AC Drive efficiency and loss estimation

The rated efficiency numbers of motors and drives are typically close to 95…98% and high energy efficiency is a good sales argument for AC drives. But users might have difficulty to convert efficiency of motors and drives to cost savings. This is the reason why DriveSize prefer to show the heat losses as such even though English word "loss" have a negative meaning too. In the other hand at very small partial loads low efficiency numbers might give wrong conception about the magnitude of losses.

Typical losses are important when computing the energy savings, while worst case losses shall be considered when guaranties are involved and when the losses are to be measured. In some cases customers demand guaranteed drive efficiency values in one or more operational points. Sometimes these values are linked to penalties so calculation should be as accurate as possible while being also realistic without high safety margins. The manufacturing and measuring process have always some tolerances which shall be recognized as well as the size of penalty.

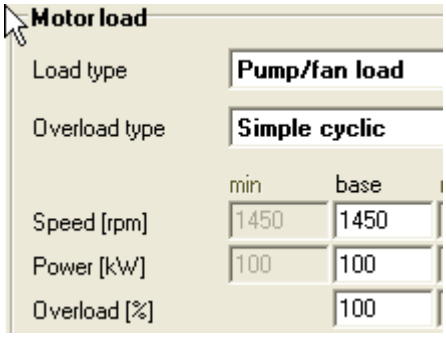
This guide helps you to report typical and worst case losses using DriveSize sales/engineering tool. Worst-case losses include reasonable tolerances, which are described in this guide.
In projects where efficiency guarantees include penalties confirm results with motors and drives technical support of ABB.

It is important to bear in mind that

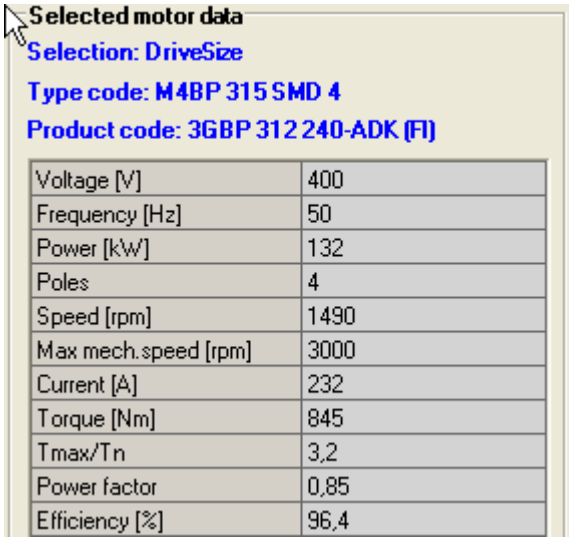
1) The international standard IEC60034 give the possibility to use quite large tolerances with nominal efficiency (15% or 10% more losses). This leads nominal efficiency values, which are higher than measured values.
2) There is some variation in efficiencies between individual drives and motors.
3) Efficiency of motor at nominal speed is anyway lower with AC drive compared to perfect sinusoidal supply.

Example, quadratic pump load

Let's start with 100kW 1450rpm pump example with ACS550. Customer wants to know the efficiency of drive and motor in design operation point and lower speeds too. Open the DriveSize and fill motor load data:



One high efficiency motor selection is M4BP 315 SMD 4:



Selected motor data

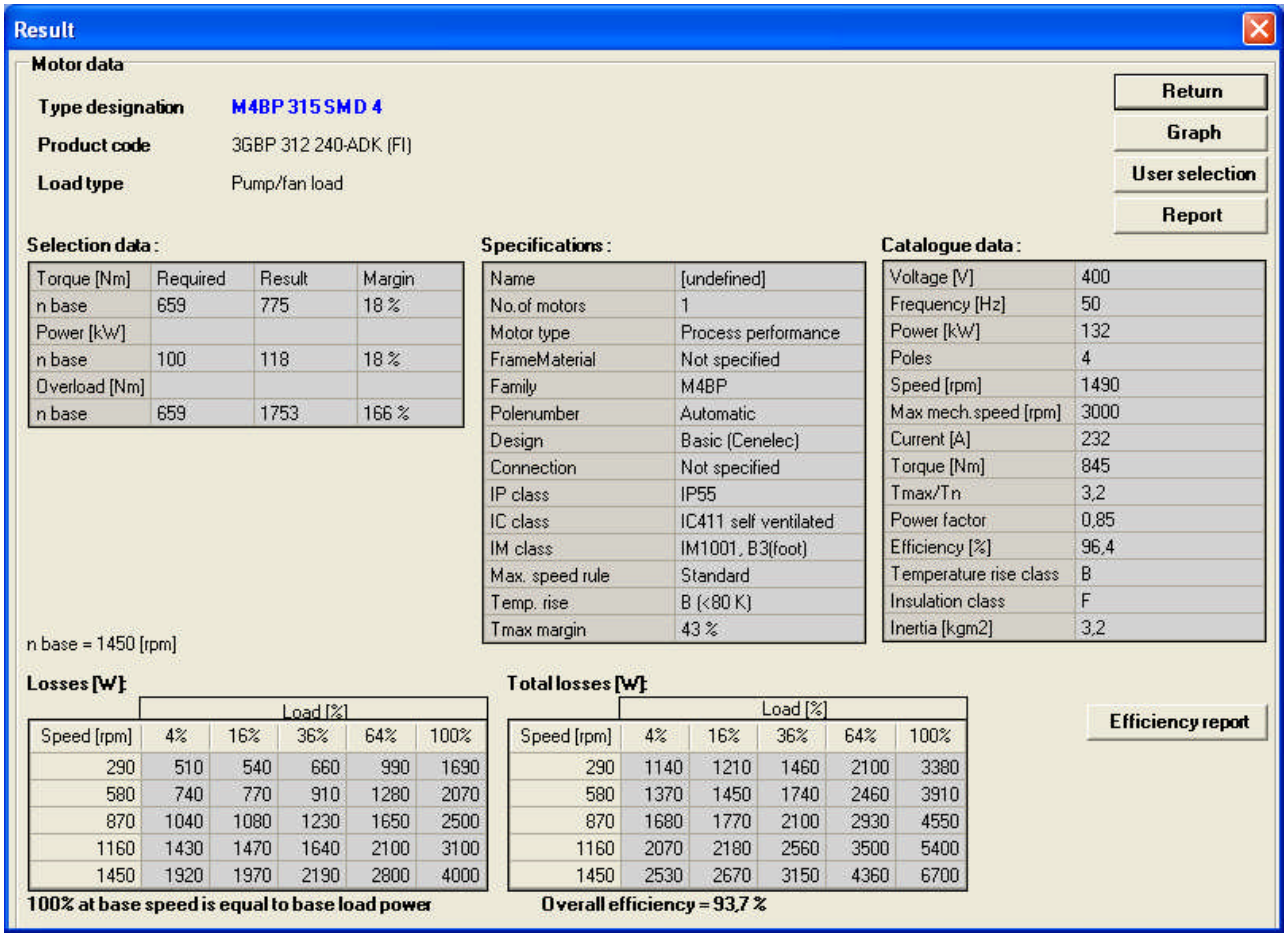
Selection: DriveSize

Type code: M4BP 315 SMD 4

Product code: 3GBP 312 240-ADK (FI)

Voltage [V]	400
Frequency [Hz]	50
Power [kW]	132
Poles	4
Speed [rpm]	1490
Max mech.speed [rpm]	3000
Current [A]	232
Torque [Nm]	845
Tmax/Tn	3,2
Power factor	0,85
Efficiency [%]	96,4

At this point the catalog efficiency of motor is shown η_{IEC}=96,4%. Please remember that this value is based on IEC60034 standard. Click “show details” icon and you will see Result window below:



Result

Motor data

Type designation M4BP 315 SMD 4

Product code 3GBP 312 240-ADK (FI)

Load type Pump/fan load

Return | Graph | User selection | Report

Selection data:

Torque [Nm]	Required	Result	Margin
n base	659	775	18 %
Power [kW]			
n base	100	118	18 %
Overload [Nm]			
n base	659	1753	166 %

Specifications:

Name	[undefined]
No.of motors	1
Motor type	Process performance
FrameMaterial	Not specified
Family	M4BP
Polenumber	Automatic
Design	Basic (Cenelec)
Connection	Not specified
IP class	IP55
IC class	IC411 self ventilated
IM class	IM1001, B3(foot)
Max. speed rule	Standard
Temp. rise	B (<80 K)
Tmax margin	43 %

Catalogue data:

Voltage [V]	400
Frequency [Hz]	50
Power [kW]	132
Poles	4
Speed [rpm]	1490
Max mech.speed [rpm]	3000
Current [A]	232
Torque [Nm]	845
Tmax/Tn	3,2
Power factor	0,85
Efficiency [%]	96,4
Temperature rise class	B
Insulation class	F
Inertia [kgm2]	3,2

n base = 1450 [rpm]

Losses [W]:

	Load [%]				
Speed [rpm]	4%	16%	36%	64%	100%
290	510	540	660	990	1690
580	740	770	910	1280	2070
870	1040	1080	1230	1650	2500
1160	1430	1470	1640	2100	3100
1450	1920	1970	2190	2800	4000

100% at base speed is equal to base load power

Total losses [W]:

	Load [%]				
Speed [rpm]	4%	16%	36%	64%	100%
290	1140	1210	1460	2100	3380
580	1370	1450	1740	2460	3910
870	1680	1770	2100	2930	4550
1160	2070	2180	2560	3500	5400
1450	2530	2670	3150	4360	6700

Overall efficiency = 93,7 %

Efficiency report

At the bottom we see that drive&motor total efficiency is 93,7% having typical heat losses 6700W only.

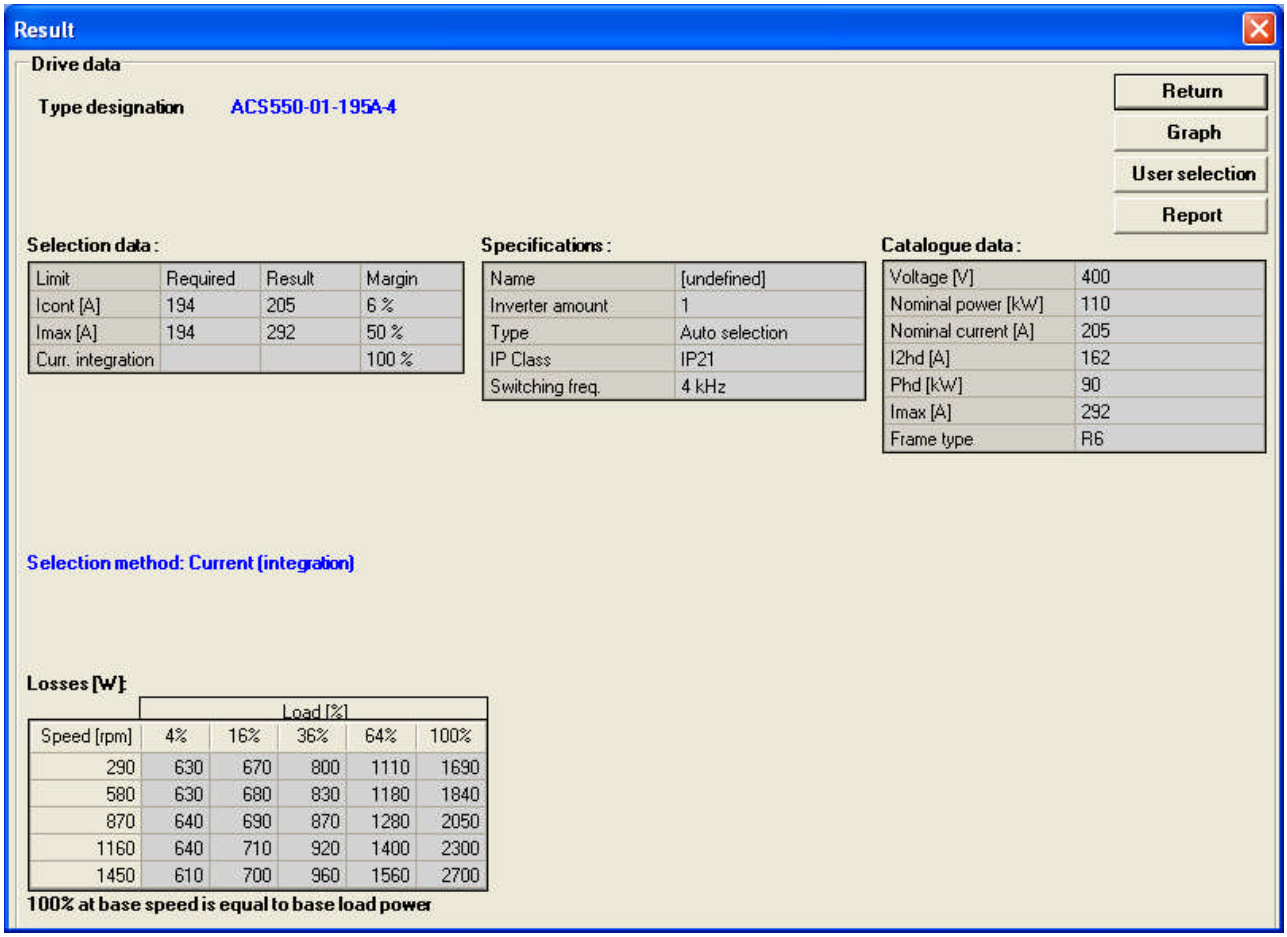
First let's take motor losses under consideration from above Result window. Full 100% load here means the base load. At that point we get 4000W typical losses.

If the pump or fan does not have much static pressure the diagonal values give the estimated losses on other speeds 20%, 40%, 60% and representing loads 4, 16, 36, and 64 loads.

For safety margin we need to consider IEC60034 tolerance for efficiency. It is -15%*(1-η_{IEC}) for 150kW and smaller motors (and -10%*(1-η_{IEC}) for bigger ones). This means about 15% higher losses for good motor but much more for bad efficiency motor. DriveSize will compute this automatically – in this case multiply the typical losses with 1.16. We get 1,16 x 4000W = 4640 W motor losses. On partial loads the minimum safety margin is 20%.
When compared to the original power requirement we have calculated worst case motor efficiency

$$\eta_{motor} = \frac{100kW}{104{,}6kW} = 95{,}6\%$$

Next let's consider frequency converter losses



The base load, supply voltage level, drive type, output current, motor power factor, motor frequency, line current etc. will have an effect to losses. They are shown with drive result window with loads 25, 50, 75, 100 and 125% for constant torque and 4, 16, 36, 64 and 100% for pump&fan types of loads. In this case the drive losses are 2700W at required base speed and power. We can now compute the drive&motor typical efficiency

$$\eta_{total} = \frac{100kW}{100kW + 2{,}7kW + 4{,}0kW} = 93{,}7\%$$

This is also shown by DriveSize Efficiency Data Sheet, will list also efficiencies in table format for other loads and speeds.

A safety margin 10% is used to compute worst case losses of frequency converter.

$$\eta_{drive} = \frac{100kW}{100kW + 2{,}9kW + 4{,}6kW} = 92{,}9\%$$

DriveSize will list the worst case losses at each load point on report. These are candidates for guaranteed values. Please refere the appendix.

Please notice that in the graph of the report the typical losses are shown.

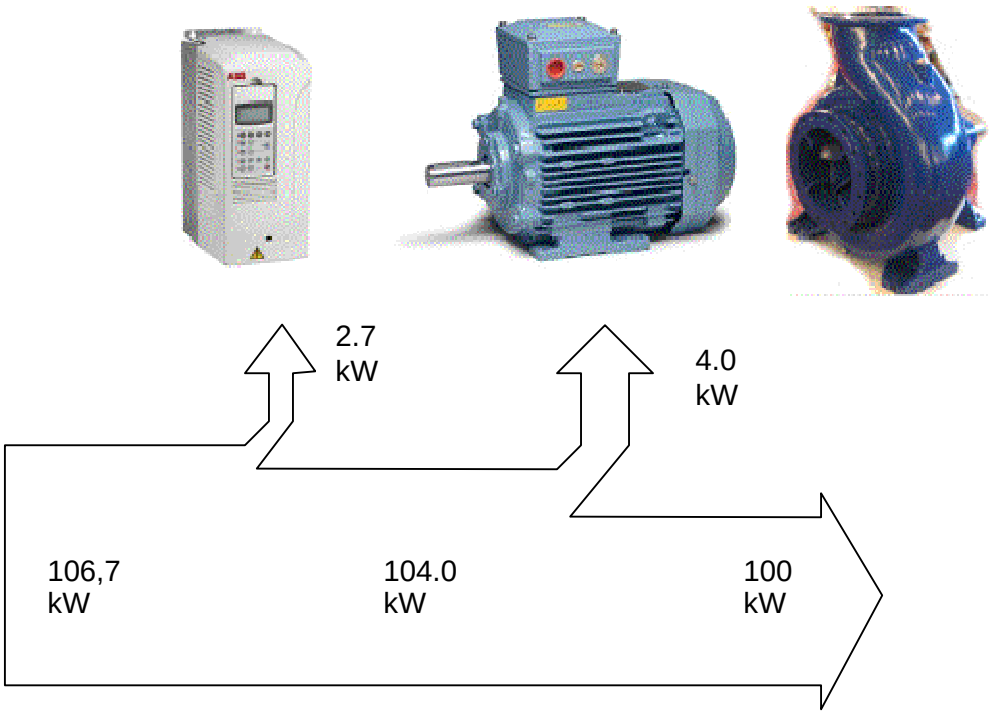
Notice following:

The Efficiency Data sheet is made also for Single drives but not for Multidrives.

The cooling water of liquid cooled units is not considered.

Cables are not considered.

Below you see the graphical presentation of loss calculations in this examble. Sometimes lower losses can be accieved by higher system voltage e.g. 690V and generally DriveSize can be used as fast calculator to compare the losses of different selections.



Appendix : Copy of DriveSize Efficiency Data Sheet.

Efficiency Data Sheet

Typical, average losses and efficiency values and worst case losses

Item No.	1.1.1

Motor load	
Load type	Pump/fan load
n min [rpm]	1450
n base [rpm]	1450
n max [rpm]	1450
Pbase [kW]	100
Tbase [NM]	659

Drive load	
Icont [A]	194
Imax [A]	194

Motor losses [kW]

	torque of Tbase				
speed [rpm]	4 %	16 %	36 %	64 %	100 %
290	0,51	0,54	0,66	0,99	1,69
580	0,74	0,77	0,91	1,28	2,07
870	1,04	1,08	1,23	1,65	2,5
1160	1,43	1,47	1,64	2,1	3,1
1450	1,92	1,97	2,19	2,8	4

Drive losses [kW]

speed [rpm]	4 %	16 %	36 %	64 %	100 %
290	0,63	0,67	0,8	1,11	1,69
580	0,63	0,68	0,83	1,18	1,84
870	0,64	0,69	0,87	1,28	2,05
1160	0,64	0,71	0,92	1,4	2,3
1450	0,61	0,7	0,96	1,56	2,7

Combined Drive & Motor(s) — Efficiency %

speed [rpm]	4 %	16 %	36 %	64 %	100 %
290	41,2	72,6	83,1	85,9	85,5
580	53,9	81,5	89,2	91,2	91,1
870	58,8	84,4	91,1	92,9	93
1160	60,7	85,4	91,8	93,6	93,7
1450	61,3	85,7	92	93,6	93,7

Worst case losses including full positive tolerance [kW]

speed [rpm]	4 %	16 %	36 %	64 %	100 %
290	1,3	1,38	1,67	2,41	3,9
580	1,58	1,67	2,01	2,8	4,5
870	1,95	2,06	2,43	3,4	5,3
1160	2,42	2,5	3	4,1	6,2
1450	3	3,1	3,7	5,1	7,8

Graph: Combined losses: