Calculation of benefit of replacing IE3 motor with IE4+ motor (75 kW, 30000 rpm) for Italy, for 0.5 of full load

1. Price of 1 kWh of active power in Italy in Euro: $Ca_{Italy} = 0.24$ Euro/kWh.

2. Power factor of the motor IE4+ at 0.5 of full load: $cos\ (\varphi) = 0.854$.

3. Price of 1 kVAh of reactive power in Italy in Euro for IE4+, for $cos\ (\varphi) = 0.854$: $Cr4_{Italy} = 0.032$ Euro/ kVAh.

   if $Cos\ (\varphi) > 0.9$, then $Cr4_{Italy} = 0$ Euro/kVAh,
   if $0.8 \le Cos(\varphi) \le 0.9$, then $Cr4_{Italy} = 0.032$ Euro/kVAh,
   if $Cos(\varphi) < 0.8$, then $Cr4_{Italy} = 0.042$ Euro/kVAh .

4. Duration of motor operation in hours per year (8 hours per day, 288 days per year): t_{work}= 2304 hours.

5. Motor efficiency of IE4+ at 0.5 of full load: η_{ie4+}= 0.944.

6. Motor efficiency of IE3 at 0.5 of full load: η_{ie3} = 0.932.

7. Active power consumption by IE4+ and IE3 motors at 0.5 of full load:

$$Pa_{ie4+} = \frac{0.5 \cdot P_{2n}}{\eta_{ie4+}} t_{work} = \frac{0.5 \cdot 75}{0.944} \cdot 2304 = 91544 \text{ kWh},$$

$$Pa_{ie3} = \frac{0.5 \cdot P_{2n}}{\eta_{ie3}} t_{work} = \frac{0.5 \cdot 75}{0.932} \cdot 2304 = 92731 \text{ kWh}.$$

8. Payment for consumed active power by IE4+ and IE3 motors at 0.5 of full load:

$$pay_{ie4+} = Pa_{ie4+} \cdot Ca_{Italy} = 21971 \text{ Euro},$$

$$pay_{ie3} = Pa_{ie3} \cdot Ca_{Italy} = 22256 \text{ Euro}.$$

9. Benefit per year due to increased efficiency

$$E_{act} = pay_{ie3} - pay_{ie4+} = 285 \text{ Euro}.$$

10. Power factor of an average IE3 motor at 0.5 of full load: $Cos\ (\varphi)_{ie3} = 0.76$.

11. Price of 1kVAh of reactive power in Italy in Euro for the IE3 motor ($Cos\ (\varphi)_{ie3} = 0.76$):

$$Cr3_{Italy} = 0.042 \text{ Euro/ kVAh}.$$

12. Reactive power consumption by IE4+ and IE3 motors at 0.5 of full load:

$$Q_{ie4+} = Pa_{ie4+} \cdot \frac{\sqrt{1 - Cos^2(\varphi)}}{Cos(\varphi)} = 55669 \text{ kVAh},$$

$$Q_{ie3} = Pa_{ie3} \cdot \frac{\sqrt{1 - Cos^2(\varphi)_{ie3}}}{Cos(\varphi)_{ie3}} = 79300 \text{ kVAh}.$$

13. Payment for consumed reactive power by IE4+ and IE3 motors:

$$payr_{ie4+} = Q_{ie4+} \cdot Cr4_{Italy} = 1781 \text{ Euro},$$

$$payr_{ie3} = Q_{ie3} \cdot Cr3_{Italy} = 3331 \text{ Euro}.$$

14. Benefit per year due to increased power factor at 0.5 of full load:

$$E_{react} = payr_{ie3} - payr_{ie4+} = 1550 \text{ Euro}.$$

15. Benefit per year due to increased efficiency and increased power factor at 0.5 of full load:

$$E_{act} = 285 \text{ Euro}, \qquad E_{react} = 1550 \text{ Euro}.$$

16. Total benefit per year due to replacement of an average IE3 motor with an IE4+ motor at 0.5 of full load:

$$E_{one\_year} = E_{act} + E_{react} = 1835 \text{ Euro}.$$