

Calculation of benefit of replacing IE3 motor with IE5+ motor (55 kW, 1500 rpm) for Italy

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

2. Power factor of an IE5+ motor: $\cos(\varphi) = 0.91$.

3. Price of 1 kVAh of reactive power in Italy in Euro for IE5+, for $\cos(\varphi) = 0.91$: $Cr5_{Italy} = 0$ Euro/kVAh.

if $\cos(\varphi) > 0.9$, then $Cr5_{Italy} = 0$ Euro/kVAh,

if $0.8 \leq \cos(\varphi) \leq 0.9$, then $Cr5_{Italy} = 0.032$ Euro/kVAh,

if $\cos(\varphi) < 0.8$, then $Cr5_{Italy} = 0.042$ 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 IE5+: $\eta_{ie5+} = 0.965$.

6. Standard motor efficiency of IE3: $\eta_{ie3} = 0.946$

7. Active power consumption by IE5+ and IE3 motors:

$$Pa_{ie5+} = \frac{P_{2n}}{\eta_{ie5+}} t_{work} = \frac{55}{0.965} \cdot 2304 = 131352 \text{ kWh},$$

$$Pa_{ie3} = \frac{P_{2n}}{\eta_{ie3}} t_{work} = \frac{55}{0.946} \cdot 2304 = 133953 \text{ kWh}.$$

8. Payment for consumed active power by IE5+ and IE3 motors:

$$pay_{ie5+} = Pa_{ie5+} \cdot Ca_{Italy} = 31525 \text{ Euro},$$

$$pay_{ie3} = Pa_{ie3} \cdot Ca_{Italy} = 32149 \text{ Euro}.$$

9. Benefit per year due to increased efficiency

$$E_{act} = pay_{ie3} - pay_{ie5+} = 624 \text{ Euro}.$$

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

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 IE5+ and IE3 motors:

$$Q_{ie5+} = Pa_{ie5+} \cdot \frac{\sqrt{1-\cos^2(\varphi)}}{\cos(\varphi)} = 59555 \text{ kVAh},$$

$$Q_{ie3} = Pa_{ie3} \cdot \frac{\sqrt{1-\cos^2(\varphi)_{ie3}}}{\cos(\varphi)_{ie3}} = 86525 \text{ kVAh}.$$

13. Payment for consumed reactive power by IE5+ and IE3 motors:

$$payr_{ie5+} = Q_{ie5+} \cdot Cr5_{Italy} = 0 \text{ Euro},$$

$$payr_{ie3} = Q_{ie3} \cdot Cr3_{Italy} = 2769 \text{ Euro}.$$

14. Benefit per year due to increased power factor:

$$E_{react} = payr_{ie3} - payr_{ie5+} = 2769 \text{ Euro}.$$

15. Benefit per year due to increased efficiency and increased power factor:

$$E_{act} = 624 \text{ Euro}, \quad E_{react} = 2769 \text{ Euro}.$$

16. Total benefit per year due to replacement of an average IE3 motor with an IE5+ motor:

$$E_{one_year} = E_{act} + E_{react} = 3393 \text{ Euro}.$$