Technical Toolbox for Technical Measures for use in SPIN-constellations

Modernization of electrical motors

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Contact information

Reinhard Ungerböck
Grazer Energieagentur GmbH
Kaiserfeldgasse 13/1
A-8010 Graz
T: +43 316 811848-17
E-Mail: ungerboeck@grazer-ea.at
Website: www.grazer-ea.at

Content and tool prepared by:

ISR-University of Coimbra

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www.epcplus.org

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Content

1. General description and explanation how-to-use

EPC+ aims at standardizing technical measures in order to make them predictable for other SPIN members (including the SPIN coordinator) and thereby to reduce transaction costs.

The toolbox can serve as a guide for the providers of EPC+-services for the standardization of the measures (design parameters, calculation method, process flow) and defines quality standards for the M&V-method. Text-modules of the descriptions may also be used for the communication with the client in order to create trust into the proposed measures.

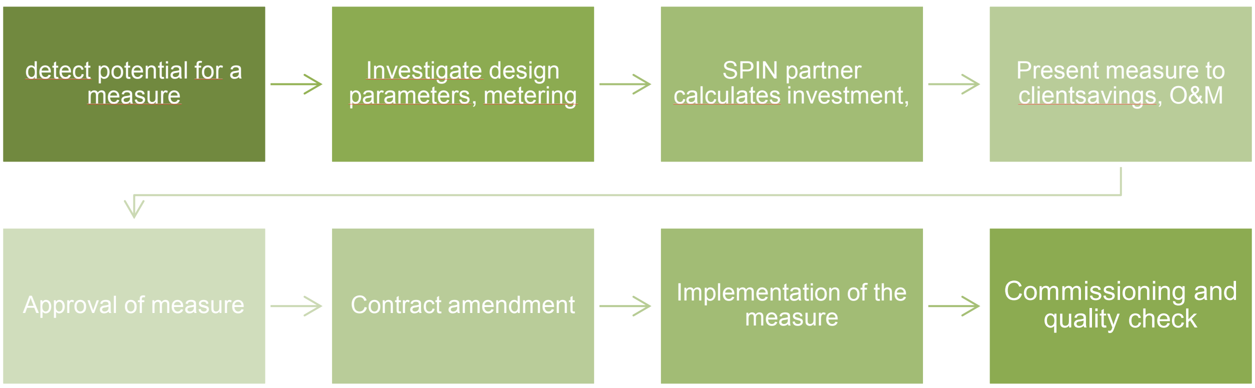
Each measure applicable for EPC+ is described on a general basis. Moreover the design parameters and the possibilities for application are defined, last but not least including a list of situations, where the specific measure is not applicable.

Calculation method

For the facilitation to introduce the measures for a SPIN the generic method of calculating effort for implementation, O&M and savings is described, ideally in form of a product-unspecific, open-source calculation tool.

Process flow

The generic process flow is identical for all measures. Therefore it is also part of the business model of EPC+, variations might be necessary for specific business cases, i.e. if measures interact with each other during their implementation or in their performance phase. See therefore also the interaction matrix of EPC measures, which serves as a quick indicator in which way measures might interact.



As a further development and because of the several players and interfaces in communication the process-flow-diagram is also visualized in the design of the ***service blueprint*** (see chapter 2.1.3)

1.1. Toolbox

Each measure is being described in general and in detail. The measures are categorized in energy-efficiency and renewable energy measures. All measure descriptions can be downloaded at http://epcplus.org/energy-service-packages/. Here is an overview of all measures that have been elaborated:

Energy-efficiency-measures:

1. Indoor lights: LED lights + control system
2. Hydraulic adjustment of heating system
3. Energy efficient pumps
4. Modernization of electrical motors
5. Night cooling
6. Optimising parameters of HVAC systems
7. Managing and metering systems for buildings
8. Renovation/replacement of heating boilers
9. Efficient windows
10. Industrial steam boiler blowdown heat recovery

Renewable energy measures:

1. Solar Thermal Domestic Heating Water
2. Biomass for heating and/or domestic hot water
3. Combined Heat and Power (CHP)
4. PV-panels
5. Wind-power
6. Heat pumps

2. Modernization of electrical motors

2.1.1. Technical description

2.1.1.1. General description (PU)

Motors systems are a major electricity consumer (about 70% of the EU industrial electricity consumption and about 35% in the non-residential buildings sector)[1]. Thus, it is easy to understand its impact on electricity consumption and also on the environment. Induction motors are the most common type of motors used in these systems, typically running for a large number of operating hours. In the past (1998-2009) motors were ranked, regarding their efficiency, from EFF1 (most efficient) to EEF3 (least efficient). Now, with the new standards (IEC 60034-30-1:2014), IE1 is the least efficient class (corresponding to EFF2) and IE4 the highest (for the moment). The following figure illustrates the regulated efficiency curves of the four existing IE classes for a 4-pole motor according to its power output.

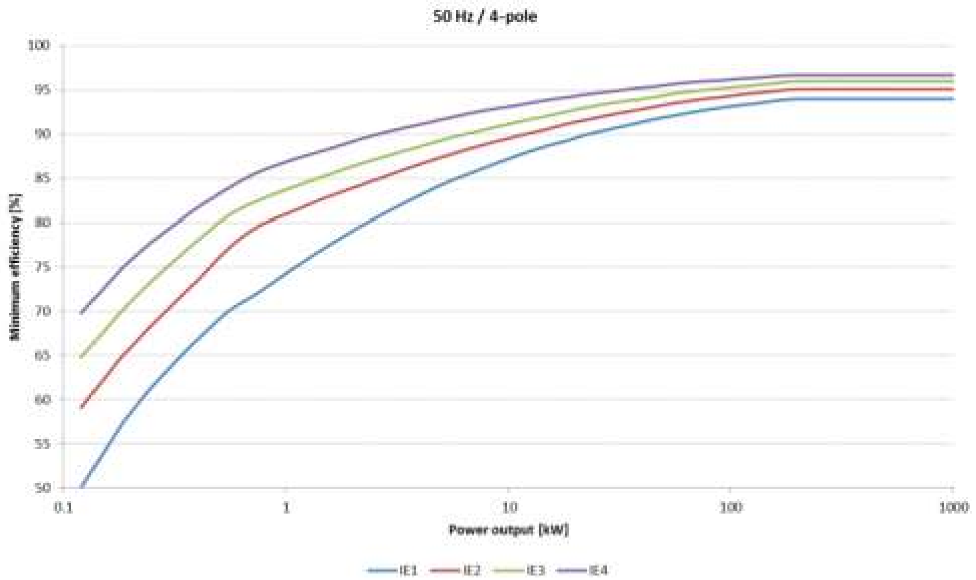


Figure 1 – IE class for 50 Hz 4-pole motors according to IEC 60034-30-1:2014

The old EFF3 is currently considered below standard (which are considered IE0); moreover, in the year 2000 these lower efficiency motors represented 70% of the EU motor´s sales[2]. If we consider an average of 15 to 20 years lifetime, we can easily spot a huge saving´s potential regarding motors. To help achieving it, the EU introduced in 2009 Minimum Efficiency Performance Standards (MEPS) with the Commission Regulation 640/2009 (amended by Commission regulation 4/2014). It specifies requirements regarding Ecodesign of

[1] IEA, Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems, 2011

[2] De Almeida, ECEEE 2015

electrical motors and the use of electronic speed drives (VSD). The next figure summarizes where we are on motors.

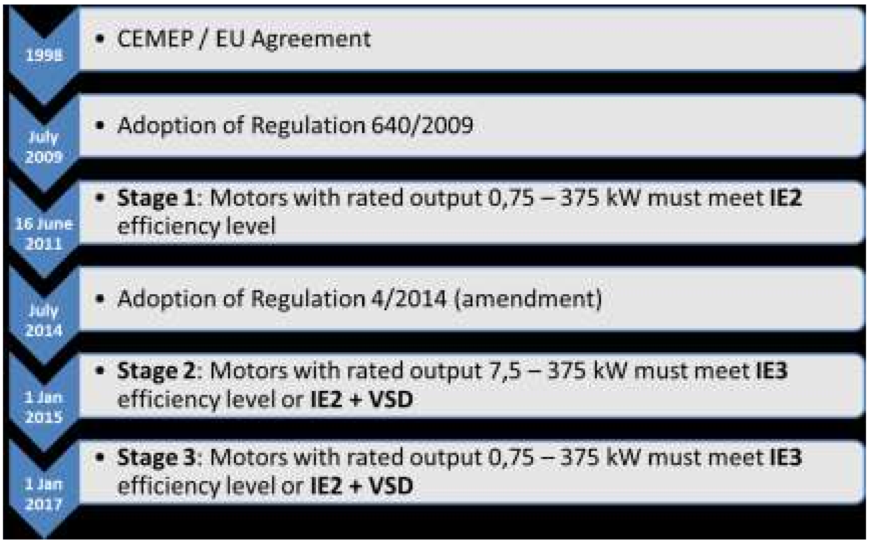


Figure 2 – Timetable of EU motor policy

If the client has an old motor running, it would be wise to consider its replacement. Through time, motors have a tendency to lose a small percentage of their original efficiency that will lead to higher energy consumption[3]. Re-winding seldom can lead it to its original efficiency and almost never improves it. In fact, given an average of 2 to 3 re-winding operations, efficiency can drop to 2% of its value[4]! Nevertheless, early replacement of electric motors is actually a rare practice in most companies where motors run to failure. Once failure occurs, they are repaired or replaced as quickly as possible, normally without considering more than the basic technical requirements (namely rated power, voltage, frequency, and speed).

A one tier change in motor´s efficiency class can pay for itself in little time (a couple of years). Besides, given efficient motor´s construction features and higher efficiency, not only will they reduce energy consumption, thus reducing its environmental impacts, as they will reduce operational and maintenance costs.

[3] Nadel S., *Energy Efficient Motor Systems*, ACEEE, 2002

[4] Ferreira F., Energy Efficient Motor Repair, 2004

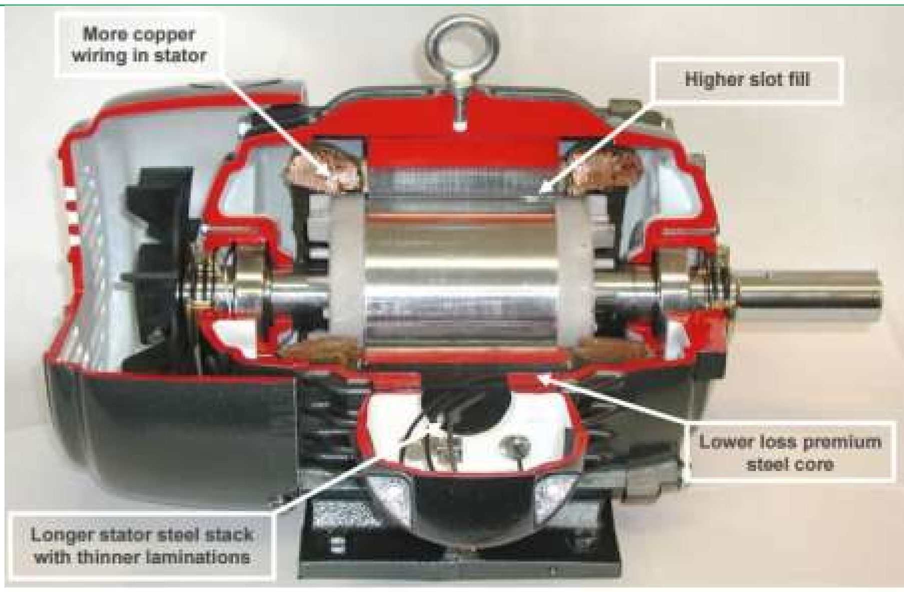


Figure 3 – Inside of a IE4 motor

The following graphic shows the result of a simple life cycle cost analysis (LCC) of a motor running 2, 4 and 6 thousand operating hours per year (over 15 years).

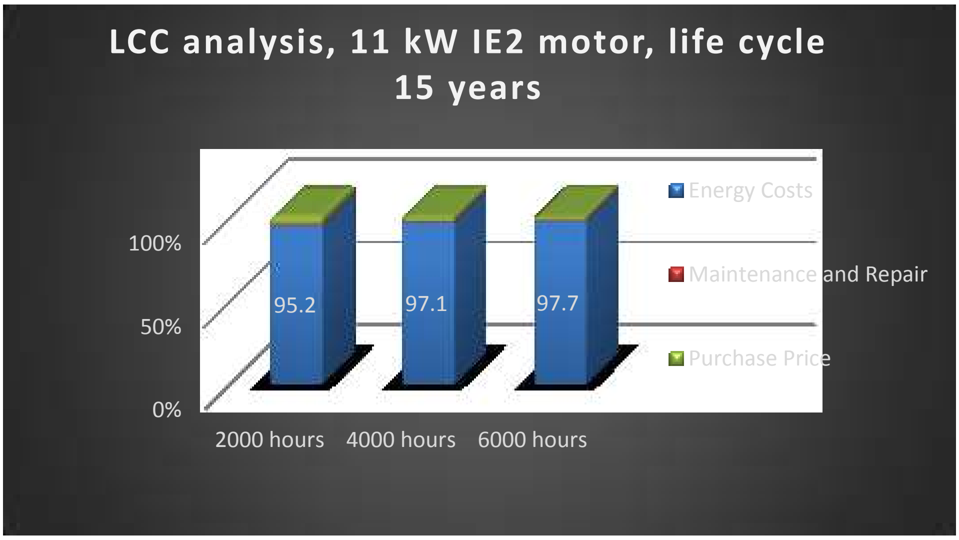


Figure 4 – LCC analysis, 11 kW IE2 motor, life cycle 15 years (Source: (Almeida, Ferreira, Fong, & Fonseca, 2008)

In addition, overall motor lifetime, productivity and production quality will increase. In effect, a motor with low energy efficiency will dissipate its losses as heat. This phenomenon does not only increase the energy cost significantly; in the course of time, the heat will also affect the motor condition, reducing its energy efficiency even further and increasing the risk of unplanned failure. In most production environments, the cost of the resulting motor downtime can mount to several times the original purchasing value of the motor. Unplanned outages can have an impact in many ways, for instance, they can slow down production, destroy goods, lead to equipment damage and additional maintenance, and leave the involved staff idle until the line is running again.

Hence, it is not just the purchasing and installation cost that must be taken into account. The energy consumption, production efficiency, maintenance costs, and the market value of the motor, at its economic end-of-life, are also factors to be considered.

It is important to recognize that many motors are included in a more complex system comprehending other components, namely: variable speed drives (VSD), a transmission system (including gears, belts, brakes and clutches), and an end-use device (e.g. pumps, fans, compressors).

For motors with significant load variations, in end-use applications such as the ones mentioned before, a Variable Speed Drive can further increase the operational efficiency of the motor. The total efficiency gain can make a significant difference on the annual energy consumption of the site. This alone will justify early motor replacement in most cases.

For already existing electric motor systems (EMS), the lack of optimisation in system layout is the main source of energy inefficiency. The lack of performance data, of reliable and established energy audit procedures, and of properly trained professionals is a serious barrier to efficient system improvements. In old motor systems, information or design data of EMS may no longer exist or are not available, motor plates are missing, nobody remembers motor specifications, the load may have changed while keeping the same system, thus becoming oversized. Hence, energy saving measures are not implemented because inefficiency has become camouflaged. If the client does not have old values nor information of the old motor, these procedures should be implemented ASAP for future control and efficiency boost.

Although motor system´s overall performance optimisation can bring considerable savings, this tool is only prepared to evaluate the main component´s replacement - the inefficient motor itself.

Although much more complex, there are software tools available or the optimisation of the entire motor system, one example being the Motor Systems Tool (https://www.motorsystems.org/motor-systems-tool) developed by EMSA[5]. This tool allows for the optimisation, including electricity savings potential, of a full motor system from power supply to end-use application. Whenever possible, it is advised that such a tool is used as they allow for a more complete assessment of the improvement options and, therefore, unlock greater savings.

2.1.1.2. Design parameters

Several scenarios, with different motor power, lifetime and operating hours, were tested in order to provide some insight for the decision making process of replacing a motor. This scenario test sheet can be downloaded at http://www.epc.org comparing *status quo* situation (IE2 motors) with a IE3 motor replacement.

- Which parameters are necessary to survey for the design of the measure?
    - Technical parameters:
        - Motor´s lifetime (expected);

[5] Electric Motor Systems Annex of the IEA Implementing Agreement for a Co-operative Programme on Energy Efficient End-Use Equipment (4E)

- Power;
- Voltage and frequency;
- Number of poles;
- Efficiency.

- Operational parameters:
  - Operating hours;
  - Load profile;
  - Maintenance cost (expected).
- Economic parameters
  - Initial cost;
  - Present energy cost;
  - Inflation rate on energy costs;
  - Interest rate on money.

- Are temporary metering necessary and which?
  - The actual load profile of the motor to be replaced is useful for the calculation of the energy consumption baseline and potential energy savings.

2.1.1.3. Measure suitable for:

- Motors between 0,75 and 7,5 kW with efficiency class less than IE2;
- Motors between 7,5 and 375 kW with efficiency class less than IE3;
- Motors between 7,5 and 375 kW with a VSD with efficiency class less than IE2;
- Motors that are due for major maintenance or replacement.

Priority should be given to older (>15-20 years old), inefficient motors with high power (7,5<kW<375) and larger operating hours (>2000h).

2.1.1.4. Measure not suitable for

- Small amount of operating hours (from an economic point of view, as the payback will become longer depending on its characteristics. Paybacks above four years are typically not well accepted). You can use our Excel tool to check whether is suitable or not regarding your needs.
- Variable speed applications (particularly pumps, fans and compressors) - the priority should be the installation of a VSD rather than investing on a more efficient motor.

2.1.2. Calculation method

2.1.2.1. Expected savings

The calculation method used in the Excel tool (can be found in the zip-file), in order to assess savings and payback when replacing a less efficient motor by an efficient one, is hereby explained. The only thing necessary is to introduce the figures in the respective parameter´s brackets in the tool.

To calculate energy consumption savings, in kWh, between an old motor (E_{old}) and a new one (E_{new}) to replace it, one must consider the number of hours (h) the motor is running, the load factor (LF), that is, what percentage of its power is really doing work according to load (W) needs, and its efficiency (η). If not available, some of this data (h, LF) can be assessed by an energy monitoring equipment installed before the installation of the new motor that will also define the baseline energy consumption (section 2.1.4).
Hence:

$$E_{old} = P_{old} \times h \times LF \div \eta_{old}$$

$$E_{new} = P_{new} \times h \times LF \div \eta_{new}$$

The difference between them will provide the energy savings ($E_{savings}$) in kWh:

$$E_{savings} = E_{old} - E_{new}$$

To calculate cost savings ($€_{savings}$) regarding the replacement of motors, we simply have to multiply the energy cost (E_{cost}), in €/kWh, by the amount of energy one has saved ($E_{savings}$). Hence:

$$€_{savings} = E_{savings} \times E_{cost}$$

To determine CO_2 emissions savings ($CO2_{savings}$), we take the resulting energy consumption savings ($E_{savings}$) and multiply it by the country´s energy mix (E_{mix}), that is, in average, how much grams of CO_2 is emitted in order to produce a kWh of energy.

$$CO2_{savings} = E_{savings} \times E_{mix}$$

There are other examples of online calculators that can also be used:

- https://www.motorsystems.org/motor-systems-tool
- http://www.landbelectric.com/energy-savings/
- http://www.weg.net/us/Products-Services/Drives/Payback-VFD-Calculator
- http://www.industry.siemens.com/drives/global/en/motor/low-voltage-motor/energy-savings-calculator/pages/default.aspx

- http://www.gates.com/catalogs-and-resources/resources/repository/calculator/energy-savings-calculator

Mandatory output parameters:

	Dimension	*Amount, formula or reference*
Cost savings	*[€/year]*	*Use the* excel-based tool developed within the scope of the project, or other on line calculators (e.g. above)
Energy savings	*[kWh/year]*	*Use the* excel-based tool developed within the scope of the project, or other on line calculators (e.g. above)
CO_2 savings	*[tons/year]*	*Use the* excel-based tool developed within the scope of the project, or other on line calculators (e.g. above)

2.1.2.2. Investment costs

Costs to be investigated and agreed on within the SPIN:

1. Inicial monitoring costs to access baseline energy consumption: renting of monitoring equipment and analysis of meetering data;
2. Material: Electric Motor, VSDs, additional equipment;
3. Installation: base price (depending on distance to client, including labour and traveling cost), price for each electric motor;
4. Permanent Metering equipment for motor (permanent - e.g. partial energy meter) or spot metering costs.

Mandatory output parameters:

	Dimension	*Amount, formula or reference*
Costs of inicial monitoring costs	*[€]*	Price components (see above)
Cost of the new material	*[€]*	Price components (see above)
Cost of installation	*[€]*	Price components (see above)
Permanent Metering equipment cost or Costs for the spot-meetering (M&V)	*[€]*	Price components (see above)

2.1.2.3. Running costs

Costs to be investigated and agreed on within the SPIN:

1. *Maintenance and Repair: base price (depending on the price established in the maintenance contract, which could include labour, travelling cost and spare parts or other materials);*
2. *Meetering Costs: base price (depending on the* distance to client, including labour, traveling cost and cost of metering equipment).

Mandatory output parameters:

	Dimension	*Amount, formula or reference*
Maintenance and repair costs	*[€/year]*	Price components (see above)
Metering costs	*[€/year]*	Price components (see above)

2.1.2.4. Expected life-span of the measure and resulting replacement-costs (if any)

Mandatory output parameters:

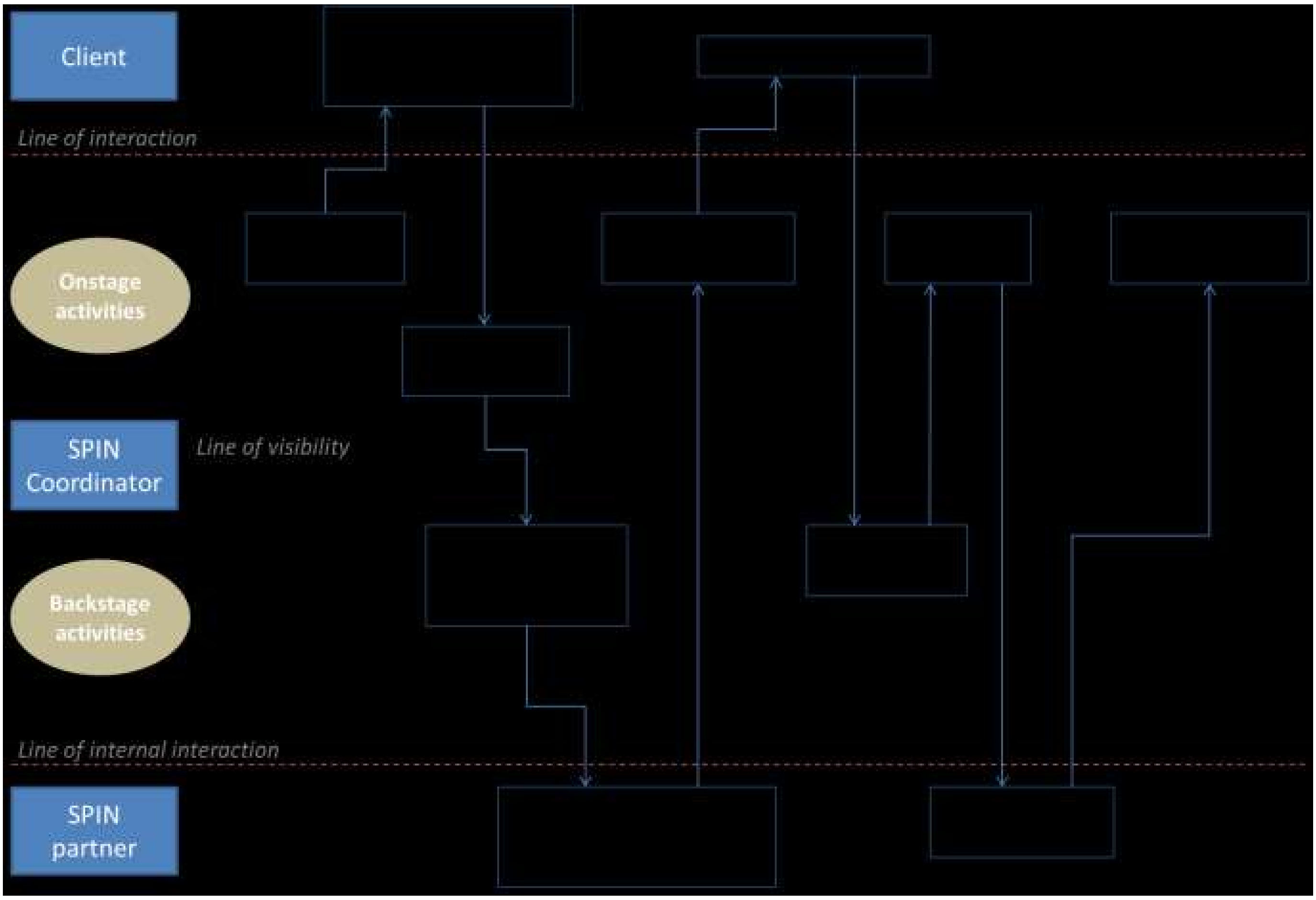
	Dimension	Observations
Life-span of the new motor	*[years]*	Motor´s lifetime extends long time after payback time

2.1.2.5. Discounted cash flow analysis and Net present value

Including Internal Rate of Return and dynamic payback period

A tool – suitable for all kinds of measures – is needed.

2.1.3. Process flow implementation: including quality assurance measures during and after implementation (PU)



In the assessment of the situation, spin coordinator must check for: Years of service (remaining lifetime), Maintenance (Average Time between failure, number of failures - if any), Efficiency (Initial and an estimate at this point), and Suitableness of motor´s power according to the load.

2.1.4. Options on measurement & verification in order to evaluate the performance in relation to the given performance guarantee

Option A of IPMVP[6]: key parameter measurement

The M&V should be performed according to option A of the IPMVP with energy measurements before and after the installation of new motor(s).

[6] International Performance Measurement and Verification Protocol - http://www.evo-world.org/en/products-services-mainmenu-en/products-ipmvp-mainmenu-en

In order to evaluate the potential savings and define the baseline energy consumption, a load profile of the motor should be done. It should be performed with adequate energy monitoring equipment (e.g. Chauvin Arnoux C.A. 8334 Power, energy and disturbance analyser) over a one week period, or another period of time capable of being representative of the working conditions of the motor, at normal working conditions. Generally, this monitoring period should not be less than a full day. This step is important to evaluate the working conditions of the motor, defining the baseline in order to evaluate the potential savings.

The M&V is extremely important in the savings calculation and baseline definition. Without this measurements (initially with the old motor and after the motor replacement), it is impossible to establish the level of savings and how the savings will be shared between SPIN and client. The savings sharing can be calculated considering the difference in the specific consumption (by hour, by each item produced, etc.) before and after the motor replacement.

After the implementation of the energy efficiency measure, an energy monitoring equipment should be installed in order to perform a continuous M&V to evaluate savings and remuneration. It should be performed during the period of time established in the EPC Contract between the SPIN and the client, giving them both insurance on the level of savings being archived. The client must have access to the data registered by the monitoring equipment. As an alternative, if the initial pre-installation measurement period reveals that the application has a stable load profile, several spot measurements during the EPC contract period could be included. The time between each measurement can be negotiated with the client, but should at least be two spot measurements per year. The spot measurements could have a duration of a week or a complete representative duty cycle for the final application.

By establishing an EPC contract the SPIN surely wants to reach the best performance possible, motor downtimes related with malfunctions and lack of maintenance, is something neither client or SPIN want. The service provider (SPIN) should establish a maintenance contract (or ensure its periodic maintenance), in order to guarantee the motor correct operation and performance has required to achieve the contracted energy savings.