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

Part 1: General requirements for setting energy efficiency standards for power driven equipment using the extended product approach (EPA), and semi analytic model (SAM)

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National foreword

This British Standard is the UK implementation of EN 50598-1:2014.

The UK participation in its preparation was entrusted to Technical Committee PEL/22, Power electronics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Ecodesign for power drive systems, motor starters, power electronics & their driven applications - Part 1: General requirements for setting energy efficiency standards for power driven equipment using the extended product approach (EPA), and semi analytic model (SAM)

Ecoconception des entraînements électriques de puissance, des démarreurs de moteur, de l'électronique de puissance et de leurs applications entraînées - Partie 1: Exigences générales pour définir les normes d'efficacité énergétique d'un équipement entraîné via l'approche produit étendu (EPA) et par le modèle semi-analytique (SAM)

Ökodesign für Antriebssysteme, Motorstarter, Leistungselektronik und deren angetriebene Einrichtungen - Teil 1: Allgemeine Anforderungen zur Erstellung von Normen zur Energieeffizienz von Ausrüstungen mit Elektroantrieb nach dem erweiterten Produktansatz (EPA) mit semi-analytischen Modellen (SAM)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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Foreword

This document (EN 50598-1:2014) has been prepared by CLC/TC 22X "Power electronics".

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-11-17
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2017-11-17

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association.

EN 50598, *Ecodesign for power drive systems, motor starters, power electronics & their driven applications*, will consist of the following parts:

- *Part 1: General requirements for setting energy efficiency standards for power driven equipment using the extended product approach (EPA), and semi analytical model (SAM)*;
- *Part 2: Energy efficiency indicators for power drive systems and motor starters*;
- *Part 3: Quantitative ecodesign approach through life cycle assessment including product category rules and the content of environmental declarations*.

The CLC/TC 22X/WG 06 is the enabled task force for dealing with the Mandate M/476 from European Commission for the standardization in the field of variable speed drives and/or power drive system products.

It has been set a close collaboration with several other technical committees (i.e. CLC/TC 2; CLC/TC 17B) in order to provide a comprehensive standard for energy efficiency aspects and ecodesign requirements together with a pilot stakeholder committee CEN/TC 197 from the customers side.

Key points:

- Requirements on the content of semi analytical models for motor system driven equipment;
- Requirements how to use them in the extended product approach.

The content could be of interest for the following technical committees CLC/TC 59X, CLC/TC 111X, CEN/TC 44, CEN/TC 113, CEN/TC 121, CEN/TC 123, CEN/TC 142, CEN/TC 143, CEN/TC 156, CEN/TC 228, CEN/TC 232 and CEN/TC 299.

It is the intention of the working group that this document, once finalized as European standard series, will be further processed to an international consensus in IEC and ISO.

Introduction

The Technical Committee CLC/TC 22X has circulated at 2010-03-31 the document CLC/TC 22X/Sec0100/DC document including the mandate M/476 from European Commission for standardization in the field of variable speed drives and/or power drive system products.

As the PDS contains converter driven motors, the requirements for measuring of the energy efficiency of motors with non-sinusoidal supply is under the responsibility of CLC/TC2 covering the requirement from Mandate M/470.

The document is based on the CENELEC technical board document referenced BT137/DG8058/INF also reproducing this EC-mandate.

The CLC/TC 22X/WG 06 as being the standardization task force for dealing with this Mandate has close collaboration with several other technical committees (i.e. CLC/TC 2; CLC/TC 17B).

Therefore CLC/TC 22X committee has been enabled responsible to clarify all relevant aspects in the field of energy efficiency and ecodesign requirements for power electronics, switchgear, control gear, and power drive systems and their industrial applications.

The sometimes controversial requirements are illustrated in Figure 1. The work has been agreed to provide the reasonable target as a best compromise.

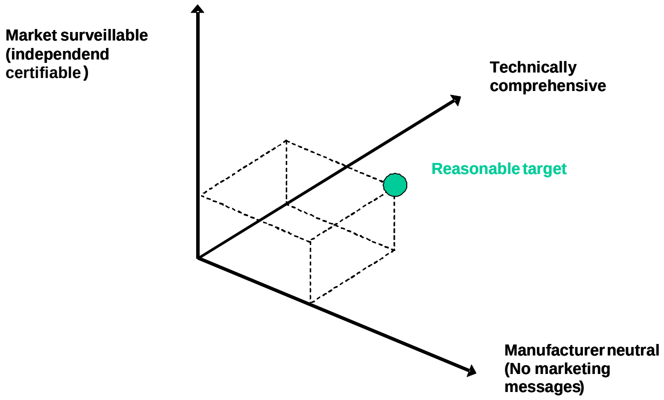

Figure 1 — Illustration of controversial requirements for the energy related product (ErP) standardization

EN 50598 is developed under the CENELEC projects number 24602 to 24604 for compliance with requirements from the horizontal mandate M/495.

Its three parts are together directly related to the mandates M/470 and M/476.

For the other mandates listed in Table 1, this standard could be applied if the future product standards developed will make reference to it.

Table 1 — Mandates of the European Commission given to CEN, CENELEC and ETSI and how they are contributed by these standard series parts

Mandates	Part 1	Part 2	Part 3
M/470 Motors		✓	✓
M/476 PDS		✓	
M/495 Horizontal all future Applications	✓	✓	✓
M/488 HVAC comfort fans	✓	✓	(✓)
M/498 Pumps	✓	✓	(✓)
M/500 Compressors	✓	✓	(✓)

1 Scope

This European Standard provides a general methodology to energy efficiency standardization for any extended product including a motor system by using the methodological guidance of the extended product approach (EPA).

It enables product committees for driven equipment with included motor systems to interact with the relative power losses of the included motor system (e.g. PDS) in order to determine the system energy efficiency aspects for the extended product by calculation.

This should be based on specified calculation models for speed/load profiles, the duty profiles and relative power losses of appropriate torque versus speed operating points.

This part of the EN 50598 series specifies the methodology of determination of losses of the extended product including a motor system and its sub-parts.

This framework is explained by an example for pumps.

This part of the standard does not specify requirements for environmental impact declarations.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 50598-2, *Ecodesign for power drive systems, motor starters, power electronics & their driven applications — Part 2: Energy efficiency indicators for power drive systems and motor starters*

IEC 60050-161, *International Electrotechnical Vocabulary. Chapter 161: Electromagnetic compatibility*

3 Terms, definitions, symbols, units and abbreviated terms

For the purposes of this document, the terms and definitions given in IEC 60050-161 and the following apply.

3.1
Energy Efficiency Index
EEI
value describing an energy efficiency aspect of an application, resulting from the extended product approach (EPA)

Note 1 to entry: If the extended product is a pump system, the EEI is the ratio of the input power to the theoretical reference power required for the application.

3.2
Extended Product
EP
driven equipment together with its included motor system (e.g a PDS, a motor starter)

Note 1 to entry: See Figure 2.

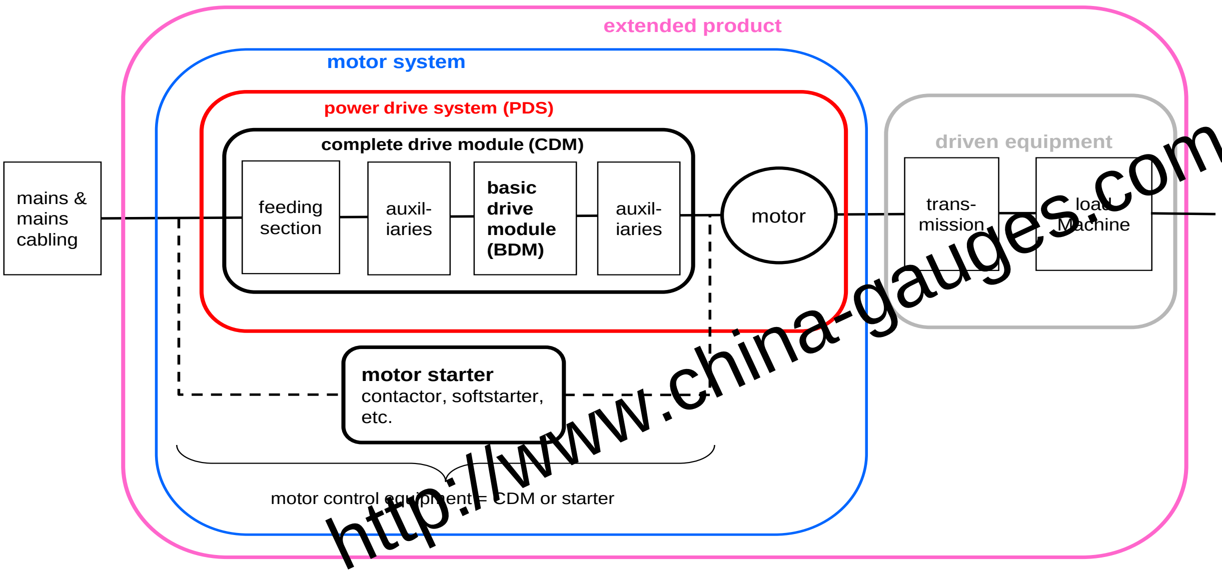

Figure 2 — Illustration of the extended product including a motor system

3.3
Extended Product Approach
EPA
methodology to determine the energy efficiency index (EEI) of the extended product (EP) using the speed torque profiles of the driven equipment, the relative power losses of the motor system and the duty profile of the application

3.4
motor control equipment
either a CDM or a motor starter

3.5
motor system
motor control equipment and a motor

3.6
duty profile
fraction of time spent at each operating point during the total operating time or a complete cycle of operation of the extended product

Note 1 to entry: Typically this profile is represented by an histogram.

Note 2 to entry: The standby mode can be included in the load time profile.

3.7
$P_{\text{Electrical}}$
power consumption [kW] of an application

3.8
$P_{\text{Electrical Max}}$
power consumption [kW] at 100 % speed and 100 % load

3.9
P_{i}
power consumption [kW] at operating point i

3.10
$P_{\text{in,CDM}}$
input power [kW] of the CDM from the power loss measurement

3.11

$P_{\text{in,PDS}}$

input power [kW] of the PDS from the power loss measurement

3.12

P_{n}

nominal Power [kW] of equipment which is typical for its population of the same rating

Note 1 to entry: See EN 60034-1 for motors.

3.13

$P_{\text{out,CDM}}$

output power [kW] of CDM from the power loss measurement

3.14

$P_{\text{out,PDS}}$

output power [kW] of PDS from the power loss measurement

3.15

P_{r}

rated power [kW] of equipment which is assigned by its manufacturer

3.16

$P_{Reference}$

power consumption [kW] used for reference, defined by the extended product committee

3.17

P_{L}

electrical power losses with the indices CDM dedicates it to the complete drive module, Mot dedicates it to the motor, Aux dedicates it to the auxiliary devices like cables, transformers or filters

Note 1 to entry: The relative power losses are the per unit losses relative to the nominal power of the device.

3.18

$P_{\text{L,CDM}}$

power losses of a CDM

3.19

$P_{\text{L,CDM, determined}}$

power losses of CDM from the power loss determination method

3.20

$p_{L,\text{CDM,relative}}$

power losses of the CDM, referred to its rated apparent power

3.21

$P_{L,\text{inverter}}$

power losses in the inverter section of a CDM

3.22

$P_{L,\text{PDS, determined}}$

power losses of PDS from the power loss determination method

3.23

$P_{\text{LT},Mot}$

total losses of a motor according to EN 60034-2-1, method 2-1-1B when supplied by a converter (non sinusoidal power supply)

3.24
Semi Analytical Model
SAM
model for determining energy efficiency characteristics of a specific motor system or driven equipment, based on mathematical equations and/or measured data

3.25

t_w
working time of an equipment

3.26
T_i
torque [Nm] at operating point i

3.27
timefraction$_i$
percentage of time when the extended product is operated at one specific operating point i

4 Requirements for the development of energy efficiency standards for extended products

4.1 General

This document specifies a methodology to determine the energy efficiency index of an application, based on the concept of semi analytical models (SAM). The methodology shall be referred to as the extended product approach (EPA).

This document also specifies the responsibilities and tasks of the different stakeholders creating or using these extended products standards, as well as the data flows in-between.

a) Specific information about the equipment shall be considered:

   1) The torque versus speed profile of the driven equipment as specified by the manufacturer of the driven equipment or the extended product technical committee.

   2) The losses of the motor system or its constituents (Motor, CDM or starter) at reference part-load operating points. These shall be provided by the different manufacturers as specified in EN 50598-2.

   3) The duty profile of the driven equipment. The extended product standards committee can for example define typical applications of their extended products, each associated with a typical duty profile

b) The extended product approach shall be used to determine an energy efficiency indicator (losses, efficiency, energy consumption…):

   1) EN 50598-2 specifies the methods for the determination of losses of the motor system using measurement and/or calculations.

   2) extended product standardization committees shall define how to combine the losses of the motor system and the losses of the load to obtain an overall energy efficiency aspects related indicator for the extended product within the defined application.

The interactions between the different stakeholders of the extended product approach are shown in Figure C.1.

4.2 Responsibility of the driven equipment technical committee

Based on the general principles described in this standard it shall be the responsibility of the driven equipment technical committee to standardize the methodology to calculate the EEI of the extended product based on a semi analytical model of the driven equipment.

The product committee shall specify and standardize:

- one or more torque versus speed profiles (load profiles) as described in 5.2 considering typical loads;
- one or more duty profiles as described in 5.3 considering the typical extended product service conditions;
- an appropriate method for determining the losses at intermediate operating points based on the data from the motor, CDM and PDS. See for example the methods in 7.3;
- a semi analytical model for the extended product considering the extended product approach (EPA) as described in Clause 7, based on the eight torque versus speed operating points as specified according to EN 50598-2 for the motor system;
- a method for determining an energy efficiency indicator for the extended product under their responsibility; see Annex B for example.

NOTE The motor system data might consist of PDS data as well as individual data for CDM and motor. EN 50598-2 provides information about the determination of PDS data based on individual motor and CDM data.

4.3 Elements included in the extended product approach

The semi analytical model (SAM) model of the driven equipment developed by the technical committee responsible for the extended product combines the information given by the CDM/PDS manufacturer according to EN 50598-2 in the operating points for the motor system. Other operating points can be calculated if needed according to 7.3.

To determine the overall losses or efficiency of an extended product implemented in an application it is required to go through several steps:

Several elements shall be combined:

a) **The SAM of the Motor System**, specified in EN 50598-2, giving its relative losses at several standardized operating points. The motor system can be a power drive system (PDS) or can consist of a motor and a motor starter (contactor, softstarter…):

   1) When the motor system is a PDS, the calculation of the losses is the sum of the losses of the CDM and motor or the total losses of the complete PDS.

   2) When the motor system is based on a motor starter, the calculation of the losses is simpler; there is no need to use any reference motor starter.

b) **The SAM of the driven equipment** (pump, compressor, fan…), giving the losses or efficiency of the load machine at typical operating points. It is the responsibility of the associated product committee.

c) **The extended product approach**, combining the SAM of the motor system and the SAM of the driven equipment (and also if necessary relative losses for the coupling). It is the responsibility of the manufacturer of the extended product. The extended product approach uses application-related data (required operating points, duty profile, working time …), in order to determine the energy efficiency index of the application. This index allows comparing the energy efficiency aspects of several motor systems for a given application, or several modes of operation of a given extended product.

Table 2 — Illustration how to combine essential elements of the efficiency contributions

Elements required for the extended product approach	Input	Output	Reference	Responsibility
SAM of the Motor System	Characteristics of the motor system (physical components, rated powers…)	relative losses of the motor system at standardized operating points	EN 50598-2	motor system product committee
SAM of the extended product (EP)	output of the SAM of the motor system and characteristics of the driven equipment (load machine)	relative losses of the EP at standardized operating points	EP standard	load machine associated product committee (e.g. CEN TC 197)
extended product approach	output of the SAM of the EP, and requirements about the application (duty profiles, operating time, etc. and tolerances	energy efficiency index of extended product for the application	EP standard	extended product associated product committee (e.g. CEN/TC 197)

5 Requirements for the semi analytical model (SAM) of the extended product

5.1 General

The SAMs for the subparts of the extended product are necessary in order to determine the overall power losses of the extended product.

The following chapter describes the basic requirements which shall be fulfilled while specifying the SAM of the extended product.

The EPA of the extended product shall include the following aspects:

— typical torque versus speed profile (operating profile) of the driven equipment

— the embedded relative losses of the motor system according to the data determined according to EN 50598-2.

The outcome of the SAM shall be used to calculate the energy efficiency index (EEI) which shall be able to quantitatively distinguish between typical solutions for an application for which the extended product is efficient and those for which the extended product is inefficient..

The EEI value shall be given in a metric scheme which allows displaying the value in the user's documentation or the catalogue.

The tolerances of the EEI shall be specified by the standardization committee of the extended product.

To judge a system regarding energy efficiency aspects all components of the system shall be taken into account. Speed regulation by using a power drive system (PDS) is advantageous in some cases, but on the other hand it also creates additional losses.

The energy savings that can be achieved are very often depending on the operating point *OP* at which the extended product is operated as required by the application.

Therefore the information about the application and its duty shall be provided by technical committees determining the SAM for the application specific extended product.

Two application-related characteristics are particularly useful for describing the extended product and the way it is operated:

a) **The torque or power versus speed profile.** This curve describes how the torque required by the driven equipment depends on its speed. It essentially depends on the type of driven equipment.

b) **The duty profile.** This graph describes the various power levels required by the driven equipment, including standby, and the fraction of time during which the equipment is operated at these levels. The duty profile essentially influences the sizing of the motor system and on how the extended product is operated in practice.

These two characteristics can be used as input data to derive the right motor control equipment of the extended product in terms of energy efficiency performance.

5.2 Torque/Power versus speed profiles

The torque or power versus speed profile describes how the torque *T* or power *P* required by the driven load varies with its speed *n*. The power is also the product of torque and speed.

Most of the existing driven equipments can be categorized into one of the basic torque and power vs speed profiles shown in Figure 3.

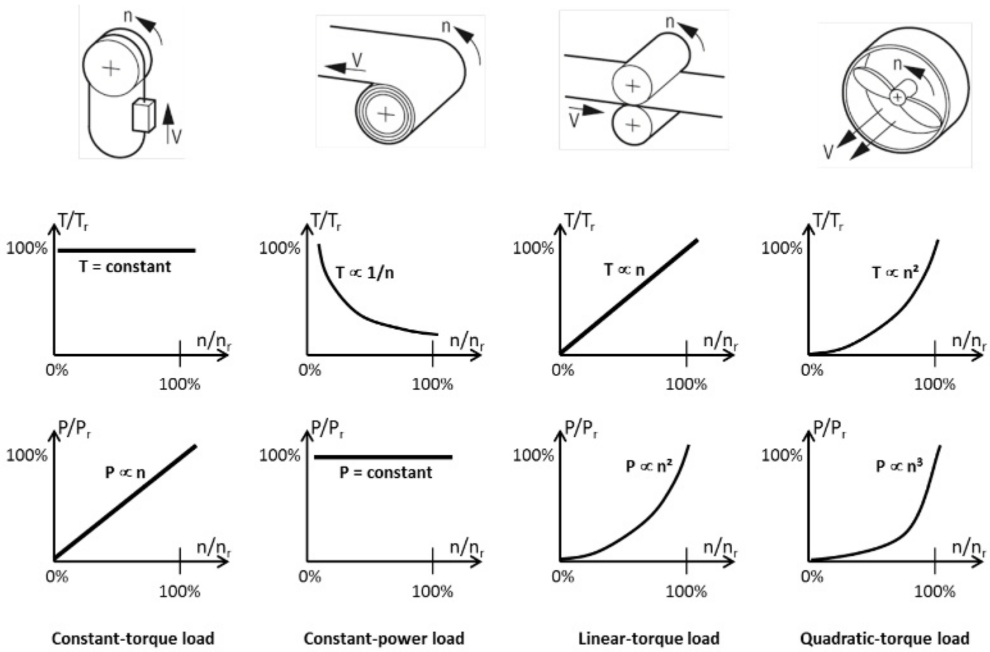

Figure 3 — Typical torque/power vs. speed profiles for different extended products

5.3 Operating points over time

The desired behavior of the extended product, as well as the characteristics of the motor, defines one or several operating points at which the motor will have to be operated.

Depending on the process demands the motor may not be running at rated output power all the time. Part load in the sense of this standard is a situation where the application requires reduced torque and/or speed compared to the rated values.

The efficiency of an extended product strongly depends on the load level. Furthermore, stand-by (SB) losses of soft starters and CDMs shall be taken into account. They are present in periods where the power part is disabled but the control is still supplied. Stand-by losses are losses generated by e.g. the power supply of the control part.

Therefore, to estimate the efficiency of an extended product and compare several potential control solutions, it is essential to know which levels of mechanical and electrical power are needed by the extended product and in which time fraction. This is the purpose of the operating points over time.

To calculate the needed electrical energy, the individual required electrical powers shall be multiplied with their time span. Time fractions in percentage shall be based on the whole operating time in one productive year of the installation.

”Operating points over time” shall be a graph describing the different levels of mechanical power required by the extended product, and the time during which the extended product is operated at each of these points.

- The Operating points OP_i on the horizontal axis shall reflect typical points for that certain extended product. One point shall be zero speed / zero torque to account for the standby losses P_{SB}.

For some extended products, the operating points may be expressed using another quantity that will make more sense for the extended product e.g. a power, a flow, etc.

In case the loss values for these points are not given by the manufacturer they shall be calculated.

- The time shall be expressed in hours per unit of time (day, year), or in fraction of the total runtime.

An example of operating points over time is shown in Figure 4.

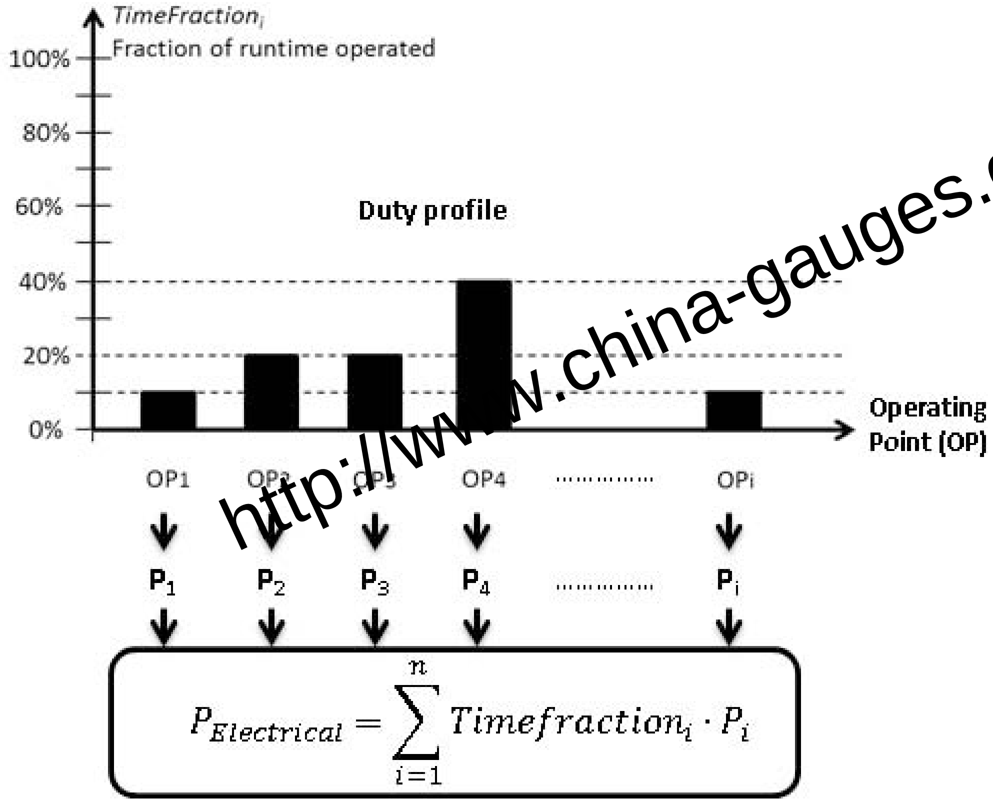

Figure 4 — Typical power required by application over time fraction = duty profile required to calculate the needed electrical energy

The duty profile describes the requirements of the extended product in terms of mechanical power. For each operating Point OPi, the electrical power P_i that shall be supplied by the mains depends on the mechanical power and the overall extended product losses (or equivalently its efficiency) at this level. The latter depends on the control strategy chosen for the extended product and shall be computed

The weighted average electrical power $P_{Electrical}$ required to run the extended product as desired is:

$$P_{Electrical} = \sum_{i=1}^{n} \left(Timefraction_i \cdot P_i \right) \quad (1)$$

The weighted average electrical power is directly relative to the electrical energy consumption (e.g. in kW.h) required by the extended product during a certain runtime period:

$$E_{Electrical} = P_{Electrical} \cdot Runtime \quad (2)$$

The weighted average electrical power (or equivalently electrical energy) shall be computed for several potential control strategies suitable for the extended product (e.g. switchgear and CDM). The designer shall then select the control strategy that yields the smallest weighted average electrical power.

6 Requirements for the semi analytical model (SAM) of the motor system

6.1 General

The SAM of the motor system (e.g. a PDS) shall include all parameters which are necessary for the determination of the relative power losses for specific different torque versus speed operating points.

The determination of the EEI of an extended product needs a description of the relative losses of the motor system in order to justify the most efficient solution.

In this chapter we provide summarized information about the inputs, outputs and principles of the SAM of the motor system. For further corresponding requirements and details requirements of the SAM of the motor systems see EN 50598-2.

For the SAM of the motor system the relative losses (specific power losses at an operation point divided by nominal power of the motor system) shall be used for specification in order to cover also cases, where the speed of the extended product is zero.

NOTE This is not aligned with the so called efficiency (η) of line fed motors which is directly given as a percentage of the mechanical output power to the sum of input electrical power and the power losses.

6.2 Speed versus torque loss points of a PDS and the associated power losses

In order to set only a few appropriate measurement points or calculation results for determination of the energy consumption of different extended products, eight points in the speed versus torque diagram shall be specified see Figure 5.

These relative losses (containing the relative losses of the motor system), are the output of the SAM for the motor system and one input of the SAM for the extended product; see Table 1.

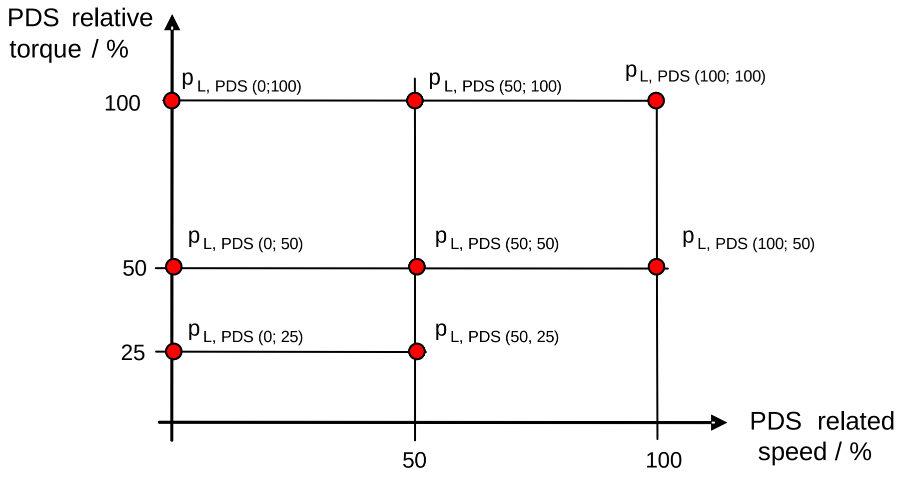

Figure 5 — Speed versus torque relative power loss operating points to determine the power drive system (PDS) losses

6.3 Requirements if the motor system contains no CDM

If the motor system contains a motor starter or switchgear the possible operating points of the motor are located at one relative fixed speed (100%), see Figure 6.

The additional power losses of a.c. motor starters according to EN 60947-4-1 or a bypassed a.c. semiconductor motor starter according to EN 60947-4-2 are considered small. The procedures to determine the relative losses of the motor system containing a motor starter is given in EN 50598-2.

NOTE No "reference motor starter" or "reference switchgear" is defined or required.

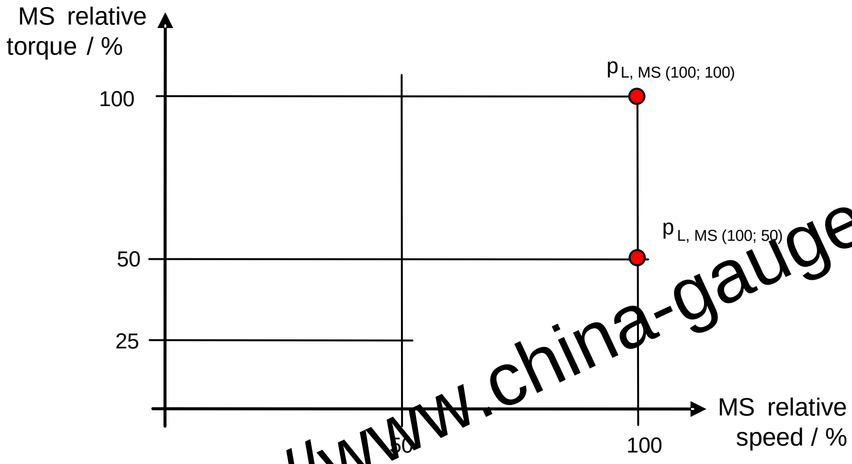

Figure 6 — Speed versus torque relative power loss operating points to determine motor starter or switchgear losses

7 Merging the semi analytical models (SAMs) to the extended product approach

7.1 General

This chapter describes how the SAMs of a motor system and the driven equipment shall be merged together in order to gain the determination for the EEI value according to the extended product approach.

The interface between both SAMs is:

- the set of relative losses at the determined torque versus speed operating points all with their with tolerances;
- average load time profile to derive the losses of the driven equipment;
- loss parameters of the driven equipment all with tolerances.

The different models and responsibilities for achieving the efficiency classification of an extended product shall merge to the complete efficiency determination of the EPA, in accordance with Figure 7.

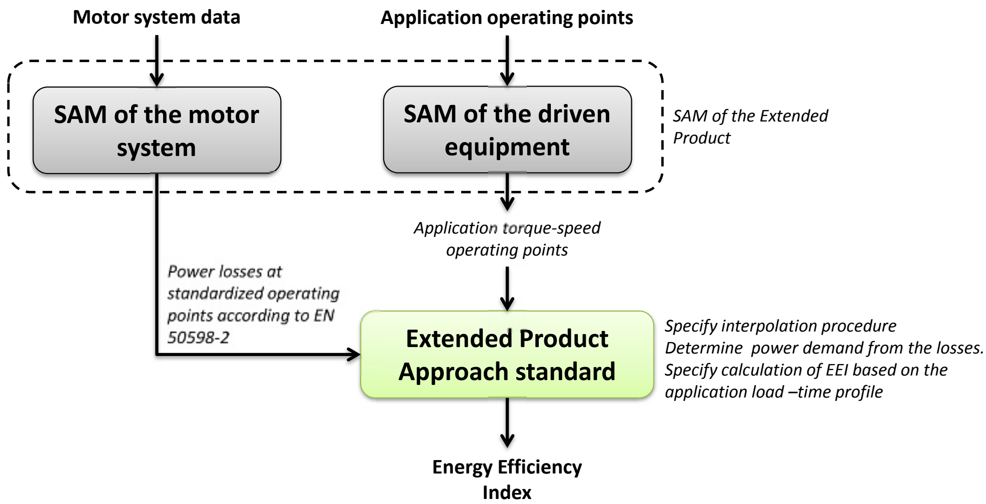

Figure 7 — Illustration of the workflow to derive the energy efficiency index of an extended product. The relative power losses of the motor system together with permissible tolerances are the input data of the extended product approach

7.2 Speed versus torque loss points of a motor system

All extended products shall be described by their physical needed drive power which is the product of torque and speed at a defined set of operating points.

The whole chart according to Figure 5 would contain theoretically an infinite number of such operating points. To limit the amount of determined losses at the operating points:

- shall match to the needs of the extended product approach (see Figure 3 as typical examples)
- shall be selected taken out of the defined values from Figure 5 or from Figure 6 according to the technology of the motor system.

7.3 How to determine intermediate speed versus torque loss points of a motor system

7.3.1 General

If the defined values are insufficiently matching to the torque versus speed characteristics the following rule shall be used to determine intermediate values for the SAM of the motor system.

7.3.2 Determination of intermediate relative losses for speed versus torque operating points of a motor system

If case that the motor system is a PDS, the losses of the CDM shall be calculated first according to EN 50598-2. In the next step, the motor losses shall be determined. In the third step, the PDS losses shall be calculated according to EN 50598-2.

In order to determine the relative losses of a motor system at any particular operating point, one of the following calculation models shall be used:

a) maximum losses in neighboured predefined operating points;

b) two-dimensional linear interpolation between neighboured operating points;

c) two-dimensional linear extrapolation with neighboured operating points if the extrapolation result is located within one of the four segments as illustrated in Figure 8;

d) loss calculation according to the mathematical model described EN 50598-2.

For the models a) and b), the operating area shown in Figure 8 shall be divided into four segments.

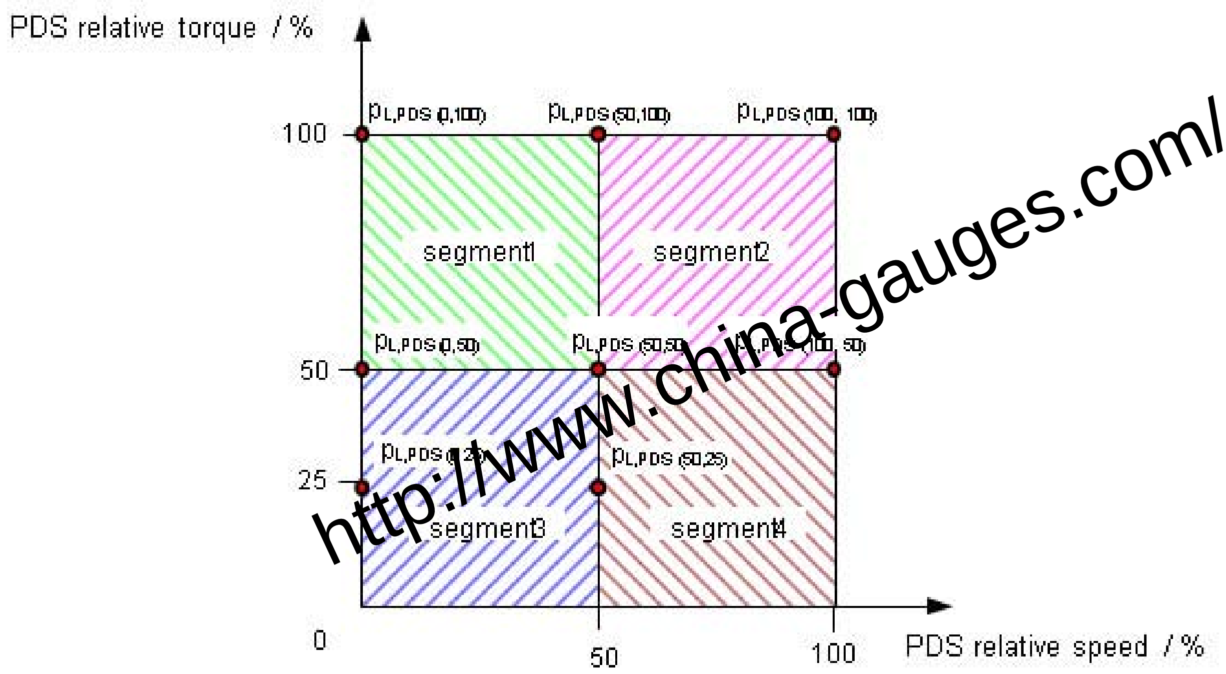

Figure 8 — Four segments of deviating operating points of a PDS

Segment 1 covers the operating points up to 50% relative PDS speed and above 50% relative torque.

Segment 2 covers the operating points above 50% relative PDS speed and above 50% relative torque.

Segment 3 covers the operating points up to 50% relative PDS speed and up to 50% relative torque.

Segment 4 covers the operating points above 50% relative PDS speed and up to 50% relative torque.

7.3.3 Loss determination by maximum losses of neighboured loss points

This way to determine the losses is very simple. However, it provides a higher deviation from the correct result than the other methods.

If for example the evaluated operating point at 75% relative PDS speed and 80% of relative torque belongs to segment 2 according to Figure 5 and Figure 8. Consequently, the neighboured operating points are $p_{L,CDM\ (50;50)}$, $p_{L,CDM\ (50;100)}$,$p_{L,CDM\ (100;50)}$ and $p_{L,CDM\ (100;\ 50)}$. The predefined operating point with maximum losses is $p_{L,CDM\ (100;100)}$. This value shall be used for further calculation.

In case the motor system contains a motor starter or switchgear the calculation shall take the same value for both operating points out of Figure 6. An example for this method is given in EN 50598-2.

7.3.4 Loss determination by two-dimensional interpolation of losses of neighboured loss points

Interpolation between four defined points A, B. C and D at an operating point Z shall be calculated in three steps.

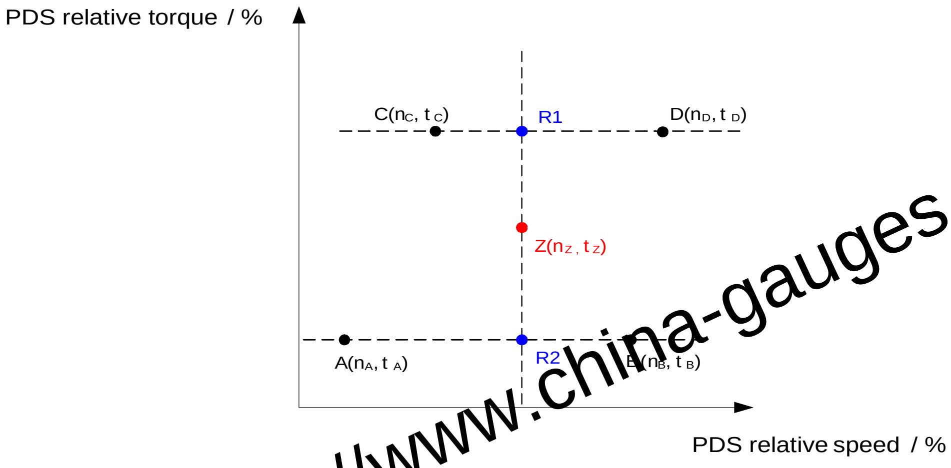

Figure 9 — Two-dimensional interpolation for deviating operating points

In the first step, a linear interpolation between points C and D is calculated for the point R1. The horizontal component n of R1 is chosen equivalent to the horizontal component n_z of the required operating point Z. If the vertical component of the points C and D are identical ($t_C = t_D$), the losses at the point R1 are a function of the horizontal component n_z only and will lead to $p_{L,R1}(n_z)$.

In the second step, the losses are interpolated in the same way for the point R2. This will lead to $p_{L,R2}(n_z)$.

In the third step, the losses in the operating point Z are finally calculated by interpolation between R1 and R2. As R1 and R2 have the same horizontal component n_z by definition, this interpolation is a function of the vertical component t_Z only. This will lead to $p_{L,Z}(n_z)$.

Inserting the values to Formula (3) gives the final calculation of the losses at the operating point Z.

$$p_{L,Z}(t_Z) = p_{L,R2} + \frac{p_{L,R1} - p_{L,R2}}{t_{R1} - t_{R2}} \cdot (t_Z - t_{R2}) \tag{3}$$

In case the motor system contains a motor starter or switchgear the calculation shall take the same value for both operating points out of Figure 6.

NOTE It is mentioned as the relative torque in the formula.

Annex A
(informative)

Example how to apply the SAM in the EPA for pump systems with a required speed versus torque loss points using the PDS

One example will be the pump systems and other flow rate machine systems which normally are associated to a parabolic like speed versus torque shape.

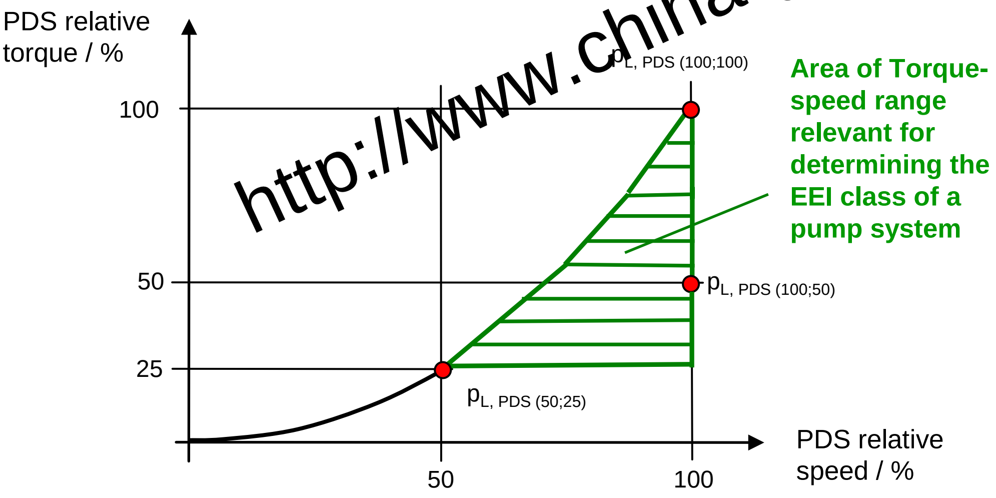

Figure A.1 — Three points of relative losses and shaded area of interest for the pump manufactures while defining their EEI (energy efficiency index)

Providing the electrical power losses of the three speed versus torque operating points $p_{L,PDS}(50; 25)$, $p_{L,PDS}(100; 50)$ and $p_{L,PDS}(100; 100)$ enables the pump manufactures to derive the power input of the arbitrary extended pump product inside the green pump unit.

The electrical power losses of the PDS at the 50% speed versus 25% torque point is the calculated sum of the power losses of all its components including the feeding transformer, if it is dedicated to feed only this PDS and all its auxiliary components such as filters and cables.

$$P_{L,PDS} = P_{L,M} + P_{L,CDM} \qquad \text{(A.1)}$$

$P_{L,CDM}$ are the power losses of a complete drive module together with auxiliaries, like filtering or active infeed converters as an alternative rectifier type, with an agreed permissible tolerance of ± 10%, see Figure A.2. It requires the most influencing service parameters for the losses.

$P_{L,M}$ is the losses of a line fed motor in the actual operating point plus its additional harmonic frequency losses at f_{sw} = 4kHz (rated power up to 90kW) or f_{sw} = 2kHz (rated powers above 90 kW), following the determination methods from IEC/TS 60034-2-3.

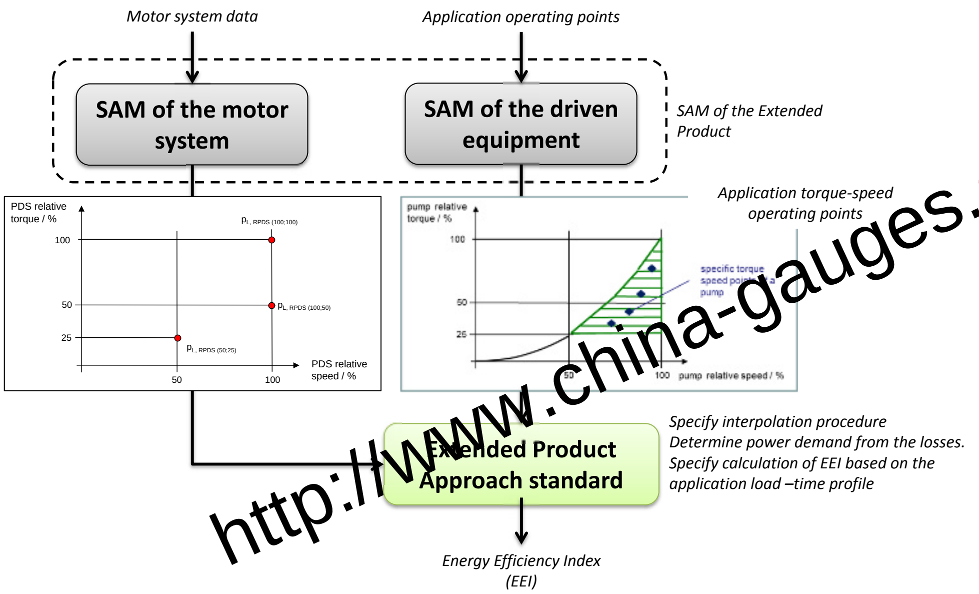

Figure A.2 — Illustrated example how the SAMs of the PDS and the pump system interact to the resulting efficiency index of a pump system

Annex B
(informative)

General calculation of the energy consumption based on the duty profile

The duty profile describes the requirements of the application in terms of mechanical power. For each operating Point OPi, the electrical power P_i that shall be supplied by the mains depends on the mechanical power and the overall extended product losses (or equivalently its efficiency) at this level. The latter depends on the control strategy chosen for the application and can be computed

The weighted average electrical power $P_{Electrical}$ required to run the application as desired is:

$$P_{Electrical} = \sum_{i=1}^{n} \left(Timefraction_i \cdot P_i \right) \tag{B.1}$$

The weighted average electrical power is directly related to the electrical energy consumption (in e.g. kW.h) required by the application during a certain runtime period:

$$E_{Electrical} = P_{Electrical} \cdot Runtime \tag{B.2}$$

The weighted average electrical power (or equivalently electrical energy) can be computed for several potential control strategies suitable for the application. The designer shall then select the control strategy that yields the smallest weighted average electrical power.

$$k_P = \frac{P_{Electrical}}{P_{Reference}} \tag{B.3}$$

The resulting factor k_p should be as close as possible equal to the value 1, if the reference power was determined to describe the mechanical power required by the application.

Annex C
(informative)

Illustration of the collaboration of different responsibilities in the extended product approach

The interactions between the different stakeholders of the extended product approach are shown in Figure C.1.

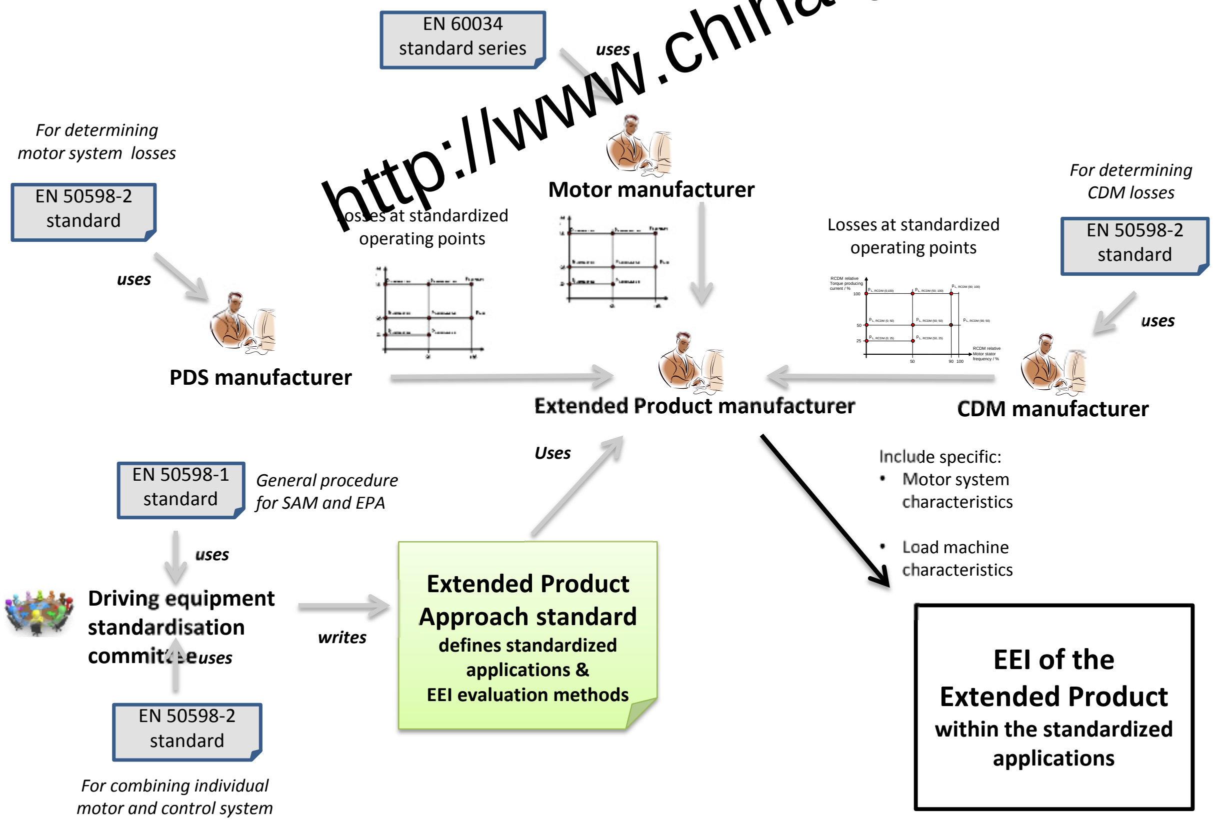

Figure C.1 — Illustration of the responsibilities and workflow to derive the energy efficiency index (EEI) of an extended product

NOTE Motor and CDM manufacturers can provide data directly to the motor system manufacturer. If the motor system is based on a starter, then only the motor losses are needed as input to the EPA.

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[6] IEC/TS 60034-2-3, *Rotating electrical machines — Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC induction motors*

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