Motor Summit , 8 October 2014, Zurich Switzerland

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

The Way Forward for IECstandards
Loss Determination of Power Drive Systems

IEC SC22G Ad-Hoc Group 17 (AHG17)

Tim Schumann
SEW-Eurodrive, Inc.
1295 Old Spartanburg Hwy.
Lyman, SC 29322
tschumann@seweurodrive.com

SEW EURODRIVE

Thanks to co-author: Dr. Benno Weiss, Siemens AG, Erlangen, Germany.

The Beginning: Requirements Of The European Commission on Energy Efficiency

ErP-Guideline 2009/125/EU

Mandate for CENELEC and CEN: M/470, M/476, M/495, M/488, M/498, M500

prEN 50598-1
EE-Standardization for Drive Applications

prEN 50598-2
Loss determination for converters and drives

prEN 50598-3
Life cycle assessment for converters and drives

INTERNATIONAL ELECTROTECHNICAL COMMISSION

Brief Overview

IEC SC22G

↓

AG15 **Energy Efficiency for adjustable speed electric drive systems - Advisory Group (AG)**

↓

Why IEC SC22G AHG17? →

AHG17 **Ecodesign for power drive systems, motor starters, power electronics & their driven applications**

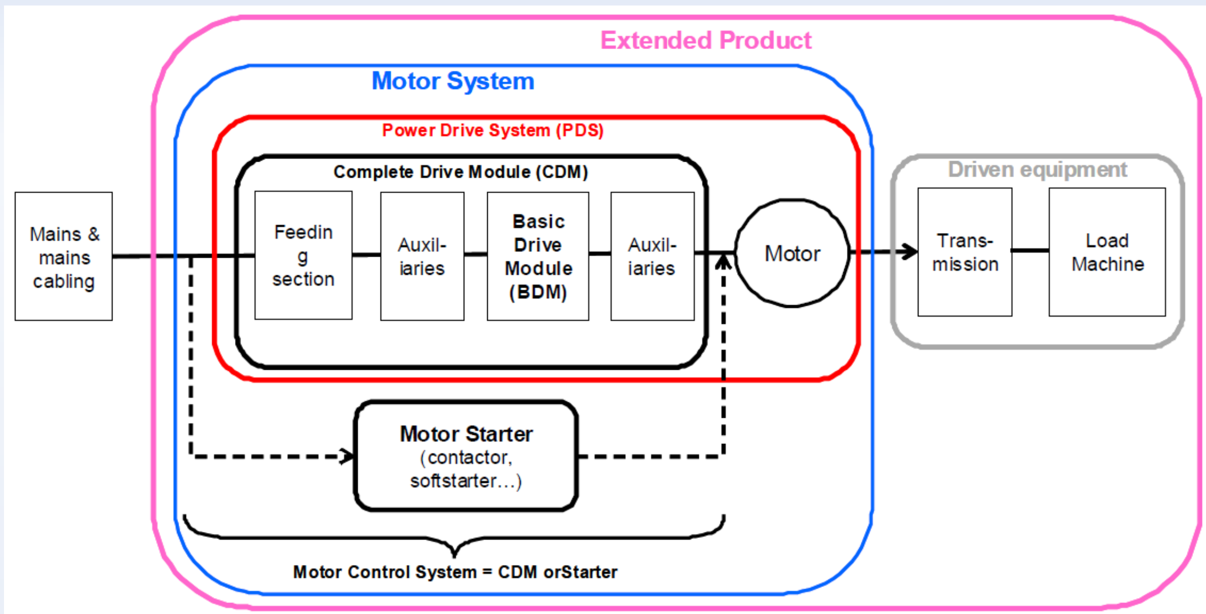
↓

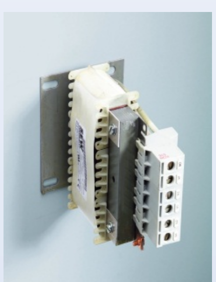
IEC 22G 22G/NP/277 →

WG18

What is a “System” and it’s IE Classification?

It can contain variety of components, e.g. Input Contactor, Variable Frequency Drive or Converter, Interconnecting Cable and Motor.





How to Define Various Components of a System

What is a Reference Complete Drive Module (CDM)?

A Reference CDM is a number to be used for the evaluation of power losses of a larger system or piece of equipment and for IE Classification.

These numbers are based on the power losses of a standard state of the art converter

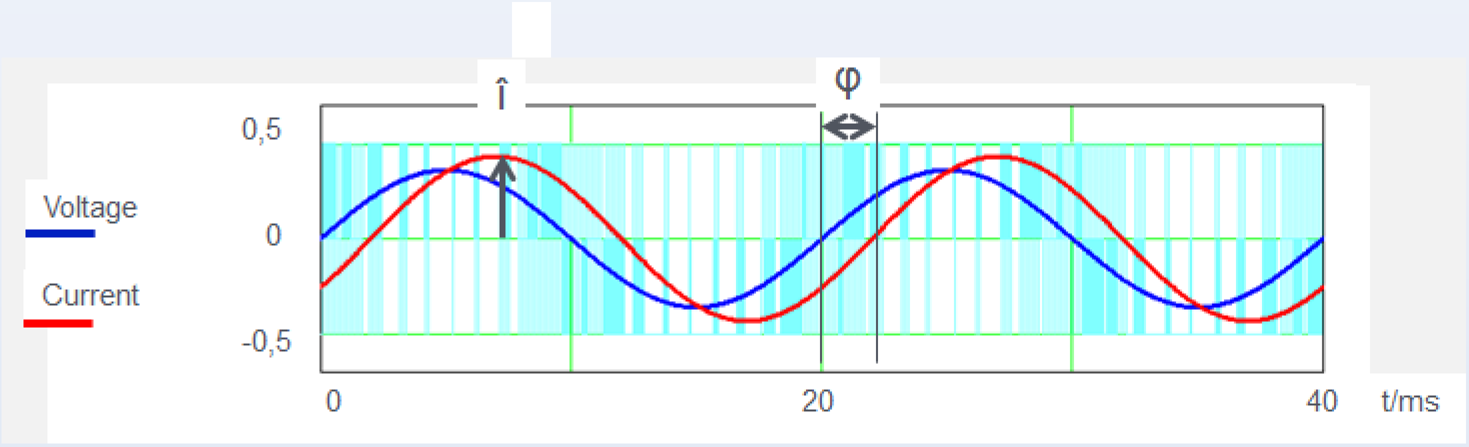
P_rM / kW	$S_{r,equ}$ /kVA	$p_{L,CDM,}$ relative (0;25)	$p_{L,CDM,}$ relative (0;50)	$p_{L,CDM,}$ relative (0;100)	$p_{L,CDM,}$ relative (50;25)	$p_{L,CDM,}$ relative (50;50)	$p_{L,CDM,}$ relative (50;100)	$p_{L,CDM,}$ relative (90;50)	$p_{L,CDM,}$ relative (90;100)
0,12	0,278	33,79	33,84	34,31	33,89	34,04	34,84	34,39	**35,87**
0,18	0,381	25,24	25,28	25,75	25,34	25,49	26,29	25,84	**27,31**
0,25	0,5	19,74	19,79	20,25	19,84	19,99	20,79	20,34	**21,82**
0,37	0,697	14,77	14,82	15,29	14,88	15,02	15,83	15,38	**16,86**
0,55	0,977	11,15	11,19	11,66	11,25	11,39	12,20	11,75	**13,22**
0,75	1,29	8,96	9,01	9,47	9,06	9,21	10,01	9,56	**11,03**
1,1	1,71	6,86	7,13	7,83	6,93	7,34	8,41	7,69	**9,53**
1,5	2,29	5,56	5,83	6,53	5,63	6,03	7,11	6,39	**8,23**
2,2	**3,3**	**4,55**	**4,82**	**5,51**	**4,62**	**5,02**	**6,10**	**5,37**	**7,21**

What is a Test Load?

A test load is an apparatus, which takes load from a converter in such a way that it produces losses in a reproducible manner.

- **It utilizes a defined converter output current amplitude depending on the required torque**

- **It utilizes a defined phase angle between the fundamental output voltage and current depending on the required torque**



What is a Reference Motor?

Standard 3-phase asynchronous motors are widely used in industrial applications. These motors are able to run direct on line or to be fed by a CDM. There is no fixed relationship between the motor and the CDM so any motor can be used with any CDM and vice versa.
In order to determine losses or efficiency classes of a complete system, the CDM user needs data from the motor manufacturer or reference values. Reference values will be provided prEN 50598-2 and IEC 61800-9-2

50 Hz 4 pole IE2 Reference motor

P_N / kW	$p_{L,RM,}$ (0;25)	$p_{L, RM,}$ (0;50)	$p_{L,RM,}$ (0;100)	$p_{L,RM,}$ (50;25)	$p_{L,RM,}$ (50;50)	$p_{L,RM,}$ (50;100)	$p_{L,RM,}$ 100;50)	$p_{L,RM,}$ (100;100)
0,12	28,9	32,8	59,9	36,6	40,5	66,8	51,5	79,6
0,18	23,8	27,1	47,3	30,6	33,8	53,4	44,4	62,7
0,25	19,5	22,4	38,0	25,3	28,1	43,2	37,5	52,9
0,37	15,0	17,6	30,7	19,5	22,1	34,4	28,9	43,2
0,55	11,7	14,4	27,7	15,0	17,7	30,1	21,8	34,2
0,75	9,3	11,7	22,8	12,1	14,5	24,7	19,2	29,5
1,1	7,4	9,7	20,5	10,0	12,3	22,2	16,2	26,3
1,5	6,0	8,2	17,9	8,3	10,8	19,7	14,0	23,9
2,2	5,2	7,2	15,5	7,4	9,4	17,9	12,7	21,4
3	4,5	6,3	13,8	6,5	8,3	16,2	11,4	19,5
4	3,8	5,4	12,2	5,6	7,3	14,4	10,2	17,8
5,5	3,0	4,4	10,5	4,7	6,1	12,6	8,8	16,1
7,5	2,5	3,7	9,3	4,0	5,3	11,2	7,8	14,7
11	2,2	3,4	8,7	3,6	4,9	10,4	7,2	13,1
15	1,8	3,0	7,5	3,1	4,3	9,2	6,4	11,9

How are the Reference Complete Drive Module (CDM) Values Defined?

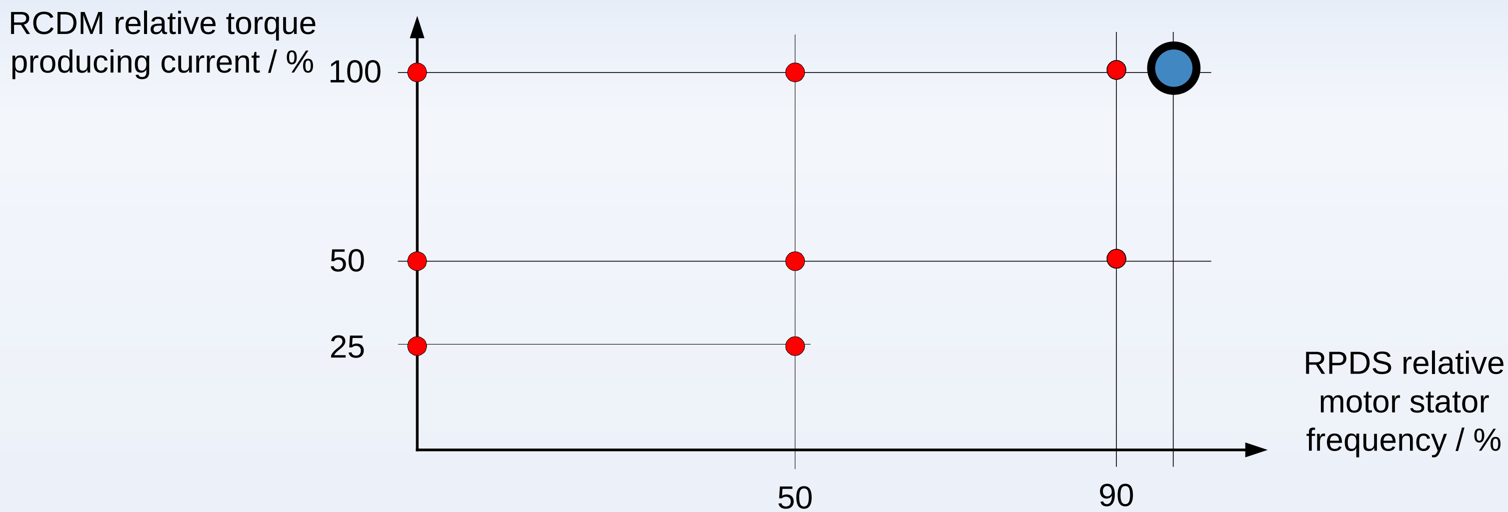
They are Defined by a Test Converter.

A test converter is an apparatus that supplies a motor its voltage and current in way that it creates losses in a reproducible way

- **It creates a three phase AC voltage system via PWM**
- **It uses a 4 kHz vector modulation**
- **It‘s dc link voltage is to avoid overmodulation**
- **It‘s definion can be found in IEC 60034-2-3**

The Relevant Operating Points of a CDM

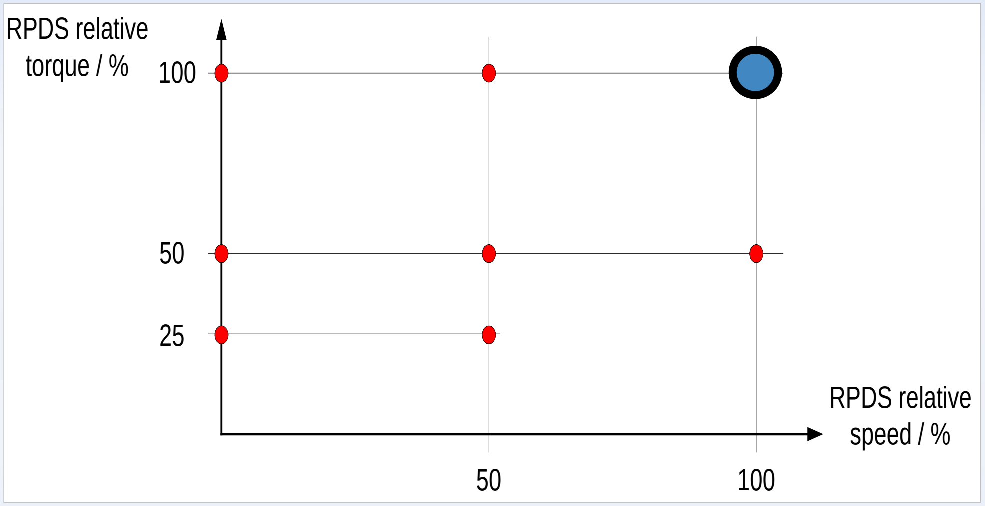
- Determines the power losses of a converter using eight defined operating points



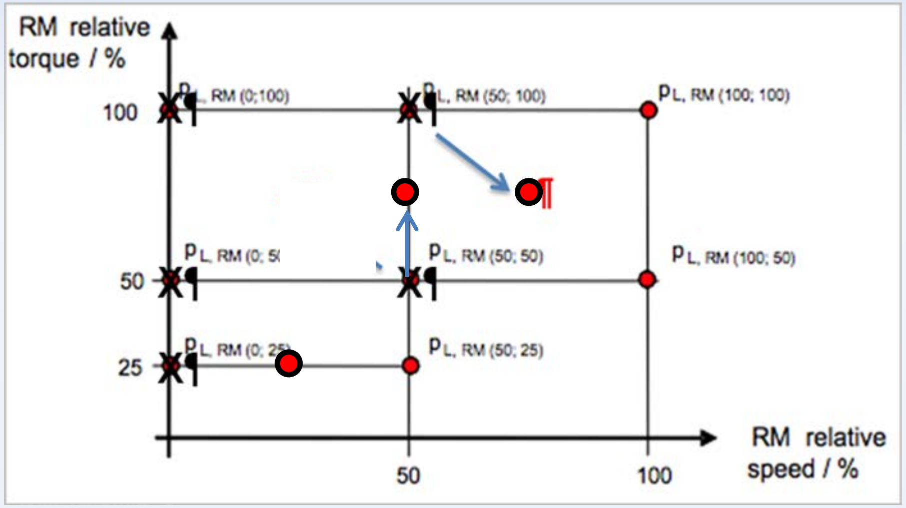
Customer

- Determines the losses at other operating points by using inter- and extrapolation
- Can calculate the required energy of the application by specifiying the operating times of the application at various operating points.

The Relevant Operating Points of a PDS



EN50598-2 Determines the losses in other operating points by inter- and extrapolation



Proposal Martin Doppelbauer for IEC 60034-30-2

Methods of Loss Determination

1) Calculation Method
   - Small effort
   - Good accuracy if the model is correct

2) Electrical Input-Output-Measurement
   - Medium effort
   - Good accuracy for PDS
   - Good accuracy for CDM requires expensive measurement equipment

3) Calorimetric measurement
   - High effort
   - High accuracy for CDM
   - Not applicable for PDS

Calculation Method

Calculation Model of a CDM

- 50598-2 offers a general calculation model that can be used for every CDM
- Individual parameters describe a concrete unit

$$P_{L,on,T} = \sqrt{2} \cdot I_{out} \, U_{T,th} \cdot \left(\left(\frac{1}{2\pi} \right) + \frac{1{,}22 \cdot m \cdot \cos\phi}{8} \right) + \frac{U_{T,r} - U_{T,th}}{I_{r,out}} \cdot 2 \cdot I_{out}^{2} \cdot \left(\frac{1}{8} + \frac{1{,}22 \cdot m \cdot \cos\phi}{3\pi} \right)$$

- Inverter losses (On-state and switching losses of transistors and diodes)
- Rectifier losses
- Line choke losses
- DC link losses
- Current rail losses
- Cooling losses
- Load independent electronics losses

Calculation model of a PDS

- Input data: losses of CDM and PDS

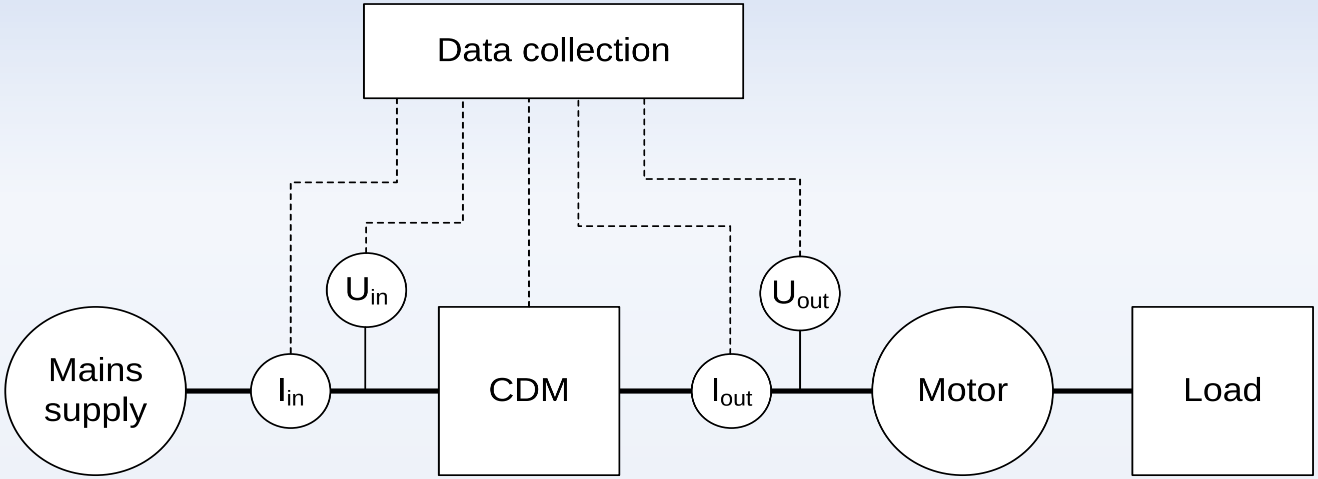
$$p_{L,PDS} = \frac{p_{L,M} \cdot P_{r,M} + p_{L,CDM} \cdot S_{r,CDM}}{P_{r,M}}$$

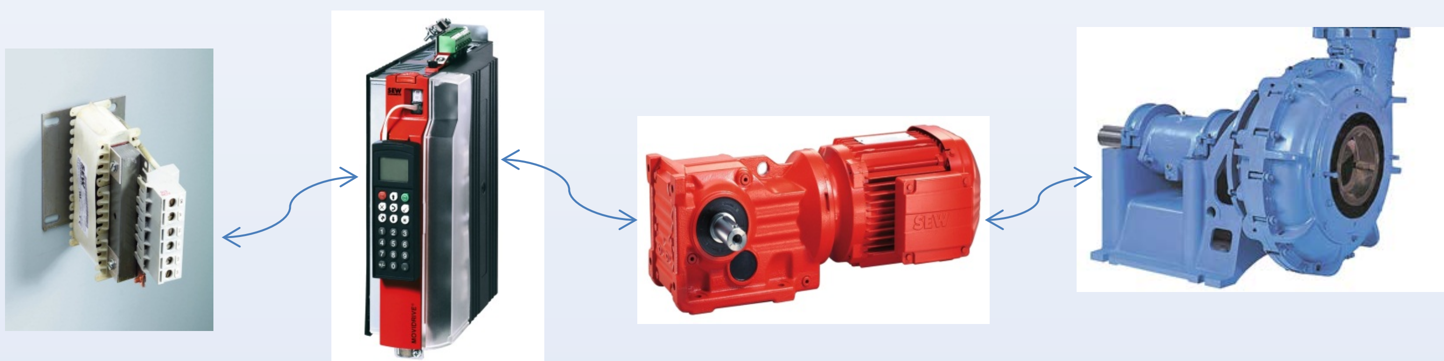
Exception: Operating point at rated speed and rated torque

- In this operating point, the output voltage of the converter is smaller than the rated motor input voltage
- In order to realize its rated power, the motor needs more current
- This higher current leads to higher motor losses

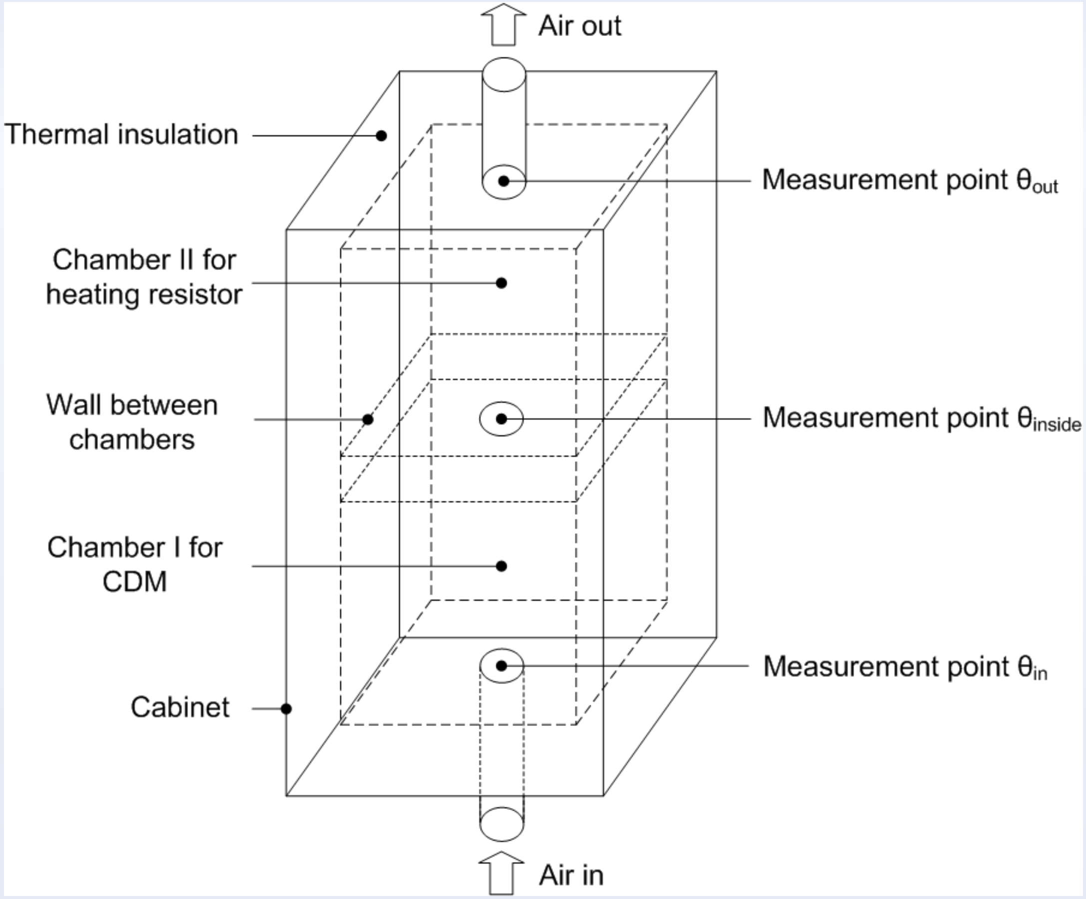
$$p_{L,PDS} = \frac{\frac{U_{r,m}}{U_{1,a,\max,\,CDM}} \cdot p_{L,M} \cdot P_{r,M} + p_{L,CDM} \cdot S_{r,CDM}}{P_{r,M}}$$

Input-Output-Measurement CDM/PDS





Calorimetric Measurement Method



$$P_{L,CDM,determined} = P_{L,resistor} \frac{\theta_{inside} - \theta_{in}}{\theta_{out} - \theta_{inside}}$$

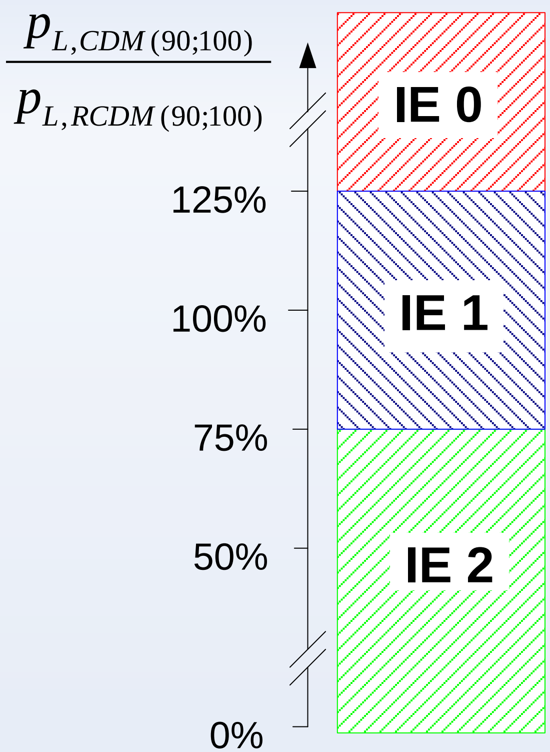
- ❖ **This is not used for a PDS**

Conditions of Loss Determination

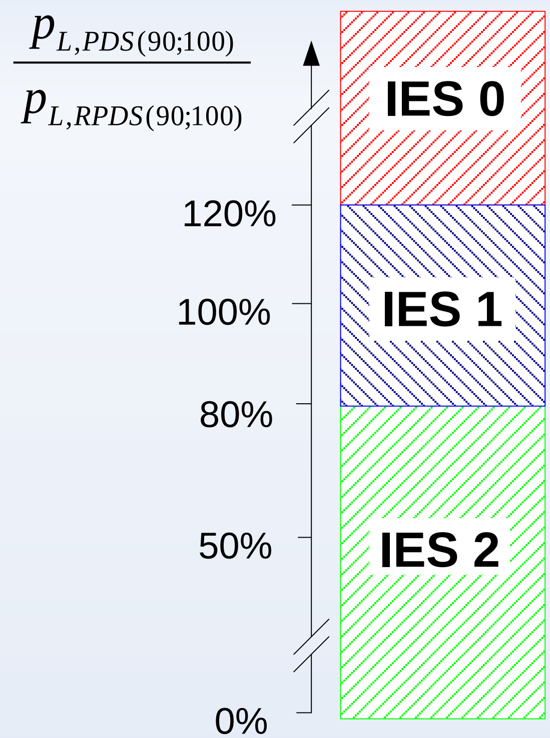
- CDM/PDS is operated at its rated input voltage
- CDM up to 90 kW is operated at 4 kHz switching frequency, higher power with 2 kHz. If this is not possible, deviations have to be documented
- All ambient temperature in the specified range is allowed. For the PDS, a temperature correction according to IEC 60034-2-1 has to be performed
- The manufacturer can freely choose the loss determination method. He is responsible for the values to be correct, as well as for tolerances

EN 50598 Classification

Converters



Power Drive Systems



A Higher IE Classification Number Means Lower Losses (same as for motors)

How to use the reference and test components

Combination of	**CDM**	**Test CDM**	**Reference CDM (RCDM)**
Motor	**determine the IES class of the resulting PDS**	determine the IE performance of the given motor (IEC TS 60034-2-3)	determine the IES Class of the resulting PDS
Test load	determine the IE performance of the given CDM	combination not used	combination not used
Reference Motor (RM)	determine the IES Class of the resulting PDS	combination not used	calculation model of a reference PDS

Guidance for motor manufacturer

Guidance for CDM manufacturer

Current Requirements to be Included in the Documentation

Information in the users documentation:

- IE(S)-class
- Losses in 7 part load points
- Losses of options
- Standby losses
- Rated frequency of the motor or test load
- All deviations of defined boundary conditions
- Maximum inverter output voltage (CDM only)

Looking forward to IEC 61800-9 series of standards

- IEC 61800-9-1 Extended Product approach based heavily on prEN 50598-1
- IEC 61800-9-2 Calculation, Testing and Classification of PDS'
  - Based heavily on prEN 50598-2 but to included global additions to meet the need of national legislation
  - Inclusions being considered but not limited to:
    - 60 Hz RCDM, RM
    - 115 V, 230 V and 460 V references
    - Expansion of test points to harmonize with IEC 60034-2-3
    - Take into consideration for harmonization with other relevant standards already developed e.g. CSA 838, AHRI 1210
    - Consider a larger tolerance at the zero speed points (Japanese request)

Thanks for Attending