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IDEAS IN MOTION CONTROL FROM MOOG INDUSTRIAL

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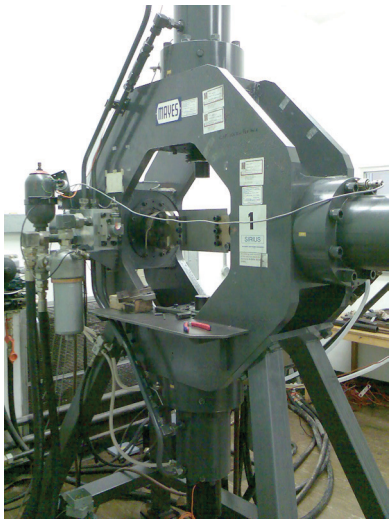
MOOG

ADVANCED TEST CONTROLLERS REDUCE RISK IN COMPOSITE MATERIAL TESTING

By Paul Garner, Senior Sales & Applications Engineer

Material testing is a sophisticated motion control application. The high forces involved and the need to protect the test specimens are just two of the common concerns of virtually all test and structural engineers. And when it comes to testing composite materials, the risks become even greater.

At the University of Sheffield in the United Kingdom, engineers are focused on an application called bi-axial material testing using the Moog Portable Test Controller to create sophisticated control loops that reproduce stresses and strains in the test specimen. The tests are complicated and time-consuming, as the specimen has to be held in the absolute centre of the machine, so that the specimen loading is perfectly symmetrical to maintain the correct stress/strain distribution. Thus the choice of test controller is critical particularly when the equipment is used in a retrofit.



Mayes Bi-Axial Material Testing Machine

Moog has extensive experience in developing and applying servo controllers that are designed for specific applications such as testing materials, components and structures. The testing of materials can be complex for a number of reasons:

1. Materials and components have complex loading patterns in the real world that must be approximated when testing.

2. New materials have unique behaviors in service that need to be better understood before these materials can be incorporate in new applications.

3. The move towards lighter, cheaper solutions means that mechanical testing has become more important in the development of next generation applications.

This article discusses bi-axial material testing where Moog's Portable Test Controller was used as part of a retrofit by the University of Sheffield. The advanced features in the Moog Portable Test Controller allowed engineers to easily and expertly create complex control loops required in order to reproduce the stresses and strains in the test specimen.

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Background

The Moog facility in Solihull, UK that focuses on Test and Simulation has worked with the University of Sheffield on several upgrades to their testing systems. The latest upgrade to a Mayes Bi-Axial test machine consisted of a complete overhaul of the machine and a new control system. The Bi-Axial machine uses a traditional cruciform fixture for testing various materials; such as steel, aluminium and composites. These materials are used in the nuclear industry, aircraft construction and civil engineering.

The test machine upgrade incorporated a four channel Moog Portable Test Controller. The complex control loops required for this customers' test were configured using the advanced features and tools provided by the Moog system. This is the kind of flexibility and support which makes the Moog Portable Test Controller stand out from the competition, due to the reduced time required to configure the controller for different tasks.

Why Use Bi-Axial Testing?

As a result of extensive conventional testing, the behaviour of normal materials under multi-axial loads is well understood. However, the failure of new materials and some composites under multi-axial loading has been poorly understood, until quite recently. As industry uses more and more composites for critical applications ranging from aerospace to Formula One cars, it is necessary to understand the behaviour of these materials in service. In the real world materials normally experience loading in more than one direction at the same time, that is, they are bi-axial loaded. The work of the University of Sheffield and other organizations with the Mayes Bi-Axial Test Machine has helped to create of a large body test data backed by a theoretical understanding of the failure criteria that apply that can help increase the adoption rate of new composites in key industries.

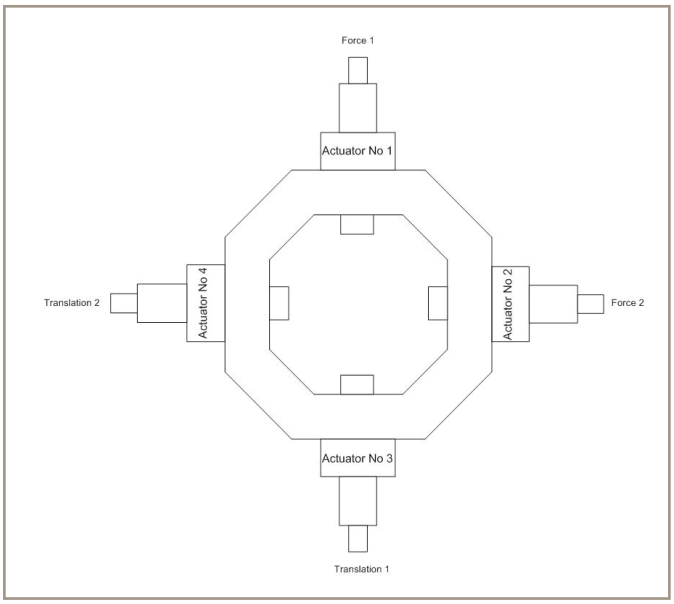
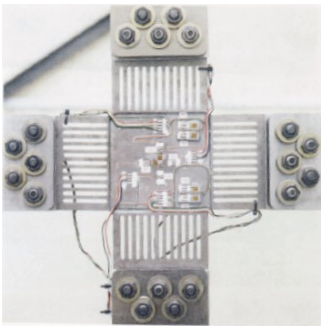


Figure 1: Bi-Axial Machine Configuration

What are the Challenges of Bi-Axial Testing?

The basic bi-axial test is called a cruciform coupon test and it can be used to measure basic material properties and study the strength of a specimen that includes specific features including open holes, loaded fasteners and impact damage sites. It is called cruciform as the test machine has a cross shaped plate as the test specimen.



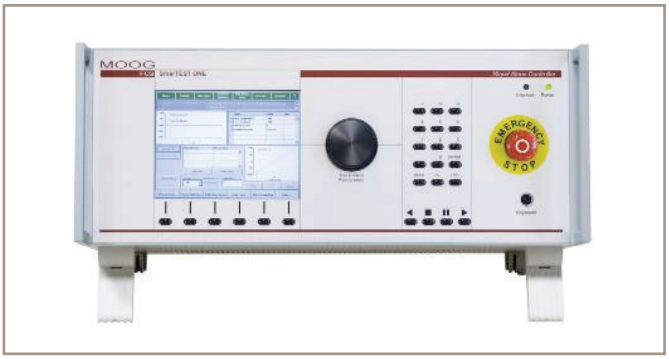
Specimen for Bi-axial Testing

Due to the inherently anisotropic (the property of being directionally dependent, as opposed to isotropy, which implies homogeneity in all directions) structure of some composite materials, their strength under normal bi-axial loading is dependent on how the loads are aligned with the fibre directions. If the applied loads are well aligned with the fibre direction then the specimen strength may exceed the value that may be obtained from simple uni-axial tests, making the bi-axial more representative of real world situations.

Bi-axial testing is notoriously complex because the specimen has to be held in the absolute centre of the machine, so that the specimen loading is perfectly symmetrical to maintain the correct stress/strain distribution. This means that the system needs to be controlled in both displacement and force, to ensure that the specimen is held perfectly centrally.

Using the Moog Portable Test Controller

The Moog Portable Test Controller incorporates a unique control loop technology to handle tests of up to 4 servo control channels. It can be used as a stand-alone controller or in conjunction with a PC. It was the ideal choice for the University of Sheffield due to its flexibility, high-performance handling of complex testing formulas and unique control loop technology for force, displacement and acceleration control.



Moog Portable Test Controller

The Moog Portable Test Controller is used to control both displacement and force in bi-axial testing through the use of User Defined Channels and Pseudo Channels. Pseudo Channels are calculation channels which can be derived from transducer feedback and have mathematical functions applied to them to create control loop inputs, such as taking a force feedback and multiplying it by the distance of a loading arm to create a torque input.

The Pseudo or translation channels are used to keep the specimen perfectly centralized within the test machine frame. Additionally the user channels are used to apply the dynamic load to the specimen in perfect symmetry. Generally the dynamic force signals can be applied to both axes simultaneously.

Most importantly, the portable test controller is configured to allow easy switching between bi-axial control and conventional uni-axial control, which greatly reduces set-up and testing time.

Conclusion

Moog's upgrade of the Mayes Bi-Axial Testing system that was completed last year also included the installation and calibration of the machine as well as the training of the University of Sheffield engineering staff. The incorporation of this application in the bi-axial machine brings the number of portable test controllers in operation to seven.

Mike Rennison Experimental Officer, Department of Mechanical Engineering said: "We chose the Moog Portable Test Controller because it is much more versatile and flexible than others on the market. It has also enabled us to progressively upgrade all our equipment to meet new challenges brought to us by our customers. Our experience with the Portable Test Controller has been highly successful and we are ordering additional equipment from Moog".

Appendix 1: Overview Moog Portable Test Controller:

The Portable Test Controller was designed based on input from customers of leading test laboratories, making it the ideal choice for simple, efficient operation in an array of testing applications. Some advantages of the Moog Portable Test Controller include unsurpassed flexibility for user-friendly, cost-effective operation in a range of testing applications, advanced safety checks built-in to ensure protection of the test article and test data and high-performance operation for both basic and complex applications. With more than 5,000 control channels installed and used daily in test labs around the world, it is a proven choice for test professionals.

Key Features

- Advanced control that is expandable up to four channels
- A portable and stand-alone test controller
- Precision control loops (e.g. force, displacement and acceleration) developed by Moog for faster and more efficient testing and reduced set-up time
- Simple operation that allows you to add just the functionality you need for cost-effective integration
- Built-in data-acquisition, integrated oscilloscope display and data storage capability on a local hard-disk, make testing easier and saving both lab space and running costs
- Compatible with any hydraulic, electric or pneumatic actuators adds to
- Easily works with all connectors for cost-effective, immediate integration
- Pseudo channel capability allowing the user to create online calculated channels using formulas and other inputs, offering greater flexibility and cost savings for the lab
- Matrix control provides measurement and control flexibility for more efficient testing
- Dual mode, bumpless switching (e.g. Force, Position) to take advantage of the full range of application
- Online adaptive control for amplitude and phase saves set-up time
- Calibration and tuning wizard to facilitate and accelerate setup.
- Expandable to 32 channels test controller version, using multiple units.

Author

Paul Garner has been with Moog since the acquisition of FCS in 2005 in the capacity of Senior Sales and Applications Engineer. Prior to joining FCS he has worked extensively in the test industry for MTS and others. Paul studied Mechanical Engineering at Wolverhampton Polytechnic and computer technology at the Open University.

BENEATH BEIJING - SUBWAY TRAIN DRIVING SIMULATORS MAKE TRAINING MORE REALISTIC

By Bai Yuan, Sales Manager China Test and Simulation

From sophisticated high-payload flight simulators to leading-edge racing simulators for Formula One teams, Moog 6 Degrees-of-Freedom (6-DOF) motion bases are the tools of choice when effective, realistic training is essential. Recently, Moog's 6-DOF simulation technology played a key role in a different kind of training environment: teaching Beijing's newest subway drivers how to handle the city's trains.

As the leading global designer and manufacturer of 6 Degrees-of-Freedom (6 DOF) motion base systems, Moog supplies flight simulator systems featuring high performance, fidelity and reliability to flight training centers and military bases in numerous countries. Moog's 6 DOF motion bases have become the tool of choice for major OEMs who seek to achieve the highest performance and training effectiveness in whole car development and simulated driving training.

The Tongji University Research Institute of Computer Simulation and Control (Tongji University) is a major rail driving simulator integrator in China. When appointed to integrate the latest subway train driving simulator for the oldest subway line in China – the Beijing Subway line 1, Tongji University adopted Moog's 6 DOF Motion Base system. This pioneering application of motion base to rail driving simulation also marks Moog's successful introduction of its motion system products into the China civil rail transit market, following past applications of its motion base systems in military flight driving simulators.

Business Challenges

The expanding rail transit network within China requires more and more trained drivers. Subway companies face a daunting challenge: How to put these drivers through pre-job safety driving training in the most effective way. Since the construction and operation of China's very first subway line in Beijing in the 1960s, train driving simulators have been used in driving training to perform simple simulations such as the simulation of a static cabin and the audio and visual environment of a train in motion. These applications were limited as they did not provide real dynamic simulation.

This project between Tongji University and Beijing Subway, the end user, involves the very first subway train driving simulator to incorporate a motion base system. Both parties had high expectations and laid down stringent project specifications concerning the floor space needed, technical requirements, simulation performance, power consumption, level of control and reliability of the motion base system.

The Solution

Moog supplied a 6 DOF motion base system including a hexapod base and a control cabinet (controller and control software) for integration into the simulator by Tongji University.

Moog's 6 DOF Motion Base system gives a driver true feel of the motion changes of a train in real-time due to the integration of some key technology:

- Controlling the lengthening and shortening of six actuator arms to simulate the motion of the cabin mounted on the motion base
- Varying acceleration and displacement outputs to simulate the speed, acceleration, deceleration, turning and road conditions of a train in motion

Moreover, the integrated control hardware and software enables both the acquisition of motion data from the motion base and ability to execute on-line changes of position instructions to the motion base. The motion base gives the true feeling of motion to a driver in the cabin who in turn controls the cab motion, forming a human-in-the loop (H2IL) driving training simulation, one of the most sophisticated kinds of simulation available today.

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Another strength of Moog's 6 DOF motion system is its all-electric technology. As a long time manufacturer of hydraulic motion bases, Moog has also become the leader in designing the latest electric versions that meet even the most stringent performance requirements. Compared to conventional hydraulic motion systems, the Moog electric system is:

- Safer on-site as there is no high pressure hydraulic path
- Energy efficient as it consumes 70% to 80% less power
- More reliable as it has less system parts
- Cost-effective to maintain and operate

6 DOF Motion Base used in Training Simulators

The unique design of Moog's hexapod-based system takes up half the space of conventional hydraulic motion bases, saving on valuable simulated driving lab space and reducing overall facilities costs. Moog's proprietary motion control software is recognized in the industry and market as the best-in-class in terms of smooth performance and realistic feel of motion.

Throughout the simulation integration, Moog put in place a dedicated Euro-China technical team, which helped Tongji University install and operate the motion base system in the early project phase. Moog software engineers also performed software testing, user training and technical support at the end user site in the later phase.

"This is the very first time we are undertaking such a complex project, which also happens to be a top-end train simulator project. To ensure success, we demand very high fidelity of the motion base system. It must be capable of effecting motion accurately and offer flexibly to give drivers the most realistic driving feel so as to maximize training effectiveness," said Mr. Xitang Tan, project leader of Tongji University. "Besides high fidelity, Moog's motion base system also has outstanding power consumption and operating noise characteristics."

"The customer selected us because of holistic considerations of our product reliability, technical maturity, performance and other factors," Tom Pierce, Moog summed up the competitive advantage of Moog's motion bases.

The Result

"The simulated train motion feels good. It's very realistic and the car is quiet" – this acclaim from a veteran driver certainly puts a smile on the face of the Moog team. The Moog technical team, together with the Tongji University as the integrator and Beijing Subway as the end user, completed the final simulation drive model and parameter testing after two years. The train driving simulator is now officially used in pre-job training of drivers on the Beijing Subway line 1.

The Next Step

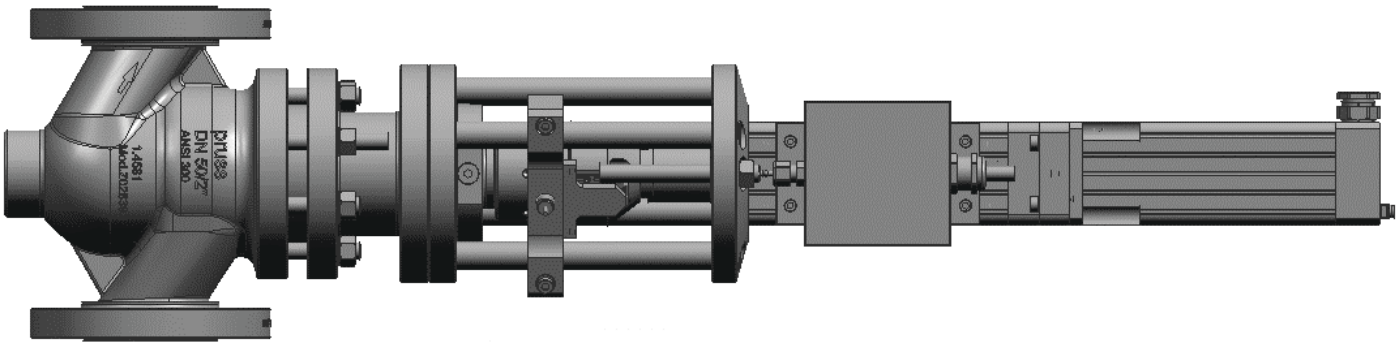
"The success of this project opens up a new frontier for us to clinch new orders and grow our partnership with Moog," declared Mr. Xitang Tan, Project leader of Tongji University. Moog's 6 DOF motion base has captured 85% to 90% of the international simulation market, including the aerospace, automobile and rail car sectors. The Beijing Subway project is Moog's first sale of driving simulation motion base for rail transit within China. Building on the success of this project, we are now actively discussing with some other integrators on partnerships to grow the rail transit driving simulation market in China.

Author

Bai Yuan is responsible for Sales in the Test and Simulation market, based in Beijing, China. He has 8 years experience in this marketplace including 5 years with Moog. He has a Bachelor of Engineering from Beijing University of Aeronautics and Astronautics.

MAKING THE SWITCH: EMPLOYING ELECTRIC ACTUATION FOR HIGHER TURBINE PRODUCTIVITY

By Fabian Erbe, Engineering Manager Services Europe and Benjamin Wehle, Design Engineer for Applications of Electromechanical Systems



Today's gas and steam turbine manufacturers continually seek any performance edge they can find. So when one German manufacturer needed a better way to maximize productivity and minimize costly downtime, Moog engineers knew they could help. Tapping into its extensive experience in electric actuation, the Moog team designed and introduced a unique integrated package that was tailored to the customer's specialized technical requirements — and offered an array of technological advantages as well.

Advantages of Electric Servo Drive Technology for Turbine Motion Control

Some features of the integrated solution included updating to state-of-the-art technology that offered the customer many advantages over conventional hydraulic designs:

- The usage of a digital controller with integrated fieldbus and self diagnostics was able to provide a much more reliable solution than previously achieved

- A warning device that alerts an operator prior to a malfunction was implemented that helped reduce downtime due to the control of positioning errors, current limits, and environmental influences (e.g., temperature)

- The automatic programming feature of the Moog Motion Controller made maintenance easier, because all changes in parameters (e.g., change of a drive) can be easily handled

- Eliminating hydraulics greatly reduced infrastructure, energy and operating costs, thereby reducing the overall total cost of ownership. For example, in standby mode the energy consumption of an electric system is nearly zero, saving energy costs over hydraulic in an industry with 24/7 operation

With a servo motor that meets requirements for global certifications for hazardous environments, Moog had the core technology and experience in-house to design specialized electric actuators. Combining this core product with our mechanical design capabilities, Moog was uniquely able to address a wide variety of customer demands of turbine control applications.

The Solution

In 2003, Moog designed for this customer a prototype solution for the control of an inlet guide vane of small gas turbines (5-12 MW). The first offering included a several Moog core building block products including a brushless servo motor, a linear servo actuator and a servo drive. It was tested on a Moog test rig as well as in a first application in the field. To this day no reliability issues have been reported and this first approach is still running effectively.

Founded on this successful experience, a long-term beneficial relationship both for the customer and Moog was established. Today Moog is able to deliver electric actuators for various turbine functions, in total up to five electric axes within one gas turbine. Each system is designed and certified with respect to the current directives for operation in an explosive environment.

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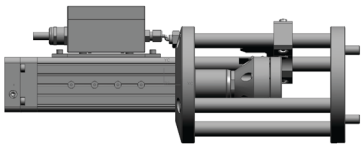
Software & Application Know-How

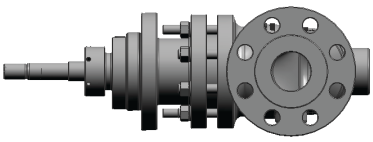
MSD Motion Controller

MSD Servo Drive

Servo Motor



Mechanical Arrangement



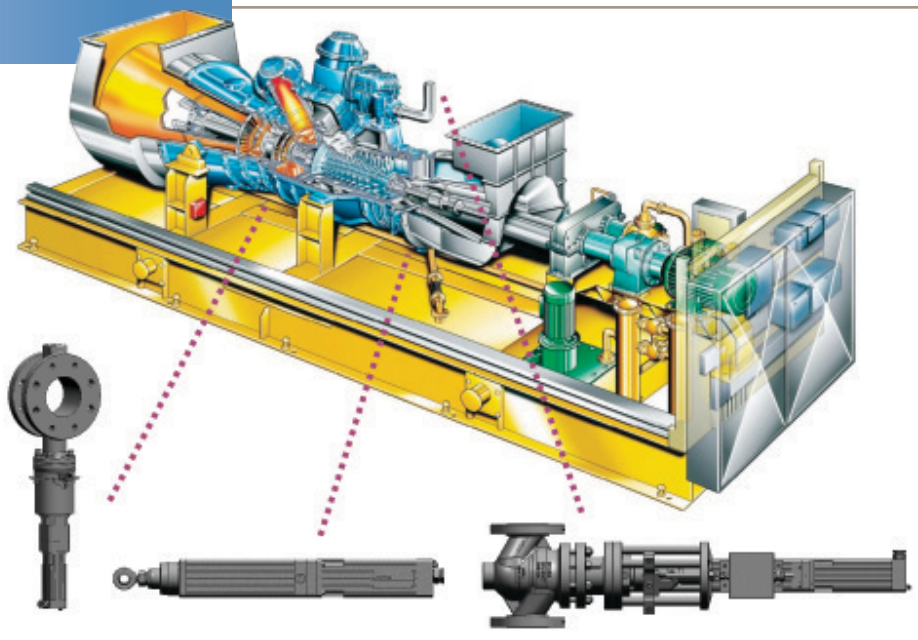
Valve

Scope of Supply

1. Software and application know how
2. Modular Multi-axis Programmable Motion Controller (MSD)
3. Modular Multi-axis Programmable Motion Controller Servo Drive (MSD)
4. Explosion-Proof Dynamic Brushless Servo Motor (ExD Series)
5. Customized mechanical adaptation of the design
6. Procurement of purchased parts, such as operating valves, to customer's specifications.
7. Support including endurance testing, commissioning, field-testing, maintenance and troubleshooting

Moog MSD Motion Controller and MSD Servo Drive

Machine Overview



Air Ratio Control Valve

Inlet Guide Vane Actuator

Fuel Gas Actuator

Section view on a typical gas turbine with highlights of the Moog actuators

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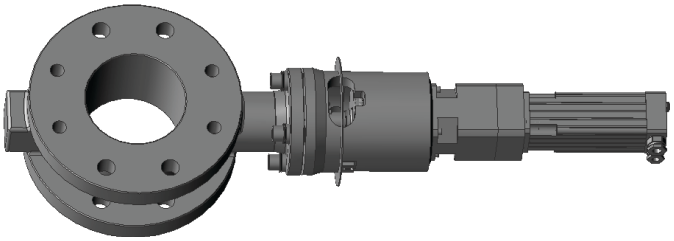
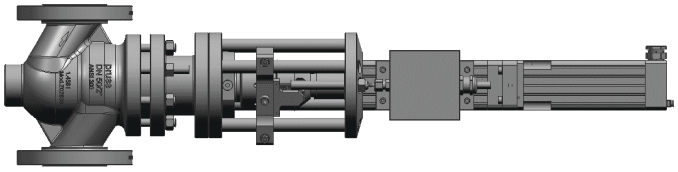
The Three Electric Axes in Detail

The Moog Fuel Metering System is used to meter air to a gas turbine and it provides some new benefits not available in the conventional design such as improved fault warning and remote monitoring for easier maintenance and diagnostic capabilities. The actuator is used to add air to the exhaust system of the turbine, to achieve better emission values. A highly dynamic servomotor, boosted by a gearbox, is used as the actuation for the system. The servo motor technology used, in conjunction with a rigid clamp coupling, achieves high levels of positioning and repeatable accuracy. An additional customer requirement was to prevent the valve from being closed completely. This is achieved by introducing an internal mechanical endstop.



Air Ratio Control Valve

The Moog Fuel Gas Actuator is used to control a linear-actuated fuel gas valve to define the exact flow of fuel gas into the turbine. A highly dynamic servo-motor is used to close the position loop of the adapted valve. The rotation of the motor is converted in conjunction with a precision ball-and-screw spindle actuator into a linear stroke motion. High levels of positioning and repeatable accuracy are achieved. As an additional safety feature the end-stops of the valve can be detected via two proximity switches.



Fuel Gas Actuator

The Moog Inlet Guide Vane Actuator is used to control the position of an inlet guide vane of a gas turbine. This is one of the most important functionalities of the gas turbine control elements, though the revolutions of the turbine are controlled with this actuator by turning the vanes in/out of the gas flow. The rotatable motion of a servomotor is converted into a linear motion by means of a ball screw.

Inlet Guide Vane (IGV) Actuator

Motion Control and Performance

One Moog Motion Controller controls up to five actuators for each turbine. The number of actuators used per machine is detected automatically. Communication to the superior PLC is realized by ProfibusDP and from the motion controller to the actuators via the integrated CANopen profile. In case of an actuator failure, no additional software is needed for parametrization as this realized with the built-in functionality of the MSC Servo Controller. The change of an actuator is detected automatically.

The commissioning is typically completed by the service department of the machine manufacturer without any support from Moog. The built-in commissioning interface is used to start up a new turbine.

Conclusion

The project involved electrical, mechanical and software engineers from the Moog facility in Böblingen, Germany working closely together with our customer to realize an innovative solution that met all requirements. The collaboration of a highly motivated project team ensured that Moog was able to deliver the high performance solution required for this challenging application. We are looking forward to further challenges in the power generation market.

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Authors

Fabian Erbe is the Engineering Manager Services Europe and he has been with Moog since 2000. He started as an application engineer in the systems group in Böblingen, Germany and worked as an Engineering Team Leader before assuming his new role in the Control Solutions organization. He studied Mechanical Engineering focusing on hydraulics at the Rheinsch Westfälische Technische Hochschule in Aachen, Germany.

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