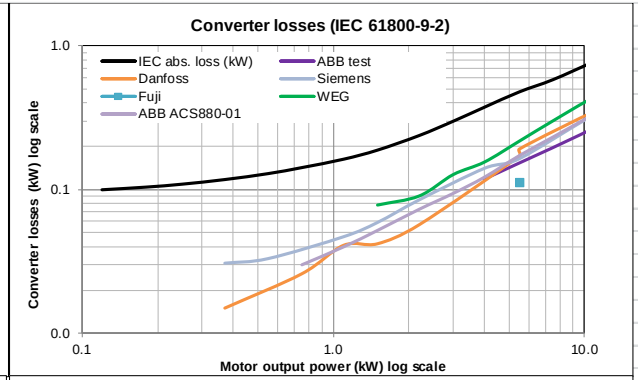
Frequency converter performance

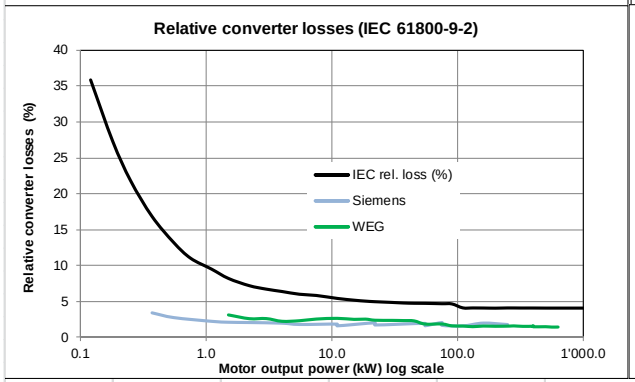
Catalogue data

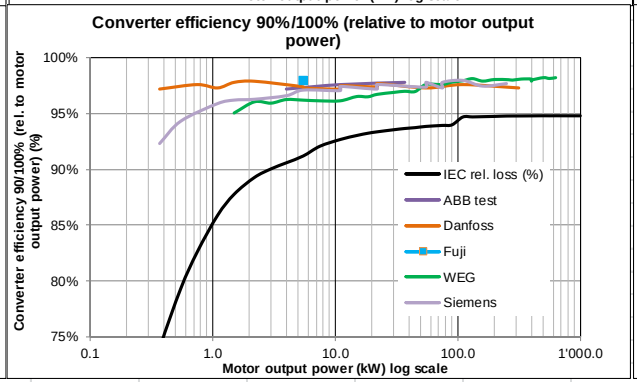
- Presentation 18 May 2017 in Graasten

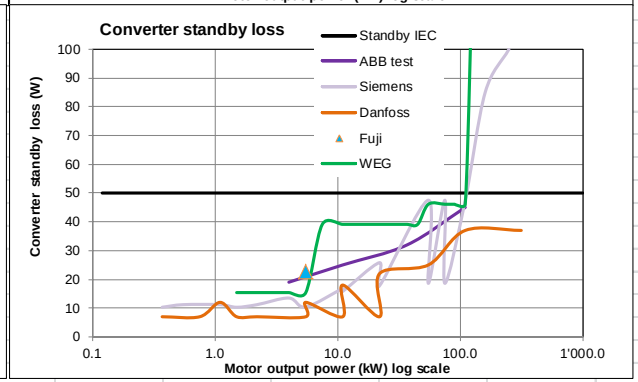












RR'C Task Force

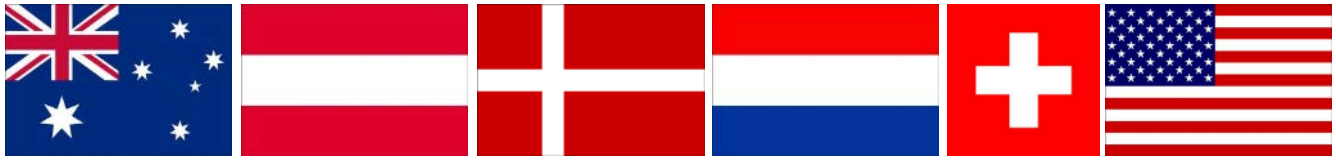
- **Project manager (PM):**
  - Sandie B. Nielsen/DK (Task Force Leader),
  - Andrea Vezzini/CH (Task Force Co-Leader)
- **Advisory group (technical support for the PM):**
  - Emmanuel Agamloh/Advanced Energy, USA;
  - Pierre Angers/Hydro Quebec, CA;
  - Andrew Baghurst/Caltest, AU;
  - CHAI Qing/China National Center for Quality Supervision and Test of Electrical Control and Distribution Equipment/Tianjin CN;
  - Kurt Stockman/University of Gent, BE.
- **Steering committee (strategic support and financial resources):**
  - Maarten van Werkhoven/NL (4E EMSA), Roland Brüniger/Swiss government CH, Representative from Danish government DK
- **Industry contact group:**
  - ABB (Freddy Gyllensten, Sweden), Danfoss (Norbert Hanigovszki, DK), Fuji Electric (Ikuya Sato, Japan), SEW Eurodrive (Tim Schumann, US); Siemens (Bill Finley, USA)

4E EMSA

Electric Motor Systems Annex

- IEA Technical Cooperation Program
- 6 countries
- 2009 – 2019; 4th phase 2019 – 2023
- www.motorsystems.org

- 4E EMSA
- Operating Agent:
  Maarten van Werkhoven/NL
- Program coordinator : Rita Werle/CH



Collaboration on RR'C between IEC SC 22G WG18 & 4E EMSA

- EMSA provides the management of the RR'C and secures the funding for new scientific evidence.
- Interested governments:
  CH, DK, AU, USA (funders in phase 1),
  plus GE, CA, JP and CN, minus AU (phase 2)
- All documents and testing results are shared with IEC WG18.
- Once the results are on the table regular IEC procedures will take over (CD/CDV/FDIS).
- 11 members of WG18 are members of RR'C Task Force in phase 1,
  all WG18 members are invited to contribute in phase 2.

Goal of RR'C

- The test method described in IEC 61800-9-2:2017 (edition 1) for converters (and in IEC TS 60034-2-3:2013 for motors driven by converters) have not been used for sufficient time to know their accuracy and repeatability.
  ► Clarify and verify test method.
- The test laboratories around the world using this test method are not yet familiar with it.
  ► Check laboratory performance
- The performance of the converters and their losses need to be verified vs. the catalogue data.
  ► Provide scientifically based and documented evidence.
- Different products from different manufacturers need to be tested as to defining the reference and IE1/IE2/IE3 levels.
  ► Clarify spread of product performance by different manufacturers.

Scientific goal of RR'C

- Accurate test results for converters
- Repeatable test method for converters
- Uniform Testing Protocol (UTP)
- Confidential intermediary RR'C test results until all results are available
- Fully documented tests
- Transparent procedures and results

- Keep in mind:
  Combined efficiency of motor and converter

RR'C Documents

Project Paper phase 2
(V3, 20180918)

4E EMSA, Task International Standards — IEC TC22 SC 22G WG 18

Round Robin tests for converter losses (RR'C)

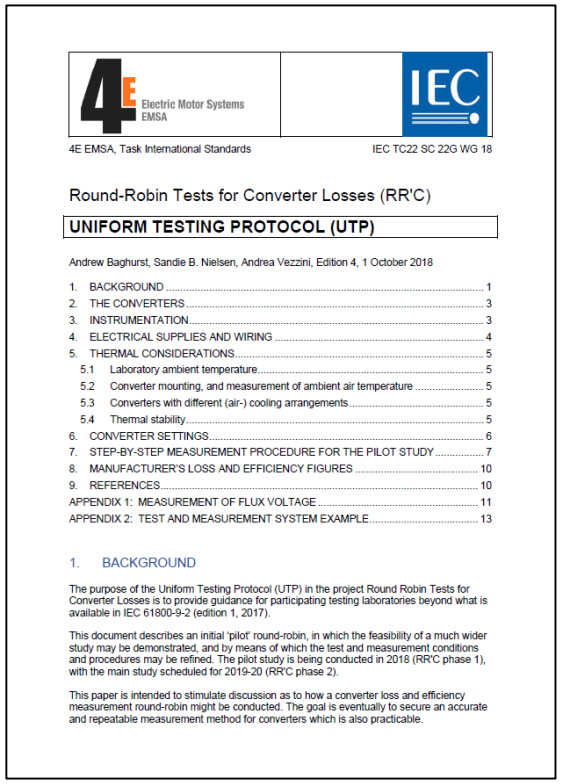
Project Paper: Phase 2

Draft proposal V3, 20180918, CUB

Draft to be discussed by the EMSA members, the project management, the advisory group, the industry contact group, the steering committee and the laboratories involved until end of October 2018

Contact: Conrad U. Brunner, Impact Energy, CH 8032 Zurich, cub@impact-energy.ch

Uniform Testing Protocol
(UTP, edition 4, 20181001)



4E EMSA, Task International Standards — IEC TC22 SC 22G WG 18

Round-Robin Tests for Converter Losses (RR'C)

UNIFORM TESTING PROTOCOL (UTP)

Andrew Baghurst, Sandie B. Nielsen, Andrea Vezzini, Edition 4, 1 October 2018

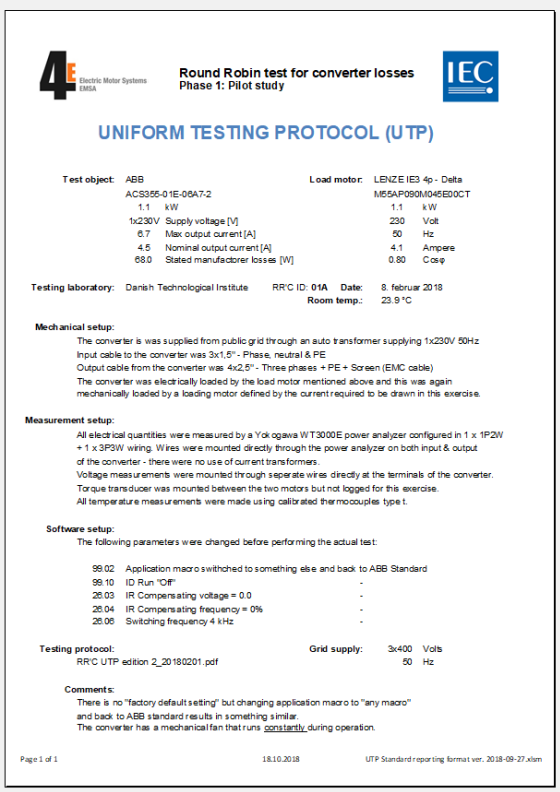
1. BACKGROUND

The purpose of the Uniform Testing Protocol (UTP) in the project Round Robin Tests for Converter Losses is to provide guidance for participating testing laboratories beyond what is available in IEC 61800-9-2 (edition 1, 2017).

This document describes an initial 'pilot' round-robin, in which the feasibility of a much wider study may be demonstrated, and by means of which the test and measurement conditions and procedures may be refined. The pilot study is being conducted in 2018 (RR'C phase 1), with the main study scheduled for 2019-20 (RR'C phase 2).

This paper is intended to stimulate discussion as to how a converter loss and efficiency measurement round-robin might be conducted. The goal is eventually to secure an accurate and repeatable measurement method for converters which is also practicable.

Standard Reporting Format
(SRF 20180927)



Round Robin test for converter losses
Phase 1: Pilot study

UNIFORM TESTING PROTOCOL (UTP)

Test object:	ABB		**Load motor:**	LENZE IE3 4p - Delta	
	ACS355-01E-06A7-2			M55AP090M045E00CT	
	1.1	kW		1.1	kW
	1x230V	Supply voltage [V]		230	Volt
	6.7	Max output current [A]		50	Hz
	4.5	Nominal output current [A]		4.1	Ampere
	68.0	Stated manufactorer losses [W]		0.80	Cosφ

Testing laboratory: Danish Technological Institute — RR'C ID: **01A** — **Date:** 8. februar 2018 — **Room temp.:** 23.9 °C

Mechanical setup:
The converter is was supplied from public grid through an auto transformer supplying 1x230V 50Hz
Input cable to the converter was 3x1,5² - Phase, neutral & PE
Output cable from the converter was 4x2,5² - Three phases + PE + Screen (EMC cable)
The converter was electrically loaded by the load motor mentioned above and this was again mechanically loaded by a loading motor defined by the current required to be drawn in this exercise.

Measurement setup:
All electrical quantities were measured by a Yokogawa WT3000E power analyzer configured in 1 x 1P2W + 1 x 3P3W wiring. Wires were mounted directly through the power analyzer on both input & output of the converter - there were no use of current transformers.
Voltage measurements were mounted through seperate wires directly at the terminals of the converter.
Torque transducer was mounted between the two motors but not logged for this exercise.
All temperature measurements were made using calibrated thermocouples type t.

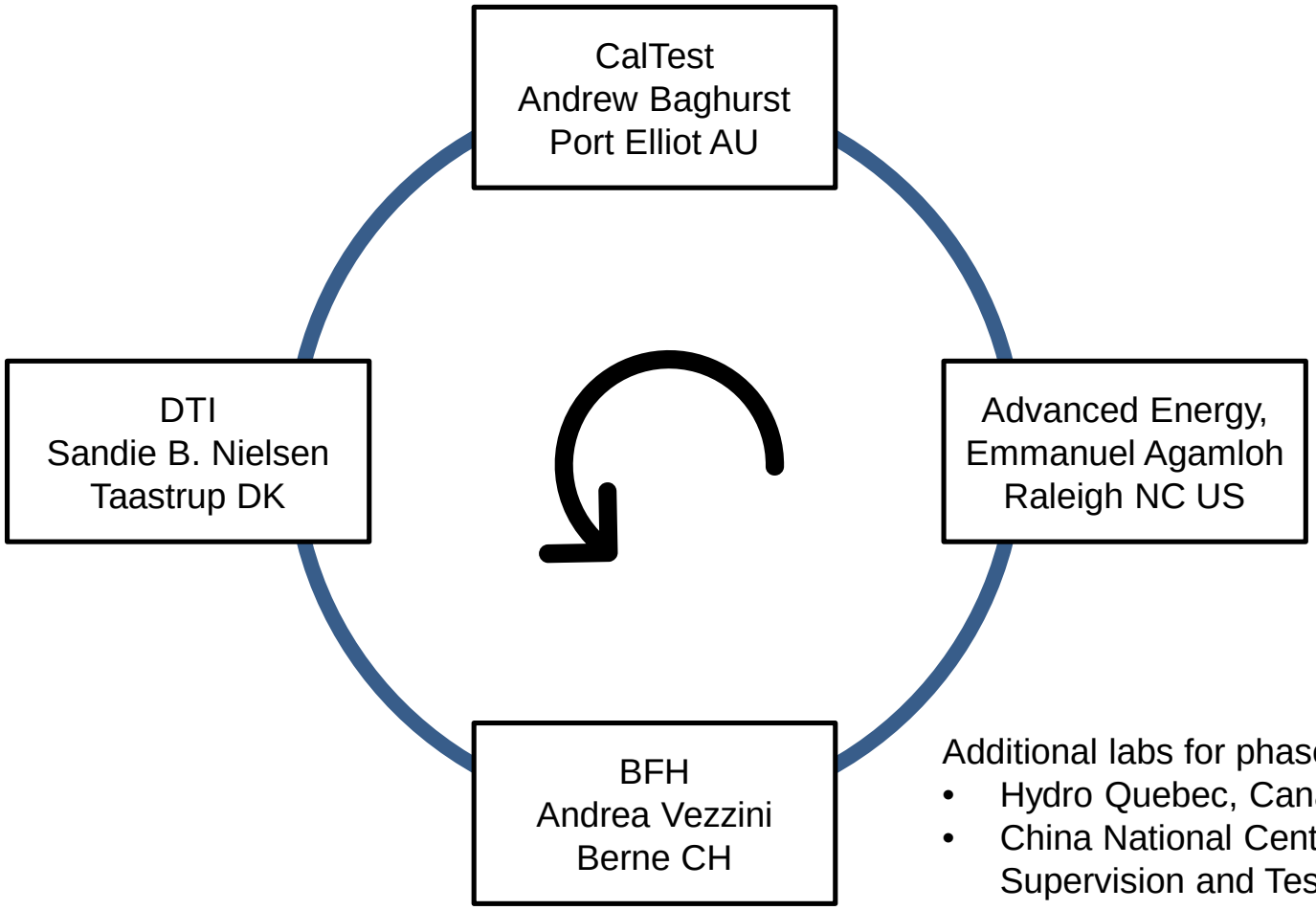
Software setup:
The following parameters were changed before performing the actual test:

99.02	Application macro switched to something else and back to ABB Standard	
99.10	ID Run "Off"	-
26.03	IR Compensating voltage = 0.0	-
26.04	IR Compensating frequency = 0%	-
26.06	Switching frequency 4 kHz	-

Testing protocol: RR'C UTP edition 2_20180201.pdf — **Grid supply:** 3x400 Volts, 50 Hz

Comments:
There is no "factory default setting" but changing application macro to "any macro" and back to ABB standard results in something similar.
The converter has a mechanical fan that runs constantly during operation.

RR'C labs in phase 1



Additional labs for phase 2:

- Hydro Quebec, Canada
- China National Center for Quality Supervision and Test of Electrical Control and Distribution Equipment
- others: Japan

List of Tests in RR'C phase 1

RR'C	Converter					Motor							Test sequence				Remarks/observations
Nr	Manufacturer	Type	Spec. / serial	Input voltage	Output power	Manufacturer	Type	Serial no	poles	rpm	IE-Code	Output power	First test	Second test	Third test	Tested at	
				V	kW					1/min		kW	Lab/date	Lab/date	Lab/date	Lab	
01A	ABB	ACS 355-01E-06A7-2	41711F3363	1x230	1.1	CMG	HLA90S-24-4	849859/007-046	4	1425	IE2	1.1	15-12-17	16-12-17		CalTest	Shipped to DTI
						SEW	DRE90M4/FI	20.0851962901.0001.11	4	1420	IE2	1.1	15-12-17	16-12-17		CalTest	
						VEM	IE2-WE1R 90 S 4	No.: 104813600920 5H	4	1435	IE2	1.1	06-02-18	09-02-18	06-06-18	DTI	Arrived in DK 31/1-18
						Lenze	M55AP090M045E00CT	No.: 10000175131227	4	1444	IE3	1.1	09-02-18			DTI	
						WEG	W22 High Efficiency	No.: 10165427-13	4	1440	IE2	1.5	06-06-18			DTI	Not feasible - Mag. current too high!
																	CDM shipped to CH - June 7th 2018
						WEG	W22 Inverter Duty	00318ET3E182T-W22	4	1760	IE3	2.2	29-10-18	30-10-18		AE	
01B	ABB	ACS 355-03E-23A1-4	41051D5043	3x400	11	CMG	HLA160M-42-4	861269/023-001	4	1470	IE2	11.0	10-01-18	12-01-18		CalTest	Shipped to DTI
						SEW	DRE160MC4/F1	20.08514447.01.0001.09	4	1475	IE2	11.0	12-01-18	15-01-18		CalTest	
																DTI	Arrived in DK 31/1-18
02A	Schneider Electric	Altivar 61	ATV61HU22N4	3x400	2.2	Brook Crompton	WP-DA100LRF-H-IE3	0B 489411	4	1450	IE3	2.2	01-02-18	05-02-18		DTI	
						BUSCK	ME100LA-4 B5	No.: 1603083439	4	1445	IE2	2.2	05-02-18			DTI	
						Brook Crompton	WU-DA100LJ-H	No.: E903478	4	1415	IE1	2.2	05-02-18			DTI	
																	CDM shipped to CH - June 7th 2018
						Hyundai	Premium Efficiency	PKP184SR235B	4	1760	IE3	3.7	30-10-18	30-10-18		AE	
02B	Parker	Parker 650	650-21140010-0F0PR0-A1	1x230	0.75	TECO	ALAA-0080M2-10004-10	No.: C2146009024	4	1430	IE2	0.75	12-02-18			DTI	
						Siemens	1LE10030DB322AB4	No.: 1708/76704793 043	4	1450	IE3	0.75	12-02-18			DTI	
																	CDM shipped to CH - June 7th 2018
						Baldor		M3116A	4	1725	IE2	0.75	29-10-18	29-10-18		AE	
03A	Lenze	i550		3x400	5.5	Lenze	MDEMAIG132-12C1N	1570357510000172839574	4	1450	IE1	5.5		14-05-18		BFH	Lenze replaced the damaged inverter
						ABB	3GBA132210-ADD	3G1C17360618333005	4	1463	IE3	5.5	04-05-18				2. test with different load motor
						Baldor	EMM3770-98(?)	ILLEGIBLE	4	1460	IE2	5.5	21-09-18			CalTest	Converter retained
						WEG	W22	01018ET3E215T-W22	4	1760	IE3	7.5	14-06-18	15-06-18		AE	
03B	ABB	ACS 380	M181300143	3x400	5.5	ABB	3GBA132210-ADD	3G1C17360618333005	4	1463	IE3	5.5	04-05-18		14-05-18	BFH	initial test
						Lenze	MDEMAIG132-12C1N	1570357510000172839574	4	1450	IE1	5.5		14-05-18			2. test with different load motor
						Baldor	EMM3770-98(?)	ILLEGIBLE	4	1460	IE2	5.5	21-09-18			CalTest	Converter retained
						WEG	W22	01018ET3E215T-W22	4	1760	IE3	7.5	13-06-18	14-06-18		AE	
03C	ABB	ACS 380	M181300140	4x400	2.2	ABB	M2BAX10LB4	3G1C18040641217003	4	1450	IE3	2.2	25-05-18	27-05-18	14-05-18	BFH	
						WEG		FH47684	4	1740	IE2	2.2	07-11-18	07-11-18		AE	
04A	Schneider Electric	Altivar 212	ATV212HU22N4	380-480	2.2	WEG W22	00318ET3E182T-W22	1032630726	4	1760	IE3	2.2	02-03-18	13-03-18		AE	
						Siemens	1LE15011AB434AA4	UD1206/1449211002-1	4	1760	IE2	2.2	31-08-18			CalTest	Shipped to DTI
04B	Schneider Electric	Altivar 212	ATV212HU30M3X	200-240	3	WEG W22	00318ET3E182T-W22	1032630726	4	1760	IE3	2.2	01-03-18	13-03-18		AE	
						ABB	M3BA100LB2	3GC11500394169012001	2		IE2	3.0	07-09-18			CalTest	Shipped to DTI
Total	4	9		min	0.75	29					min	0.75	27	17	3	47	
				max	11						max	11.0					

9 converters from 4 manufacturers
29 motors from 12 manufacturers (IE1/IE2/IE3)

47 tests
0.75 kW - 11 kW

Time Line

- **Launch RR'C November 2017 : cooperation EMSA & IEC SC22G WG18**
  (1st phase: until 28 February 2019),
  - goal: clarify testing method (Uniform Testing Protocol)
  - budget circa EUR 75 k (CH, DK, AU, US) with 8 products
- **4 participating laboratories (phase 1)**
  - CalTest, Australia, Andrew Baghurst
  - DTI, Denmark, Sandie B. Nielsen
  - BFH, Switzerland, Andrea Vezzini
  - Advanced Energy, USA, Emmanuel Agamloh
- **Intermediary report phase 1 no 2 to IEC SC 22G WG18 and EMSA**
  (Workshop at Motor Summit on 13 November 2018, in Zurich)
  - 35 tests, 9 converters, 23 motors
  - Surprising good repeatability
  - UTP clarified
- **Plan for phase 2 with 7 participating labs**
  (1 March 2019 - 31 October 2021)
  - Goal: quantitative evidence for check on reference and IE-classes
  - Participants: 3 from phase 1, plus GE, JP, CN, CA, (minus AU because of lack of funding!), total 7 labs
  - Plus 2 (-3) labs for stationary tests of large converters (200 kW - 1000 kW)
  - Budget circa EUR 280 k with 60 products to be tested

Contact

- Conrad U. Brunner, Impact Energy, Zurich Switzerland cub@impact-energy.ch,
- Sandie B. Nielsen, Danish Institute of Technology (DTI), Denmark
- Andrea Vezzini, Berne University of Applied Science (BFH), Switzerland
- Emmanuel Agamloh, Advanced Energy, USA
- Andrew Baghurst, CalTest, Australia

- www.motorsystems.org
- www.topmotors.ch
- www.motorsummit.ch

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CONCLUSIONS

Conrad U. Brunner, Zurich

Workshop at Motor Summit, Zurich

13 November 2018

Discussion, excerpts

1. MD: as simple as possible, as good as possible.
   Input Voltage 400 / 460 V. Dependency on frequency. Try to include it? Reference current for converter: simplifies things, defined by manufacturers. Converter losses <>total system losses. Different requirement for converter with higher capability.
2. BW: Torque producing current important. Frequency important. Measuring uncertainty: +/- 5 to 10%. Very low power drives, uncertainty? No load has the pulses at zero: disabled. Correction factor depending on functionality.
3. NH: SAM beauty: inside to calculate. CDM definition. Compact/standard/premium. Compare simple drives.
4. PA: surprised little deviation
5. KS: IE3 or IE4?
6. TS: losses so small.

Summary of report and discussion

- RR'C organization established
- RR'C phase 1: work according to plan
- UTP established
- Test results have high repeatability

Next steps

- Final report RR'C phase 1:
  WG18 meeting
  9 - 21 February 2019, Melbourne AU
  PUBLICATION: EMSA report

- Kick-off RR'C phase 2:
  9 - 21 February 2019, Melbourne AU
  include 0.12 - 1000 kW
  premium/standard converters