“It’s basically a 140 ton stage production that goes up and down, tilts 100º and rotates 360º.”

— Ian Hall, Lead Engineer, Siemens Industry, Inc.

KÀ by Cirque du Soleil at the MGM Grand in Las Vegas is a mega-scale live theater experience. Yet, to an engineering audience, the motion control going on behind the scenes is a drama unto itself...

KÀ by Cirque du Soleil is a grand (as in MGM Grand) story about the classical relationships between young and old, good and evil, peace and war, electronics and hydraulics, motion and control. Not that the hydraulics were ever the villain in this story, or the electronics the hero. It’s just that the production’s original electro-hydraulic stagecraft had begun to show certain limitations and inefficiencies – among these, the potential for a single-point failure to bring the stage and an entire performance to a sudden stop.
“We needed system redundancy,” explains Mark Castle, Head of Automation at KÀ. “First, we could potentially lose shows because of a failed input card or a wire coming out of a terminal block causing an unplugged sensor. Secondly, we needed a closed-loop approach for the braking and releasing of the stage movements; and thirdly, we wanted an HMI system that would immediately tell us of any problems during a performance.”

Castle says Siemens motion control was brought onto the project to answer a central challenge: Transition the massive live theater production from a system based on pressure management, to a system based on openly dynamic positioning and control. As a first measure of response to this challenge, Siemens developed a mechatronic model to analyze the extensive range of requested and potential motion control performance. This model guided the development of the system and the delivery of the following attributes.

Failsafe redundancy

To address the problem of single point failures, the production’s new Siemens-designed motion control system relies on Siemens Simatic S7-400H safety controllers to govern paired, redundant master-and-slave Simotion C230 motion controllers. All encoder-based motion applications were designed to have as many as four encoder backups, each application controlled by a “voting” system that instantly detects and “votes out” a failed encoder to automatically bring the next encoder online.

According to Ian Hall, Siemens’ lead engineer on the three-year project, the automation of the stage required a level of redundancy the company often engineers into industrial motion control applications; but in the Las Vegas world of large-scale theater, motion control takes on dramatically different interpretations. One of these is the interplay between the performers and the stage.

“What made the project especially challenging was the complex hydraulics and the natural oscillation of the stage,” Hall recalls. “The motion of the stage has a very low natural frequency, so it is very easy to excite the stage and get it bouncing. So we needed to consider two variables from the outset – the mechanical build and the fundamental design. The stage is pulled up on four hydraulic cylinders. The cylinders are inverted, because you could not push the weight of the stage up without the rods bending. So, as the four cylinders pull the stage, you have these cylinders filling with oil until fully retracted 70 feet from the lower basement floor. As the stage rises, the motion reaches a low natural frequency of about 1.8 hertz. So we needed to control this. More specifically, we needed to control the hydraulic servo valves and the energy behind those servo valves that provide the hydraulic power. We needed to design a control system to regulate hydraulic energy, but the ultimate goal was to achieve a consistently high level of stage performance that was on par with the actors, making the whole production work smoothly.”

With the new motion control system in place, redundant backup is now instantaneous, as Mark Castle’s operations team witnessed not long after the new system went live.

“We had an encoder fail on us after we switched over in February,” Castle remembers. “The new Siemens controller voted out that encoder input and sent us a message advising that we had the problem, which we addressed the next morning. That encoder fault could have been a show-stopper. But with the encoder voting in place, it was quite a different feat.”
Closed-loop efficiency

Castle notes that the original five-year-old system controlling the stage was once state-of-the-art, so the inefficiencies of the system were accepted as idiosyncratic over time, including the practice of conducting a “swell-up routine” to initiate braking release for every one of the 40 crane moves that occur during a show.

“The prior routine required that we initiate a move to the controller,” Castle explains. “The controller would then send pressure to the valves, and then to the cylinders, and the cylinders would confirm that they saw the pressure; and then we would back the pressure off to a level that we knew would stabilize the crane; and when this happened we would release the brakes and start the move. So every move required this seven or eight second swell-up. And then, at the end of every move, we’d have the crane set its brakes and relieve its pressure back to the reservoir banks.”

Castle says, now with the new system in place, the mechanical brakes are released at the start of a production and are not applied again until the end of a production. The Siemens closed loop system is entirely automated to smoothly move and hold the stage, always synchronized with the choreography on stage. In view of the fact that the mechanical braking system had previously been activated 40 times a show, two shows nightly, five nights a week, significant costs have been eliminated in regard to brake maintenance, repair and replacement.

Castle observes that the stage also no longer “breathes” between moves. The floating motion of the stage, in addition to the seven-to-eight second delay related to every brake release, was also idiosyncratic of the system. As a result, a range of adaptive behaviors became standard operating procedure for the on-stage performers and all others involved in the production. Among these behaviors was the need to script the action for every scene based on the lag time between stage movements.
Real-time monitoring

Siemens application engineers, Kimberly Cornwell and Barry Hawley, recall that the project’s control and communication challenges were largely a matter of programming and testing over many months. Both downplay the drama of reconfiguring the Simotion C230 motion controllers for redundancy – not a standard function of the original product design. The robust technology platform within the product enabled the team to innovate on-site, to successfully integrate redundant motion control with the Siemens WinCC HMI monitoring stations throughout the theater complex. This high level of redundancy extended to bus level communications as well, with the integration of both Profibus and Ethernet connectivity.

“They can now manage a lot of data,” says Cornwell. “The redundancy in the communications was complex, with over a thousand possible ways to flow data back and forth from one network to another, from the main power controllers to the backup main controller and between the redundant motion controllers. We programmed for interlocking, keeping pumps running, turning pumps on so we have pressure, opening and closing valves, and providing for different shutdown scenarios."

While dozens of HMI “client” stations were deployed to an hydraulic control room, Barry Hawley says that the new system extends to a production room in back of the theater and to stations elsewhere, bringing extremely flexible and scalable HMI to the entire complex.

“Multiple servers and client stations can be located anywhere in the facility,” Hawley says. “Also, the operators can segment out these screens to at least a couple hundred screens. So now they can trend all of the cylinder pressures, which they could not do before, or trend positions over pressure. The Siemens WinCC monitoring stations also interface with a Stage Technologies Nomad console.”
The final act — repeatable performance

At the end of the project, Cirque du Soleil conducted a validation process to assure that all expectations of the new motion control system had been met. Technical Director, Erik Walstad, who coordinates across all of the artistic and automation activities, says that the validation process went quickly and smoothly, with one interesting outcome.

“It was fascinating to see how the Siemens engineering team reacted to the feedback from everyone,” Walstad recalls. “Unlike an industrial setting, we were evaluating “production” in the context of live entertainment. The Siemens team was hearing what the artists had to say, what the technicians had to say, seeing the rehearsals and collaboratively refining everything.”

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— Mark Castle, Head of Automation at KÀ

Walstad points to greater performance as the final achievement of everyone involved.

“The response from the performers was that the new system was very smooth and they liked the feel,” Walstad reports. “Visually, having watched the cues thousands of times, we could see that the stage movement was smoother and more elegant; and we now had the added benefits of a system that will enable us to tune the moves, to make changes in the cues, and we didn’t have that flexibility before.”

Mark Castle, whose goal from the beginning of the project was to improve the automation by way of redundancy, cost reduction and process monitoring, agrees that the overall outcome was greater performance.

“We have a lot of moving stages and moving scenery here,” Castle says. “Our automation department takes pride in the role we play in every performance. What we strive for is to have our machinery do the same thing over-and-over again with repeatable precision, making exactly the same moves twice a night, five nights a week. That’s why we went with Siemens. Their hardware was configurable to the performance we wanted and their application engineers made that performance happen.”