

## Motor Upgrades

### Scope

The scope of this exercise was to produce the calculations required to be able to quantify the Return of Investment resulting from the upgrade of Motor Systems. The upgrades considered are (i) the improvement of motor efficiency and (ii) coupling the motor to inverter driven variable speed drives.

### Overview

The calculation is modular, based on a number of motors. The user inputs the variables listed in Table 1 for each motor or number of similar motor. Variables i1 to i3 describe the current system. The proposed motor upgrade is described using Variables i4 to i11. The efficiency of the current motor at its current loading is inputted in variable i3. The efficiency of the proposed upgraded motor is defined in variable i5. A table with the minimum 50 Hz efficiency values defined in IEC/EN 60034-30-1:2014 (based on test methods specified in IEC 60034-2-1:2014) is reproduced in Appendix 1. The efficiency values vary with motor power output, number of poles and IE code.

The coupling of the motor to inverter driven variable speed drives is described using variables i6 to i12. Three user defined power levels are used ( $P_1$ ,  $P_2$ , and  $P_3$ ), which can be calculated at say 100%, 75% and 50% of the rated motor power. The proposed running time at the different levels is defined in variables i6 to i8.

Input variables i1 to i12 are inputted for the different motors (numbered 1 to n).

Variable No	Input Variable	Symbol	Unit
i1	Motor Output Power – Motor N	$P_M$	kW/motor
i2	No of similar motors	$N$	No
i3	Efficiency of Current Motor	$M_{eff,c}$	%
i4	Current Motor Utilisation	$t_c$	hrs/day
i5	Efficiency of Proposed Motor	$M_{eff,p}$	%
i6	Proposed Utilisation time at Power Level 1	$t_1$	hrs/day
i7	Proposed Utilisation time at Power Level 2	$t_2$	hrs/day
i8	Proposed Utilisation time at Power Level 3	$t_3$	hrs/day
i9	Motor Output Power Level 1	$P_{M1}$	kW

i10	Motor Output Power Level 2	$P_{M2}$	kW
i11	Motor Output Power Level 3	$P_{M3}$	kW
i12	Average Inverter Efficiency	$I_{eff}$	%

Table 1: Required Inputs – Motor Upgrades

The user inputs the costs in financial variables fi1 to fi4 (listed in Table 2) and defines the discount rate and the required Return of Investment (ROI) period in variables fi5 and fi6 respectively. The appropriate electricity tariff is defined in variable fi7. The tariffs are shown in Appendix 2.

Variable No	Input Variable	Symbol	Unit
fi1	Dismantling Cost	$C_1$	€
fi2	Disposal Cost	$C_2$	€
fi3	Capital Cost	$C_3$	€
fi4	Installation Cost	$C_4$	€
fi5	Discount Rate	$i$	%
fi6	ROI period	$R$	Years
fi7	Electricity Tariff	$r$	€/kWh

Table 2: Required Inputs – Financial

The algorithm calculates and presents the outputs listed in Table 3 and Table 4.

The current, proposed and saved electricity consumption and corresponding costs are calculated in variables o1 to o10 and fo1.

The Return of Investment and the Payback period (variables fo3 to fo6) are calculated based on the savings (variable fo1) and the total investment cost (variable fo2).

Variable No	Output Variables	Symbol	Unit
o1	Current Electricity Consumption – Motor N	$E_{CN}$	kWh/day
o2	Proposed Electricity Consumption – Motor N	$E_{PN}$	kWh/day
o3	Electricity Consumption Savings – Motor N	$E_{SN}$	kWh/day
o4	Percentage Electricity Savings – Motor N	$S_N$	%

o5	Total Annual Current Electricity Consumption	$E_C$	kWh/year
o6	Total Annual Current Electricity Cost	$C_C$	€/year
o7	Total Annual Proposed Electricity Consumption	$E_P$	kWh/year
o8	Total Annual Proposed Electricity Cost	$C_P$	€/year
o9	Total Annual Electricity Consumption Savings	$E_S$	kWh/year
o10	Percentage Electricity Savings	$S$	%

Table 3: Calculated Outputs

Variable No	Output Variables	Symbol	Unit
fo1	Total Annual Electricity Cost Savings	$C_S$	€/year
fo2	Total Investment Cost	$C_t$	€
fo3	Pay Back Period - Simple	$t_{SPB}$	years
fo4	Pay Back Period - NPV	$T_{NPV}$	years
fo5	ROI after R years	$ROI_R$	€
fo6	Percentage ROI after R years	$ROI_{R\%}$	%

Table 4: Calculated Outputs - Financial

## Conclusion

A preview with three motors and dummy values is shown in Appendix 3. The three options shown are for (i) motor upgrade, (ii) inverter coupling, and (iii) both motor upgrade and inverter coupling. The number of motors can be increased accordingly.

## Appendix 1: Minimum 50 Hz efficiency values defined in IEC/EN 60034-30-1:2014

Output (kW)	IE1				IE2				IE3				IE4			
	2pole	4pole	6pole	8pole	2pole	4pole	6pole	8pole	2pole	4pole	6pole	8pole	2pole	4pole	6pole	8pole
0.12	45.0	50.0	38.3	31.0	53.6	59.1	50.6	39.8	60.8	64.8	57.7	50.7	66.5	69.8	64.9	62.3
0.18	52.8	57.0	45.5	38.0	60.4	64.7	56.6	45.9	65.9	69.9	63.9	58.7	70.8	74.7	70.1	67.2
0.20	54.6	58.5	47.6	39.7	61.9	65.9	58.2	47.4	67.2	71.1	65.4	60.6	71.9	75.8	71.4	68.4
0.25	58.2	61.5	52.1	43.4	64.8	68.5	61.6	50.6	69.7	73.5	68.6	64.1	74.3	77.9	74.1	70.8
0.37	63.9	66.0	59.7	49.7	69.5	72.7	67.6	56.1	73.8	77.3	73.5	69.3	78.1	81.1	78.0	74.3
0.40	64.9	66.8	61.1	50.9	70.4	73.5	68.8	57.2	74.6	78.0	74.4	70.1	78.9	81.7	78.7	74.9
0.55	69.0	70.0	65.8	56.1	74.1	77.1	73.1	61.7	77.8	80.8	77.2	73.0	81.5	83.9	80.9	77.0
0.75	72.1	72.1	70.0	61.2	77.4	79.6	75.9	66.2	80.7	82.5	78.9	75.0	83.5	85.7	82.7	78.4
1.1	75.0	75.0	72.9	66.5	79.6	81.4	78.1	70.8	82.7	84.1	81.0	77.7	85.2	87.2	84.5	80.8
1.5	77.2	77.2	75.2	70.2	81.3	82.8	79.8	74.1	84.2	85.3	82.5	79.7	86.5	88.2	85.9	82.6
2.2	79.7	79.7	77.7	74.2	83.2	84.3	81.8	77.6	85.9	86.7	84.3	81.9	88.0	89.5	87.4	84.5
3.0	81.5	81.5	79.7	77.0	84.6	85.5	83.3	80.0	87.1	87.7	85.6	83.5	89.1	90.4	88.6	85.9
4.0	83.1	83.1	81.4	79.2	85.8	86.6	84.6	81.9	88.1	88.6	86.8	84.8	90.0	91.1	89.5	87.1
5.5	84.7	84.7	93.1	81.4	87.0	87.7	86.0	83.8	89.2	89.6	88.0	86.2	90.9	91.9	90.5	88.3
7.5	86.0	86.0	84.7	83.1	88.1	88.7	87.2	85.3	90.1	90.4	89.1	87.3	91.7	92.6	91.3	89.3
11.0	87.6	87.6	86.4	85.0	89.4	89.8	88.7	86.9	91.2	91.4	90.3	88.6	92.6	93.3	92.3	90.4
15.0	88.7	88.7	87.7	86.2	90.3	90.6	89.7	88.0	91.9	92.1	91.2	89.6	93.3	93.9	92.9	91.2
18.5	89.3	89.3	88.6	86.9	90.9	91.2	90.4	88.6	92.4	92.6	91.7	90.1	93.7	94.2	93.4	91.7
22	89.9	89.9	89.2	87.4	91.3	91.6	90.9	89.1	92.7	93.0	92.2	90.6	94.0	94.5	93.7	92.1
30	90.7	90.7	90.2	88.3	92.0	92.3	91.7	89.8	93.3	93.6	92.9	91.3	94.5	94.9	94.2	92.7
37	91.2	91.2	90.8	88.8	92.5	92.7	92.2	90.3	93.7	93.9	93.3	91.8	94.8	95.2	94.5	93.1
45	91.7	91.7	91.4	89.2	92.9	93.1	92.7	90.7	94.0	94.2	93.7	92.2	95.0	95.4	94.8	93.4
55	92.1	92.1	91.9	89.7	93.2	93.5	93.1	91.0	94.3	94.6	94.1	92.5	95.3	95.7	95.1	93.7
75	92.7	92.7	92.6	90.3	93.8	94.0	93.7	91.6	94.7	95.0	94.6	93.1	95.6	96.0	95.4	94.2
90	93.0	93.0	92.9	90.7	94.1	94.2	94.0	91.9	95.0	95.2	94.9	93.4	95.8	96.1	95.6	94.4
110	93.3	93.3	93.3	91.1	94.3	94.5	94.3	92.3	95.2	95.4	95.1	93.7	96.0	96.3	95.8	94.7
132	93.5	93.5	93.5	91.5	94.6	94.7	94.6	92.6	95.4	95.6	95.4	94.0	96.2	96.4	96.0	94.9
160	93.8	93.8	93.8	91.9	94.8	94.9	94.8	93.0	95.6	95.8	95.6	94.3	96.3	96.6	96.2	95.1
200	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.3	95.4
250	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.5	95.4
315	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4
355	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4
400	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4
450	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4
500-1000	94.0	94.0	94.0	92.5	95.0	95.1	95.0	93.5	95.8	96.0	95.8	94.6	96.5	96.7	96.6	95.4

## Appendix 2: Enemalta Tariffs

<b>Band</b>	<b>Cumulative Consumption (kWh)</b>	<b>Tariff (€/kWh)</b>
1	0 - 2,000	0.1215
2	2,001 - 6,000	0.1275
3	6,001 - 10,000	0.1373
4	10,001 - 20,000	0.1485
5	20,001 - 60,000	0.1613
6	60,001 - 100,000	0.1500
7	100,001 - 1,000,000	0.1403
8	1,000,001 - 5,000,000	0.1275
9	5,000,000 & over	0.1080

