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LOW-SPEED MOTOR EXPERIENCE

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Abstract

Most mechanical draft cooling towers used around the world operate by using standard mechanical air moving equipment such as an axial fan, a gear box, a drive shaft and a motor. As presented in the previous paper, a low-speed motor directly coupled to an axial fan [3] can present benefits to the cooling tower industry. This paper describes low-speed motor experiences of one European cooling tower manufacturer.

Keywords:

Low-speed motor, direct drive motor, coupled with axial fan

1. Introduction

Direct drive motors for cooling tower applications aren't something new. As soon as the very first thermal power stations were built early in the last century, cooling towers were the weakest point. First cooling towers were very simple - natural draught type with simple wooden cooling fill.

Cooling efficiency was low and incremental gains in performance could be reached partly by cooling fill improvement and partly by increased air flow. These requirements are rather in conflict. Dense cooling fill increases air flow resistance, but decreases air draught.

The tower height is limited by construction limitations or economic reasons, thus the only way to increase air flow through the tower is by means of a powered fan. Discrepancy between required fan speed and much higher motor speed has been solved by use of mechanical transmission, (rubber or leather) belts at first, and a gearbox reducer at later stages. In spite of indisputable technical progress, each solution also brought its own disadvantages. Unreliability and short service life is typical for belts; oil leakage and heavy construction, or necessity of oil cooling is typical for gearbox reducers. The idea of low-speed motor coupled directly with axial fan has been born.

Figure 01: Gearbox application installed in Lukoil refinery, Bourgas, Bulgaria

2. **Low - speed motors development**

The first motors, as known to us intended for direct driving of cooling tower fans were produced in the Soviet Union in the early 60's. These low-speed motors, known as VASO type motors were robust, rigid-welded frame motors providing power output 75 and 90kW with the speed of 220 RPM. These motors were mainly used in the Russian market.

First prototypes were developed in Czechoslovakia 20 years later, but systematic development and first commercial "in operation" activity was accomplished at the beginning of the 1990´s. First evolutionary induction motors in Czechoslovakia were already two-speed with switchable DAHLANDER windings. Typical motor performances are given in the following Table 01:

✍ ***Note:*** *DAHLANDER winding means pole-changing winding in a ratio of 2:1*

Parameter	**Unit**	**I**	**II**
Output power	kW	75 / 9,5	110 / 15
Speed	min^{-1}	209 / 104	184 / 92
Voltage	V	3 x 400	3 x 400
Frequency	Hz	50	50
Design	—	IM 3231	IM 3231
Enclosure	—	IP 44	IP 44
Insulation class	—	F	F
Cooling	—	IC 418	IC 418
Mass	kg	2450	3280

Table 01: First induction motors

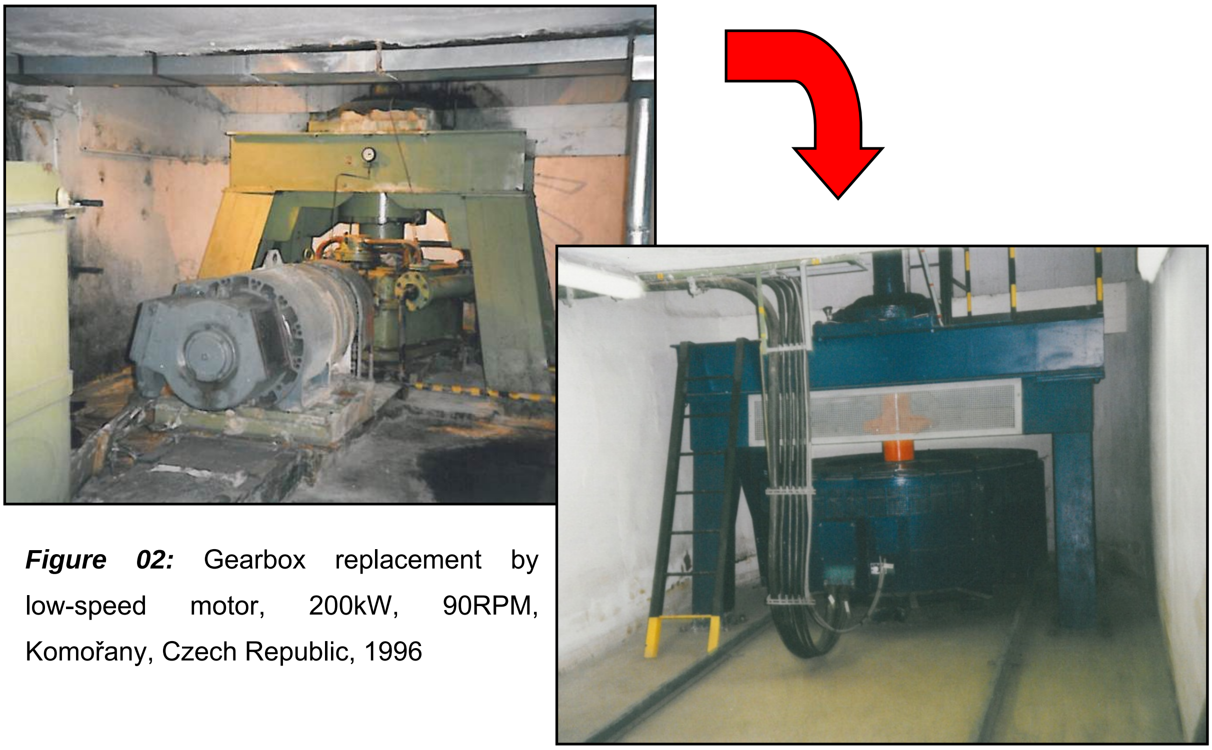


Figure 02: Gearbox replacement by low-speed motor, 200kW, 90RPM, Komořany, Czech Republic, 1996

Regular low-speed motors could be offered as two-speed induction motors as well as single-speed motors or motors intended for power supply from frequency inverters.

Synchronous motors with permanent magnets installed on the rotor are another item being successfully produced.

In comparison with the same power-asynchronous motors, these are significantly smaller and continuously controllable. The size difference is caused by significantly improved power factor of the synchronous motor.

Figure 03: Low-speed motor type PMD75-160D, double speed, 75kW, 160 RPM

In order to protect winding against moisture condensation, all well engineered motors are fitted with heating elements, which are switched on during long-term shut-down periods, e.g. during winter season.

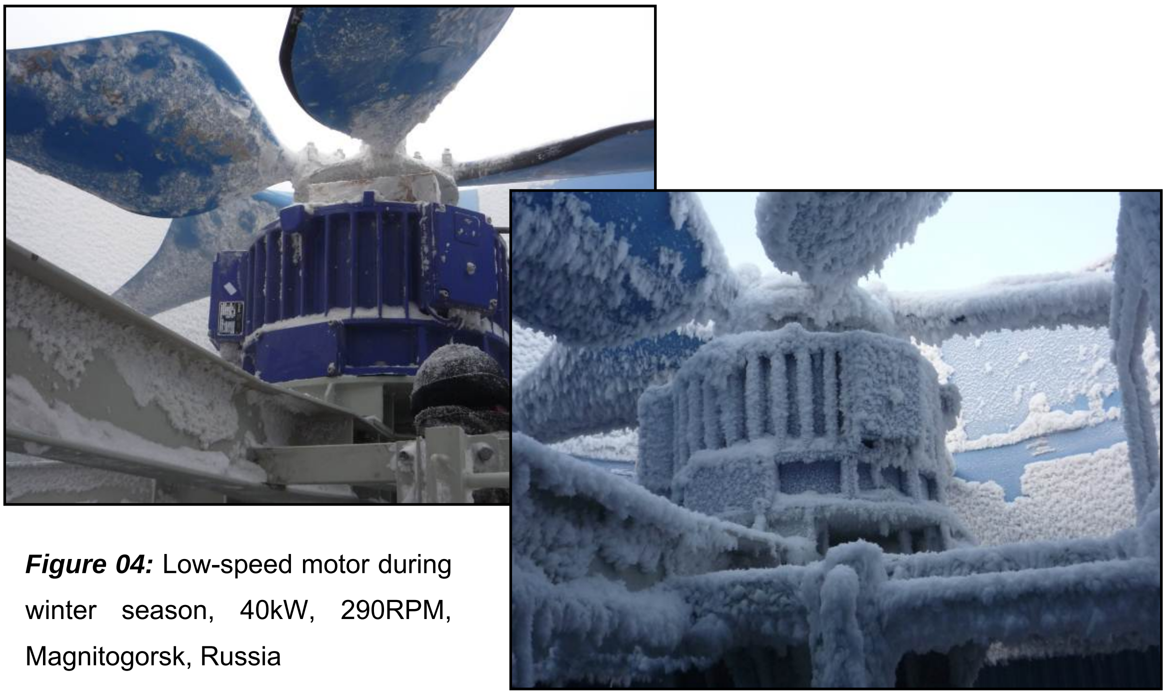


Figure 04: Low-speed motor during winter season, 40kW, 290RPM, Magnitogorsk, Russia

3. Motor monitoring

In order to record temperature during operation, all motors are equipped with several protecting sensors. There are two sets of three PTC thermistors embedded in the motor winding and two Pt100 resistance thermometers for both bearings. This is the monitoring equipment of regular low-speed motor.

✍ ***Note:*** *Pt100 is a type of resistance thermometer with resistance reference value 100Ω at 0°C.*
PTC thermistors yield very steep resistance-temperature characteristic, suitable for ON-OFF control.

Customized motors may contain two-stage winding thermal protection by means of PTC 130 and PTC 145 sensors. Another option could be KTY instead of PTC, or Pt100 thermometers. Vibration transducers become almost standard monitoring equipment of low-speed motors. Output signals of all sensors can be continuously recorded by monitoring apparatus.

✍ ***Note:*** *KTY is silicon-semiconductor based thermometer with quadratic resistance - temperature characteristic. In comparison to PT100 thermometer, KTY is cheaper however, less accurate.*

By continuously measuring all parameters such as winding temperature, bearing temperature and vibration level, it provides protection of driver and fan. All emergency situations could be signaled or stopped in emergency.

Emergency situation	**Reason**
Winding temperature rising	Winding failure
	Motor overloading
Bearing temperature rising	Insufficient greasing
Vibration level increasing	Bearing failure
	Motor mechanical disorder
	Fan impeller damage
	Loosen hinges

Table 02: Emergency situation

Monitoring unit can work separately or could be linked by means of any standard interface to the control system, e.g. local monitoring system or plant control system.

Figure 05: Local monitoring system

Because of the 8-10 m/s air speed inside the fan stack at motor level the motor is cooled sufficiently enough by its own ribs. Moreover, as described above, low-speed motors are equipped with several protection elements.

4. Low-speed motor meets nuclear power plant safety requirements

Like other equipment used in nuclear power plants, direct drives must meet very strict safety rules and severe service conditions.

Parameter	Unit	Main winding	Auxiliary winding
Output power	kW	160	22.5
Speed	RPM	145	73
Voltage	V	3x6000	3x400
Current	A	26	88
Frequency	Hz	50	50
Duty	-	S1	S1
Power factor	-	0.65	0.48
Efficiency	%	93	80
Design	-	IM 3231	
Enclosure	-	IP55	
Insulation class	-	H	
Cooling	-	IC 418	
Ambient temperature	°C (°F)	60 (140)	

Table 03: List of motor parameters required for Nuclear power plants

Power supply from two different mains and high ambient temperature are occasionally specified but is an unusual requirement.

Due to the safety reasons, low-speed motors should run both in regular-operation conditions and in emergency-operation conditions of the nuclear power plant. That is the reason why a supply from two independent mains is important.

Therefore it is not possible to use the motor with two-speed (pole-changing winding), in spite of speed ratio 2:1 and output power ratio 8:1, being demanded.

That is the reason why a nuclear grade motor has got a 40 - pole high voltage winding and an 80 - pole low voltage winding, both embedded in the same slots.

Another technical challenge is to place a direct driver into cooling towers in chemical plants, especially petroleum refineries. These explosion-proof motors must match the rating Exd IIB+H_2 (certificates IECEx and ATEX) according to international standards IEC and EN.

✍ ***Note**: Ex…explosion proof – generally; d…flameproof; IIB+H_2…motor intended for explosive gas atmosphere except acetylene and carbon-disulphide; T4 … motor surface temperature up to 135°C; IECEx scheme as per IEC Standard; ATEX scheme as per EN Standard.*

5. Low-speed motor experience

During 20 years of positive experience, low-speed drives have replaced standard gear-box reducer based mechanical drive units, which had held a dominant position in this field for over the past 60 years. During this time period, more than 700 direct drives, primarily in Central and Eastern Europe, have been put into the operation

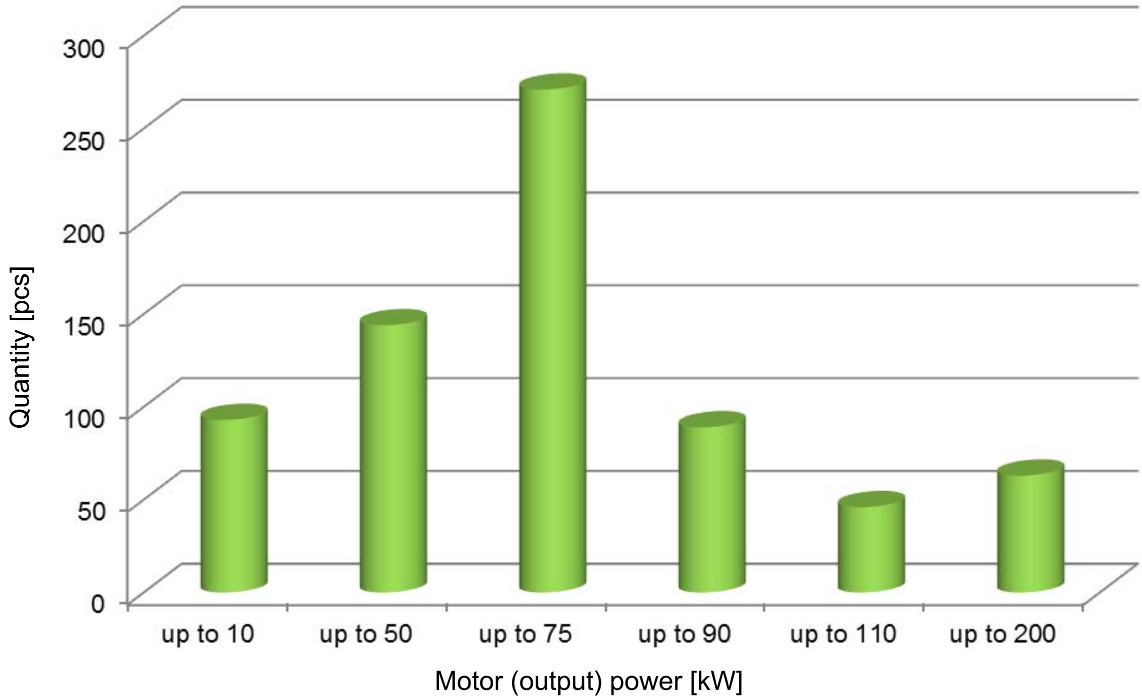
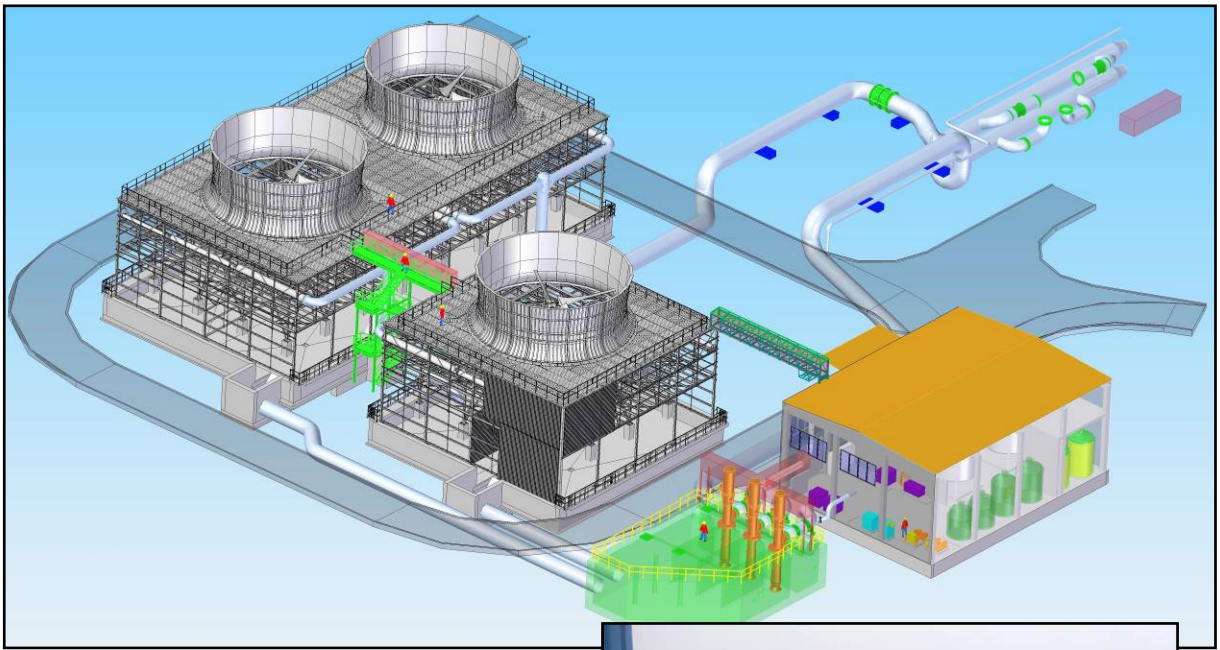


Figure 06: Low-speed motor installation



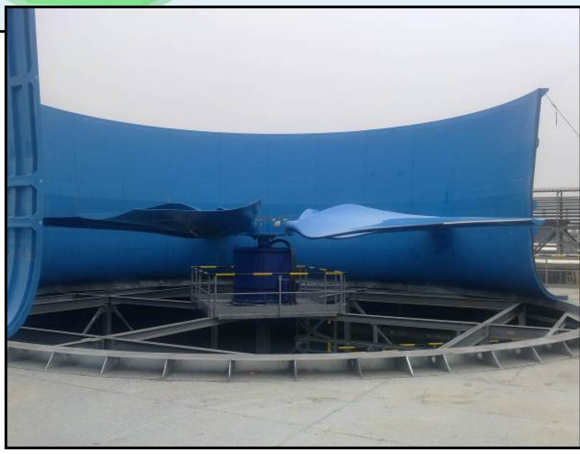


Figure 07: Steel structure cooling tower equipped with low-speed motor, 200kW, 90RPM, Slovnaft refinery, Slovakia [4]

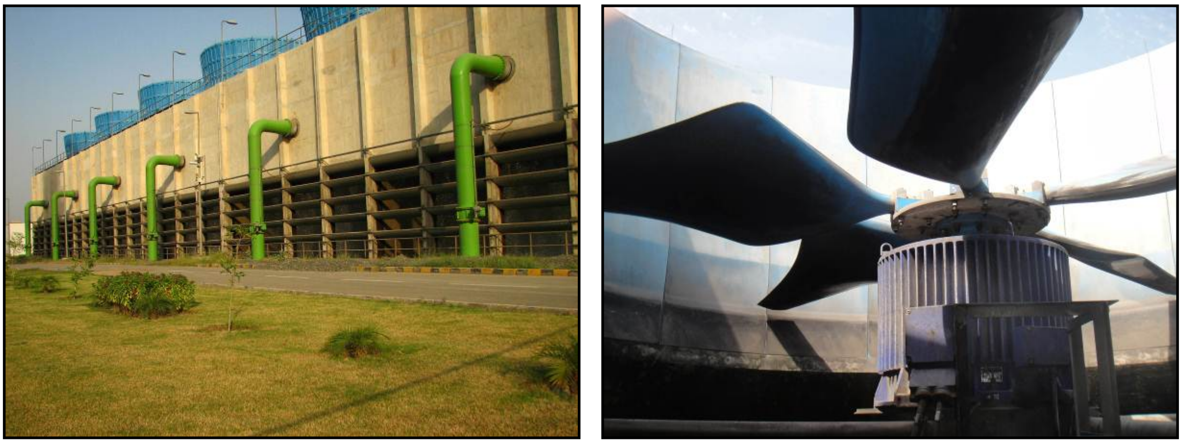


Figure 08: Low-speed motor in RCC cooling tower, 75kW, 180RPM, Balloki power plant, Pakistan

Figure 09: Microcooler equipped with low-speed motor, 8kW, 485 RPM, Chrudim, Czech Republic [3]

As seen from the table below, there are many low-speed motor advantages, compared with gear-box reducer installation.

Benefit	**Reason**
Simple mechanical construction	Only two greased bearings
	Fan directly coupled with motor
Long service life of whole set	Much lower vibration than gear-box application
No damaged bearings during shut-down period	Slow movement of fan impeller due to natural draught
Maintenance free	Without oil lubrication system
Energy saving	Gear-box losses eliminated
De-freezing application	Fan impeller reverse direction

Table 04: Low-speed motor benefits

Two important environmental aspects of these drives cannot be omitted, such as low noise and no oil leakage.

On the other hand, low-speed motor has got its own disadvantages. As described by Figure 10 bellow, low-speed motor weight is significantly more than weight of regular motor. This could be reason, why low-speed motor solution may not be recommended for cooling tower refurbishment. Structural adjustment could be technically or economically unacceptable.

Another important disadvantage could be initial cost. As could be noted from Figure 11, initial costs difference of low power motors is more than cost difference of bigger ones.

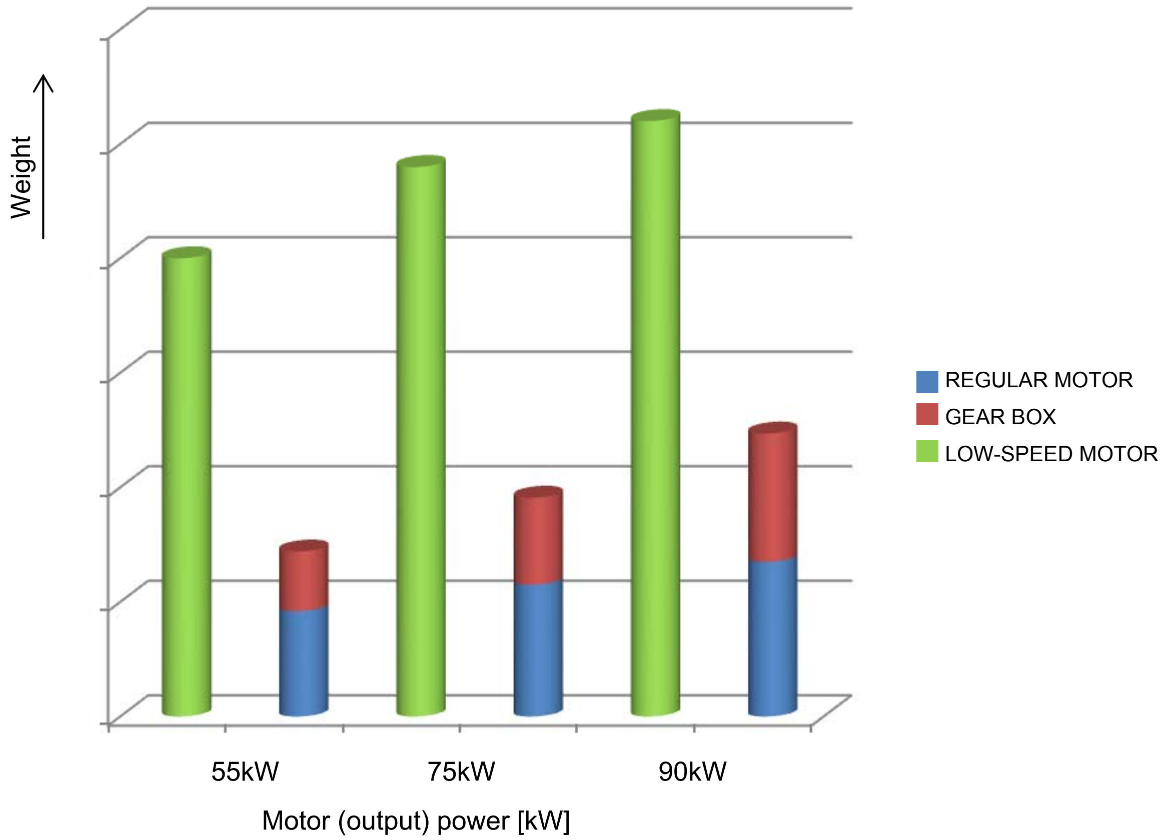


Figure 10: Weight comparison

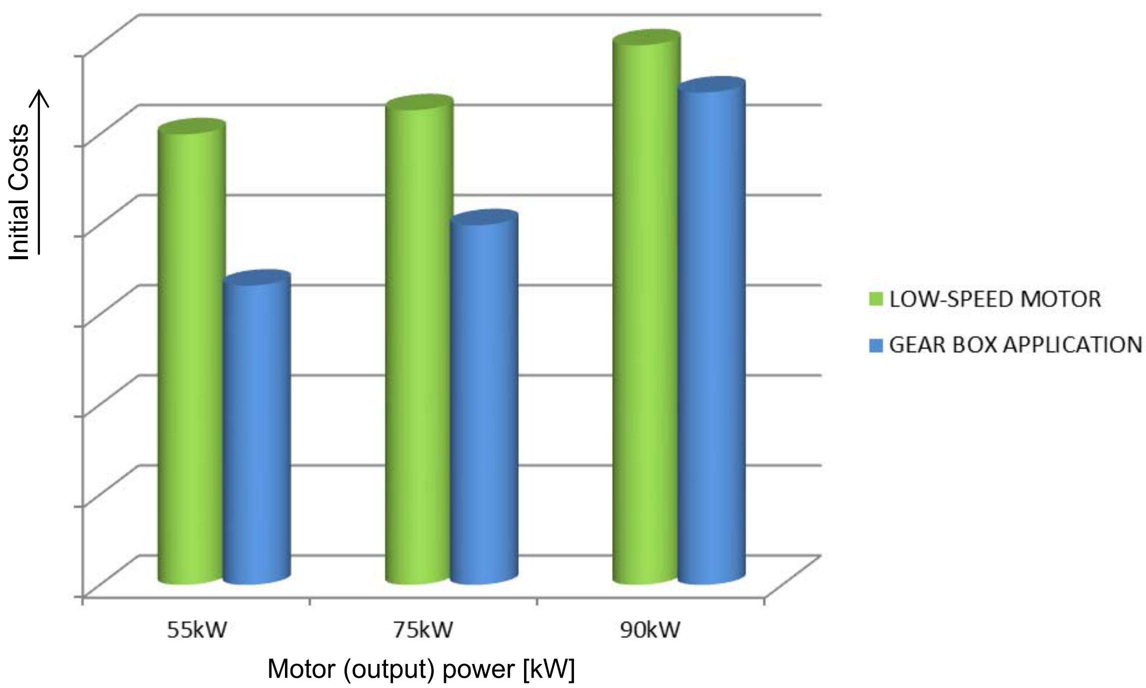


Figure 11: Initial costs comparison

6. Conclusion

Direct fan drives in induced draught cooling towers have many benefits as outlined above. Which is the result of an interaction between motor, fan, cooling fill, water distribution and tower construction development. The best advantages of a low-speed motor are its own simplicity, reliability, energy savings, low noise and low maintenance. These characteristics along with corrosion-proof materials, high-quality coatings and low vibration levels are the main reasons for this motor's long service life. 15 years' service interval between motor's bearing replacements in such an aggressive cooling tower environment is sufficiently self-explanatory. These are valuable aspects for economic evaluation, often neglected by economists.

✍ ***Note**: 130 000 hours of bearings service interval could be reached by correct grease maintenance. As clearly stated in low-speed motor manual, old grease should be replaced by new one, after seven years in operation*

References

[1] List, Paměti, ČES 1992

[2] Casidy, Stack, Applying Adjustable Speed AC Drives to Cooling Tower Fans, PPIC 1988

[3] Kubíček M., Myneni M.K.: Replacement of the concrete cooling tower by steel structure cooling tower during the operation, TP12-03, 2012 Cooling Technology Institute Annual Conference, Houston, Texas, USA

[4] Tichý Z., Cooling and circulatory center CC8, Edison Project, Slovnaft, Slovakia 2012, pp. 27-31