



Raising the waters

Lift irrigation is getting a boost from ABB's synchronous motors

JARI LINDSTRÖM, TAPIO RAUHALA, MAGNUS REJSTRÖM – In India, the scarcity of water is unfortunately a harsh reality. Still, the country's economy relies on agriculture. But how is farming possible on land located in high or arid regions? The answer is lift irrigation, a technique that involves lifting large volumes of water from a river or reservoir to be redistributed in channels, transforming farming conditions in these areas. The process involves both a vertical pump and a motor. Synchronous motors in particular are well-suited for the combination of high power and low speed found in vertical pump applications. The motors operate with high efficiency under normal constant speed conditions and can handle the demanding counter-torque curve of a pump during start-up. ABB has supplied more than 20 custom-built synchronous motors from 4 to 30MW – most of which have individual pumping capacities varying from 10 to 25 m³/s – for lift irrigation projects in India.



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With more than 70 percent of the world's fresh water consumption dedicated to agriculture [1], it is no wonder that in a land as geographically diverse as India, lift irrigation systems are required to maintain the country's agricultural productivity.

Lift irrigation systems are comprised of one or more pumping stations with three to 10 pumps per station. Installations may also include a storage dam and – when pure gravity is insufficient to redistribute the water – a series of pump-equipped booster stations. Thanks to this technology, water distribution can be provided at pumping capacities of close to 700 m³/s to large areas involving distances of up to 300 km, and 60 m altitude differences.

Title picture

ABB's high-efficient synchronous motors help farmers irrigate dry farmland in Andhar Pradesh, India's fourth-largest state, increasing crop yields and improving revenues.

ABB has designed and supplied more than 20 synchronous vertical pump motors ranging from 4 to 30 MW for lift irrigation projects in India → 1. The equipment was provided in cooperation with a large pump manufacturer, which was responsible for delivering, erecting and commissioning the pumps.

Pump up the volume

Pumping is typically performed at a constant speed, and the combination of high power and low speed makes a synchronous motor the most economical choice for lift irrigation applications → 2. The pump arrangement is a vertical assembly with the motor on top, connected to an impeller through a bolted flange coupling → 3. As a result, the motor and the pump must be regarded as one system from a calculation point of view. This influences the mechanical design in terms of the shaft dimension and the position of the bearings.

Although they can be made to other specifications, the motors delivered to India were designed for a power supply of 11 kV at 50 Hz. Each motor has an electrical design customized for its particular pumping application, taking into account the required head and pumping volume (m³/s). (Head refers to the vertical distance a pump can lift a column of water.)

Starting position

Depending on the capacity of the grid, the motors are either started as direct-on-line (DOL) or fitted with a frequency converter. Motors in water-pumping applications must be accelerated against the full pump counter-torque curve. At zero speed the load will be 20 percent of the maximum, depending on the properties of the pump itself. During start-up, the load torque will increase exponentially up to 100 percent; this is a demanding challenge when a motor is started DOL and moves to full speed in about 3 to 6 s. Therefore it is essential that the supply network has sufficient short-circuit capability and that the mo-



Type:	Synchronous motors in vertical pump applications
Delivered:	2008–2011
Purpose:	Lift irrigation projects in India
Designation:	AMZ
Voltage:	11 kV
Frequency:	50 Hz
Power output:	4–30 kW
Speed:	300–600 r/min
Poles:	10–20
Shaft height:	1,250–2,500 mm
IP class:	54 and 55
Cooling:	Air-to-water

With frequency-controlled starting, the motor is started and accelerated to full speed by a variable-speed drive before it is synchronized to the network.

tor is designed to withstand the resulting heat generation and current in the rotor. An alternative to DOL starting is frequency-controlled starting, which is the most common method in large-volume pump applications → 4. Here, the motor is started and accelerated to full speed by a variable-speed drive before it is synchronized to the network. This type of starter consists of switchgear, transformers and a load-commutated inverter (LCI).

As soon as the motor has been synchronized, the frequency converter is bypassed and the system moves to operation at constant speed. The starting time is about 60 seconds longer than with DOL starting, but this difference is usually acceptable in water-pumping applications. Most importantly, the electromechanical stress during starting is significantly reduced. Frequency-controlled starting lim-

its the current that a motor draws from a network to between 50 and 60 percent of the rated current, avoiding voltage dips that could damage the motor and cause network disturbances.

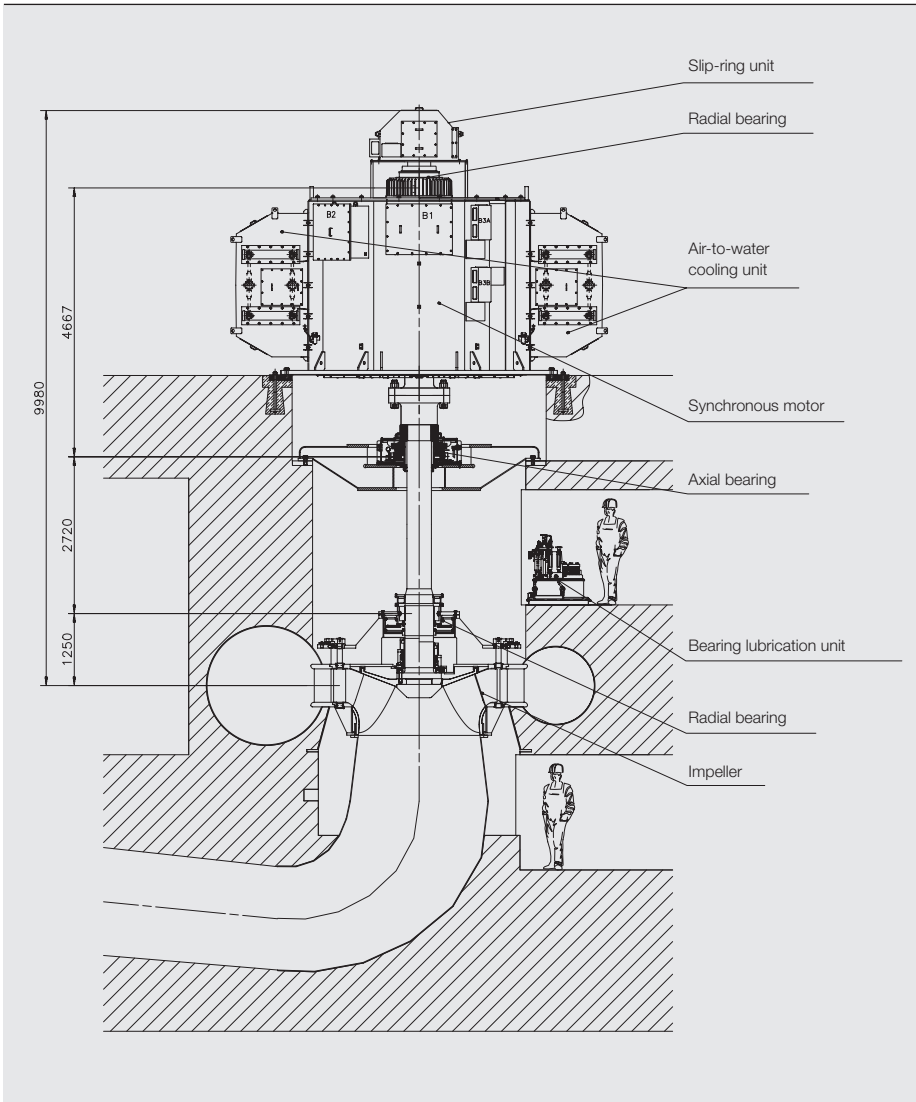
Starting the motor with a frequency converter also offers technical and commercial advantages in terms of smaller motor size, lowering the investment required. The motor consumes less energy and does not need to be larger than the size required for constant-speed operation.

Excitation control

The excitation equipment, however, is slightly more complicated when a frequency converter is used for starting. To supply the field current to the rotor, slip rings are installed on the motor shaft with access via removable inspection covers. The slip rings, together with the mounting flange or hub, are usually made of steel and are normally mounted as a single unit. Slip-ring units with brass rings, as well as split flange-mounted units, are available on request. The slip-ring unit is equipped with brass connection pins for installation.

In addition to voltage and excitation control, the system also has functions for motor protection. Once the motor is running at constant speed, the excitation system will react if the operating conditions change, for example when a valve is opened. The system corrects the power factor back to the desired value, ensuring stable operation.

3 The pump assembly is vertical, with the motor on top of the impeller.



Pumping is typically performed at a constant speed, and the combination of high power and low speed makes a synchronous motor the most economical choice in lift irrigation projects.

Shafts and bearings

When it comes to the mechanical design of synchronous motors in vertical pump applications, each project demands customization. The main variables are the required speed and power for a specific pump, as well as the actual pump design. From these data, the shaft dimension and bearing arrangement can be derived.

From a design point of view, the motor-pump assembly should be regarded as one system. The shafts are connected through a rigid coupling, so stress calculations must consider them as one long shaft. Consequently, the design involves shaft lengths of up to 10 m, which increases the risk of resonance between the operating speed and lateral frequen-

cies. There may be excessive vibration in the assembly, resulting in fatigue damage and shortening of the lifetime of the

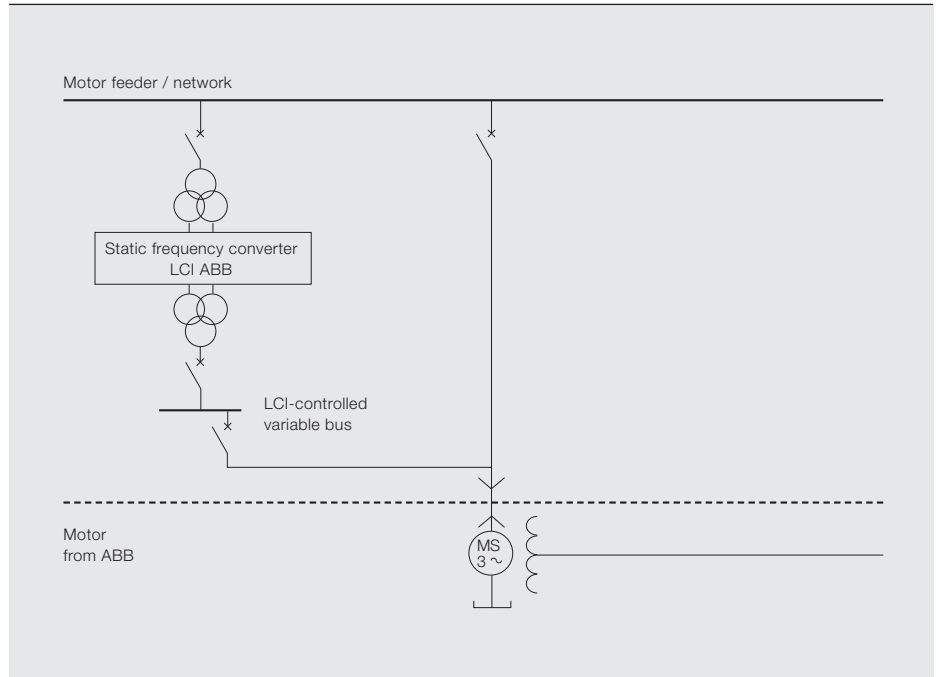
Synchronous motors in vertical pump applications are a cost-efficient and reliable solution.

shaft and bearings. This problem is solved by adapting the diameter and length of the shaft, or by changing the position of the bearings, so that the operating and lateral frequencies are safely separated → 5.

The motor and pump shafts are forged in solid steel, and the bearing arrangement includes two guide bearings and a thrust bearing for axial loads.

ABB's synchronous motors are built in a self-supporting full frame and are customized for the expected environmental conditions.

4 The most common starting method is via a frequency converter.



The bearings are all journal bearings specially designed for vertical operation and are fitted with an oil circulation and cooling system. Axial loads range from 300 to 1,100 kN, while radial loads are relatively low. Journal bearings are preferred over rolling bearings because they can bear high axial loads.

Structural support

ABB's synchronous motors are built in a self-supporting full frame and are customized for the expected environmental conditions. The stator frame is a rigid steel structure designed to withstand vibration induced by the driven equipment. The core is built of stacked, high-grade, low-loss laminated electrical steel sheets insulated on both sides with a heat-resistant, inorganic coating. Radial cooling ducts ensure uniform and effective cooling of the stator.

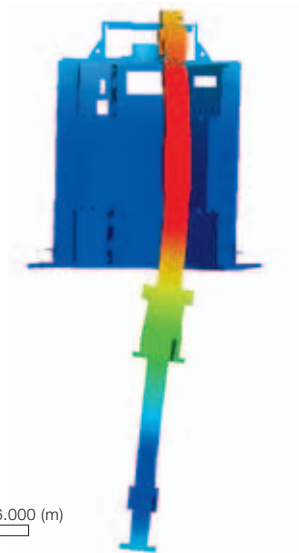
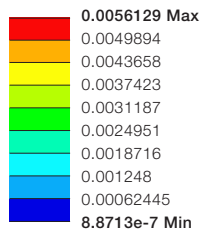
Stator windings are made of form-wound rectangular copper wire insulated with multiple layers of fiberglass-reinforced mica tape. All materials used, including the vacuum pressure impregnation (VPI) resin, exceed thermal class F (155°C) requirements. After insertion into the corresponding slots and prior to VPI, the coils are held firmly in place by slot wedges and surge ropes at the coil heads.

For 30 years, ABB has been using the Micadur® Compact Industry (MCI) insulation system based on the VPI method.

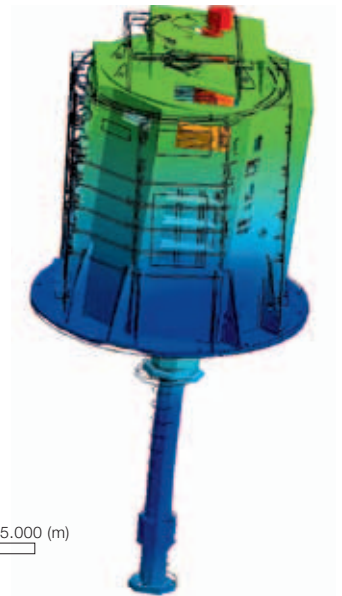
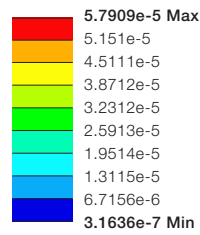
MCI windings require very little maintenance; usually it is sufficient to ensure that the ingress of moisture or dirt does not compromise the cooling ability of the winding when the motor is not operating.

The rotor is also made to match the insulation class of the stator, and it is normally equipped with a separate rotor center that is shrink-fitted onto the shaft. Wound rotor poles are normally manufactured from 2 mm laminated steel sheets, pressed together by steel bars that are welded to the end plates. The pole structure is either integrated or the poles are secured to the shaft or rotor center with bolts from above or below, or they are secured by dovetails. The poles are often fitted with a damper winding designed to suit the application.

The cooling for this type of pumping application is adapted to accommodate the fact that the motors are typically placed in an enclosed machine room, from which excess heat must be expelled. This expulsion is achieved by circulating cooling air through the active parts of the motor and then through air-to-water heat exchangers. This configuration passes almost no heat to the immediate motor environment, which helps create good operating conditions in the machine room. In terms of protection, the motors are rated IP 54 or IP 55, depending on the operating conditions.



0.000 1.500 3.000 4.500 6.000 (m)



0.000 1.250 2.500 3.750 5.000 (m)

5a The lowest undamped lateral frequencies are 8.6 Hz and 10 Hz, and the damped maximum responses are 9.6 Hz and 11.4 Hz. The shaft's lateral frequencies are close to operation speed, so the design is not acceptable. A stiffer rotor shaft and shorter shaft assembly should be considered.

5b The lowest undamped lateral frequencies are 13.3 Hz and 13.4 Hz, and the damped maximum responses are 14.8 Hz and 15.3 Hz. This gives adequate margin – about 20 percent – to runaway speed of 12.5 Hz (750 rpm).

An efficient solution

Taking into account the costs related to energy consumption and maintenance, as well as the initial investment, syn-

ABB is a major worldwide supplier of large synchronous motors. Backed by the resources of ABB's global organization, the company provides reliable and efficient service in process industries, the marine and offshore sectors, utilities, and a number of special applications. And the future for synchronous motors is promising, as ABB foresees an increasing number of lift irrigation projects in other areas with inconveniently located water.

Water distribution can be provided at pumping capacities of close to 700 m³/s to large areas involving distances of up to 300 km, and 60 m altitude differences.

chronous motors in vertical pump applications are a cost-efficient and reliable solution. The motors have low losses, resulting in high efficiency – and the network power factor can be compensated for by adjusting the motor's power factor during operation.

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Reference

- [1] The 3rd United Nations World Water Development Report: Water in a Changing World (WWDR-3) 2009.