The drive to win

ABB's direct torque control (DTC) technology is assisting with the world's largest roof and video display

BRAD COBO, KEN GRABER – As the saying goes, everything is bigger in Texas. The new home of the Dallas Cowboys – the US state of Texas' National Football League team – is certainly no exception. At a cost of almost $1.3 billion, this enormous structure encompasses over 3 million square feet, and seats up to 100,000 fans. Even though the first football playing season ended not so long ago, the stadium already holds some significant world records – such as the largest enclosed NFL stadium, longest single-span roof structure and largest high-definition video display. While football might be what this icon is best known for, the engineering that went into designing the structure is no less impressive. From the mechanization of the retractable roof, to the 600 ton video-board hoist system, ABB drives have played a major role.

The retractable roof is comprised of two moveable panels – each weighing over 750 metric tons.

With industry-leading features such as direct torque control and easily configurable master/follower operation built in to the motor drives for the massive sports arena, the choice for drives was clear. This stadium, utilizing ABB and a host of other technologies, has raised the bar on "moving architecture" for facilities that are used by millions of people.

Moving architecture

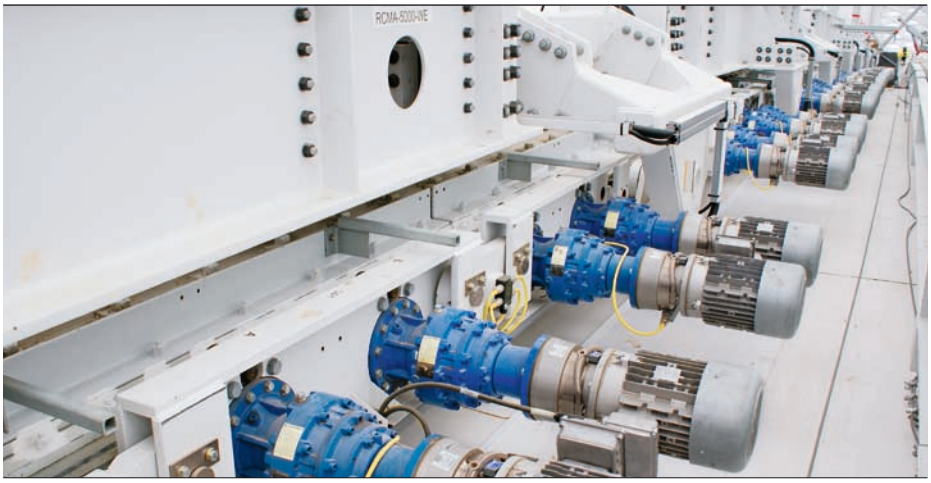
Building on a legacy that started 50 years ago, the Dallas Cowboys have gained worldwide recognition by winning five Super Bowls, eight NFC (National Football Conference) crowns and 19 division titles. Along the way, their home always has been as impressive as their record. The original home of the Cowboys, Texas Stadium, was widely known for the hole in its roof – a curious feature at the time. The open roof is one element that was carried over into the new stadium for practical reasons: The retractable roof and moveable end-zone glass doors allow ample sunlight and natural ventilation to flow through the stadium. This type of open design gives fans the sense of being outside, in the elements, where the game of football began. If Mother Nature should become too much to bear, as the weather frequently can be during hot Texas summers, the roof and doors can be closed in a matter of minutes. It is this kind of flexibility that makes the new stadium a true multipurpose venue. And with the football season lasting only six months each year, a host of other events are held in the off-season to maintain the venue's profitability.

To retract the roof, ABB's DTC algorithm calculates the current state of the motor 40,000 times per second and determines the best IGBT switching pattern to produce the needed torque.

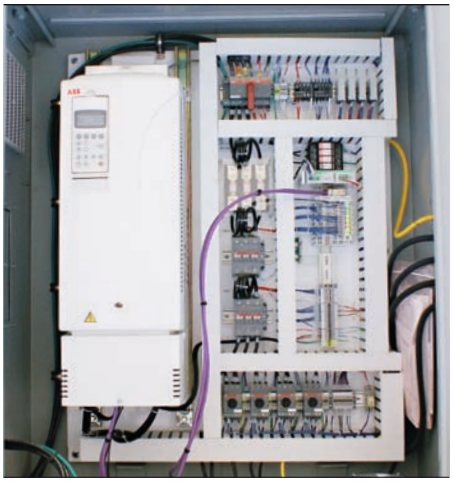
Retractable roof

The retractable roof is comprised of two moveable panels – each weighing over 750 metric tons. Supporting that enormous load, a full 3.5 percent of the entire roof weight, are two box trusses that span the length of the stadium – over 370 m. Sitting on top of each truss is a steel rail similar to that used by train cars. The panels roll freely along this rail, but are anchored in place by a gear rail, or rack and pinion system. This is a critical component that allows a team of 128 7.5HP motors, with planetary gear reducers, to pull the panels up the inclined roof. The slope of the incline varies, up to 24 degrees when the panels are fully open. Multiple gear motors were chosen

1 128 7.5HP gear motors drive the retractable roof panels. Photo © Uni-Systems



2 ACS800-U11 line-regenerative drive. Photo © Uni-Systems



The Profibus network that connects each ACS800 drive to the PLC allows control and monitoring, as well as a safety feature called “torque proving.”

for the design, in order to provide redundancy and manage the safety risk created by the steep travel path. The multiple motor brakes and gear teeth engaged with the gear rack prevents the failure of any single component from allowing the roof panels quite literally to roll off the roof and fall into the parking lots. This redundant design also allows the retractable roof to be operated with up to five of the 32 motors offline in each quadrant ➔ 1.

Optimal torque at zero speed

The steep incline creates one additional problem, too. When the panels are fully open and a command is given to close, the motors must start under an enormous load. This high starting torque demand normally requires the high-performance motor control provided by a closed-loop vector drive. This approach, however, was not advisable, due to the high cost and complexity associated with so many motor encoders. Instead, the engineers at Uni-Systems [1] took advantage of ABB’s direct torque control (DTC), which allows an almost identical level of performance without the headache of encoders. Using a 100 MHz digital signal processor, the DTC algorithm calculates the current state of the motor 40,000 times per second and determines the best IGBT [2] switching pattern to produce the needed torque. This feature is unique to ABB and is one of the main reasons these drives were chosen over those from competing vendors.

The ACS800 drives also are line-regenerative drives ➔ 2. This feature allows the drive to decelerate the motors without the use of a brake resistor. As the panels move from an almost level and fully closed position to a fully open position on a downward slope, they cross a point where the motors transition from motoring to braking. It is during this braking phase that the drives are called upon to slow the motors and keep the opening speed under control. This braking technique is accomplished by converting the kinetic energy of motion to electrical energy inside the drive – a process called dynamic braking. Normally the drive dissipates this excess energy as heat, using a brake resistor in much the same way a car braking while headed downhill causes the brakes to get hot. This heat, or thermal energy, is essentially wasted. A line-regenerative drive is an alternative solution that, instead, sends this energy back to the utility. While the amount of energy recovered is small, about $ 14 worth per opening cycle, the benefits of not having to install brake resistors were significant, and justified the additional cost of line-regenerative drives.

Teamwork

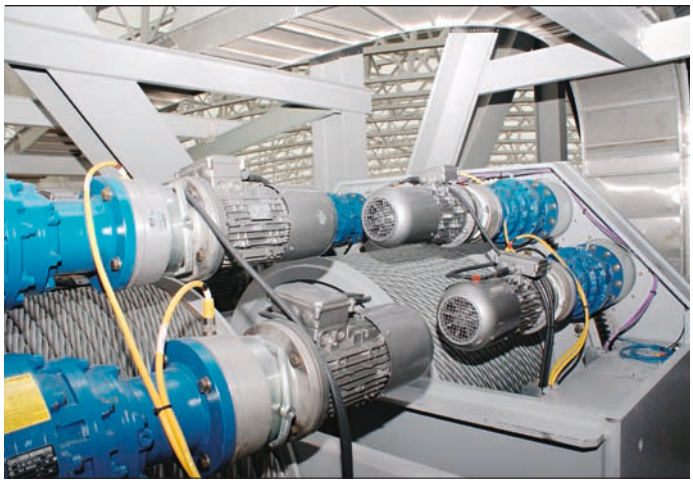
Coordinating the motion of 128 gear motors to ensure they all work together is no small feat, but one that the ACS800 drives accomplish fairly easily through their built-in load-sharing feature. A total of 32 drives, divided into four groups of eight, are used to drive the 128 gear motors (four motors per drive). Each group of eight drives has one speed-controlled “master” and seven torque-controlled “followers.” This so-called master/follower network allows these individual motors

Footnotes

1 See www.uni-systems.com
2 IGBT: insulated-gate bipolar transistor

3 600 ton high-definition video display.
Photo © Blake Marvin / HKS, Inc.

4 Video board hoist drums.
Photo © Uni-Systems



to work together as a team. The master drive runs at a speed given by the PLC (programmable logic controller) over Profibus and, using the DTC algorithm, calculates the actual torque needed to maintain this speed — and then sends this value over a fiber-optic link to the follower drives as a torque reference. The follower drives run at whatever speed is necessary (subject to a speed window) to achieve this torque value. This type of arrangement ensures that all of the motors will share the load equally. And with a master/follower update time of only 2 ms, the system responds to changes in load very quickly, ensuring that the roof panels stay well away from those parking lots.

While the Profibus network that connects each drive to the PLC allows both control and monitoring, it also can be used to implement one of many safety features critical to the retractable roof system. One such feature is called "torque proving," which makes sure that each motor is online and generating torque before allowing the brakes to be released. For example, whenever a roof panel is moved, the PLC will begin by sending all master drives a run command with a very slow speed set point. Since the brakes have not yet been released, this causes the drives to generate torque. Each drive reports its actual torque back to the PLC, where it is compared with a minimum value. Once the PLC sees that all drives are generating at least this amount of torque, it will give the final command to release the brakes. At that moment, the drives will assume control over the panel movement and begin accelerating. This torque-proving feature is a critical safeguard, but only one of several used on the roof system.

Hoisting a $40 million view

Perhaps the most prominent feature of the stadium, the video board, also is the largest of its kind in the world ➔ 3. Manufactured by Mitsubishi Electric Diamond Vision™, the two 22 m by 49 m (72 feet by 160 feet) displays span from one 20-yard line through to the other. Each is a true high-definition display, capable of a 1920 × 1080 resolution in a 16:9 format. On the ends are two smaller displays, measuring 8 m (27 feet) high by 15 m (48 feet) wide. The net impact achieved via the 30 million individual LEDs pales only in comparison to its price tag: $ 40 million – more than the entire cost of the first Cowboys stadium.

While the video board initially was suspended from the roof at a fixed height of 27 m (90 feet), it soon became apparent that some method of raising and lowering it was needed. An upcoming concert by the internationally famous rock band U2 required that the board be raised another 3 m (10 feet), to accommodate their stage equipment. The Cowboys once again turned to Uni-Systems to design and install a hoist system for the video board. By using a cable drum design borrowed from previous stadium projects, they were able to complete the job with minimal cost and in a very short amount of time. The plan involved distributing the weight of the 600 ton board over 16 hoist drums, using four motors per drum for redundancy and load sharing. Each end of the video board is supported by a group of eight hoist drums, giving the ability to move each side independently, should the board need to be leveled. When working together, they can raise or lower the board from 8 m (25 feet) to 35 m (115 feet) above the field. Four 5 HP motors per drum were used and fed from two ACS800 line-regenerative drives. With one master and seven followers, the load-sharing arrangement was identical to that used on the roof. The torque-proving safety feature also was implemented as one of several layers within the overall safety system.

An additional eight drums were installed, but not for lifting purposes. These so-called stay drums use cables anchored to the four corners of the video board ➔ 4. This prevents any undesired back-and-forth swaying motion due to air currents passing through the stadium when the roof and end-zone doors are open. The drums are torque controlled and main-

The weight of the 600 ton video display is distributed over 16 hoist drums, using four 5 HP motors per drum for redundancy and load sharing.

5 Moveable end-zone glass doors. Photo: Brad Cobo

Driven by ABB ACS350 drives, five of the seven 12 × 37 m glass panels part in the middle to create a 55 m wide opening in 6 minutes.

tain a fixed tension on the stay cables any time the main hoist is operating. A speed-windowing feature in the drive also was used to place a limit on the speed the drive can run, while trying to maintain its torque set point. This important setting prevents the drives from releasing and regathering cable too quickly, and thus provides a degree of damping, which serves to resist any abrupt video board movements. The tuning involved to make this a success was simplified via ABB DriveWindow software, which is used to monitor the movements of several drums at once. With so many motors and drives required to operate in harmony, this real-time monitoring ability was essential.

Moveable end-zone doors

At each end of the stadium, just beyond the end-zone goal posts, are moveable glass partitions, which are more similar to walls than doors → 5. Each wall is comprised of seven glass panels with each measuring 12 m (38 feet) wide by 37 m (120 feet) tall. Two outboard panels are fixed, and the remaining five are operable. Driven by ABB ACS350 drives, these panels part in the middle to create a 55 m (180 feet) wide opening in 6 minutes, blurring the distinction between what is indoors and out.

Postgame

ABB is proud to have been a part of the moving architecture that is the new Cowboys Stadium. From simple conveyors to the world's largest retractable roof, ABB drives are regarded for their ability to provide high-performance motor control, while being very easy to use. With industry-leading features such as direct torque control, and with the help of competent technical partners like Uni-Systems, the Cowboys Stadium project is an example of how technology and know-how can come together to solve extraordinary problems – a winning combination every time. While the company's products are not immediately visible in the stadium, they are the products that provide a seamless experience for users, and deliver peace of mind year-in and year-out to the property owners.

Title page photo by Brad Cobo.

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