

Calculation of benefit of replacing IE3 motor with IE4+ motor (75 kW, 30000 rpm) for Italy, for 0.75 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 IE4+ motor at 0.75 of full load: $\cos(\varphi) = 0.912$.

3. Price of 1 kVAh of reactive power in Italy in Euro for IE4+, for $\cos(\varphi) = 0.912$: $Cr4_{Italy} = 0$ Euro/ kVAh.

if $\cos(\varphi) > 0.9$, then $Cr4_{Italy} = 0$ Euro/kVAh,

if $0.8 \leq \cos(\varphi) \leq 0.9$, 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 0.75 of full load: $\eta_{ie4+} = 0.955$.

6. Motor efficiency of IE3 at 0.75 of full load: $\eta_{ie3} = 0.943$.

7. Active power consumption by IE4+ and IE3 motors at 0.75 of full load:

$$Pa_{ie4+} = \frac{0.75 \cdot P_{2n}}{\eta_{ie4+}} t_{work} = \frac{0.75 \cdot 75}{0.955} \cdot 2304 = 1356893 \text{ kWh,}$$

$$Pa_{ie3} = \frac{0.75 \cdot P_{2n}}{\eta_{ie3}} t_{work} = \frac{0.75 \cdot 75}{0.943} \cdot 2304 = 137449 \text{ kWh.}$$

8. Payment for consumed active power by IE4+ and IE3 motors at 0.75 of full load:

$$pay_{ie4+} = Pa_{ie4+} \cdot Ca_{Italy} = 32565 \text{ Euro,}$$

$$pay_{ie3} = Pa_{ie3} \cdot Ca_{Italy} = 32988 \text{ Euro.}$$

9. Benefit per year due to increased efficiency

$$E_{act} = pay_{ie3} - pay_{ie4+} = 423 \text{ Euro.}$$

10. Power factor of an average IE3 motor at 0.75 of full load: $\cos(\varphi)_{ie3} = 0.84$.

11. Price of 1kVAh of reactive power in Italy in Euro for the IE3 motor ($\cos(\varphi)_{ie3} = 0.84$):

$$Cr3_{Italy} = 0.032 \text{ Euro/ kVAh.}$$

12. Reactive power consumption by IE4+ and IE3 motors at 0.75 of full load:

$$Q_{ie4+} = Pa_{ie4+} \cdot \frac{\sqrt{1 - \cos^2(\varphi)}}{\cos(\varphi)} = 60910 \text{ kVAh,}$$

$$Q_{ie3} = Pa_{ie3} \cdot \frac{\sqrt{1 - \cos^2(\varphi)_{ie3}}}{\cos(\varphi)_{ie3}} = 88783 \text{ kVAh.}$$

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

$$payr_{ie4+} = Q_{ie4+} \cdot Cr4_{Italy} = 0 \text{ Euro,}$$

$$payr_{ie3} = Q_{ie3} \cdot Cr3_{Italy} = 2841 \text{ Euro.}$$

14. Benefit per year due to increased power factor at 0.75 of full load:

$$E_{react} = payr_{ie3} - payr_{ie4+} = 2841 \text{ Euro.}$$

15. Benefit per year due to increased efficiency and increased power factor at 0.75 of full load:

$$E_{act} = 423 \text{ Euro,} \quad E_{react} = 2841 \text{ Euro.}$$

16. Total benefit per year due to replacement of an average IE3 motor with an IE4+ motor at 0.75 of full load:

$$E_{one_year} = E_{act} + E_{react} = 3264 \text{ Euro.}$$