Developments in nuclear valve actuation technology

Rotork has been involved in the supply of electric actuators for installation in nuclear power plants since the 1960s and since the 1970s the company has been a participant member of the sub-committees of the US Standards Committee responsible for drafting various IEEE 382 standards. This extensive experience of nuclear operations and nuclear qualifications is now contributing to the development of new products.

Fig 1 – Rotork is investing millions of pounds in the future of its nuclear valve actuation business

By Ivan Burnell, Rotork

Electric actuator developments

The company is introducing its latest electric valve actuator ranges for nuclear new-builds, tailored to suit the specific requirements of the internationally predominant nuclear island designs. The NE actuator range has been developed for use in EDF and AREVA (EPR) nuclear power stations. The ND DC (direct current) and NA AC (alternating current) actuator range has been developed for Westinghouse AP1000 Pressurised Water Reactor (PWR) nuclear power stations. These new designs are developments of the widely proven Rotork NA range that has been fully qualified to IEEE 382-1996/2006, comprising a simple single-stage worm drive in an oil bath gearbox, electric motor, torque and limit switches and a separate terminal compartment to which all electrical components are wired. The actuators are designed for a working life of sixty years.

Environmental sealing

The importance of effective environmental sealing cannot be over-emphasised, particularly in view of the length of working life. Electric actuators are normally inactive and even in conventional plant applications, where the valve is in regular use, most actuators are idle for over 99% of the time. In safety related systems the operating frequency and duration is even lower, dictated almost entirely by the periodic plant test programme. Therefore the ultimate reliability of electric actuators depends on how well the electrical components are protected from the external environment. Inside the nuclear containment, the ambient temperature and humidity will rise to extreme levels during a Design Basis Event (DBE), at which time the motorised valves must perform their safety related functions.

Rotork electric actuators utilise 'O' ring sealed sleeve jointed watertight and dust tight enclosures as standard, housing all internal components in a pressure-tight enclosure which excludes dirt and moisture and prevents temperature change induced breathing. For added security a separately 'O' ring sealed terminal compartment is used to ensure that internal electrical components are fully protected even during on-site wiring. This 'double-sealed' design protects the actuator even if leaking through conduit seals is experienced, as this can only

Fig 2 – Rotork Type NA (left) and NE electric valve actuators

affect the terminal compartment itself. Its effectiveness has been confirmed during nuclear environmental qualification testing, when conduit entry leakage was simulated during the loss of coolant accident test and the actuator continued to operate during and after the test.
In a further development, during site maintenance in nuclear installations it is advantageous to keep personnel exposure times to a minimum, so the demand for a quick disconnect system has increased. Rotork has therefore designed a combined power and control plug-and-socket assembly for use inside the containment area, conforming to the relevant IEC safety standards. 'O' ring sealing is included in the design to preserve the environmental protection when the plug components are disconnected, maintaining the 'double-sealed' design principle.

Torque limiting

Some nuclear actuators on safety-related valve duties are sized to ensure that they will operate under abnormal conditions such as voltage drop and high temperatures. This results in actuators being sized so that they are capable of producing up to 4 times the valve design thrusts at normal voltage and temperatures, which could cause valve damage. Additionally this often results in valves having to be designed to accept the increased loads, meaning that they are usually larger and heavier, which impacts piping design and adds cost to the plant. It is possible to protect the valve by fitting a brake. However, the prevention of damage by an electro-mechanical brake cannot be guaranteed as it remains energised with the motor. A mechanical torque limiter that is totally independent of environmental conditions, voltage and control system delays will guarantee protection under any circumstances.
Working with a number of customers and end users, Rotork has developed an innovative and entirely mechanical patented solution that will ensure that excess motor torque cannot be applied to the valve, even in the event of a torque switch failure, incorrect wiring, incorrect phase rotation or an electrical fault.
The Torque Limiting Brake is fitted internally between the actuator motor and gear case, without adding to the actuator's overall dimensions. It works on the axial movement of the worm shaft, which is always proportional to the torque produced at the actuator output. A brake disc fitted to the worm shaft comes into contact with brake pads in the open and close operating directions when the actuator output torque reaches an adjustable limit between 1.4 and 2 times the required valve torque.
The greater the torque applied by the motor, the greater the braking force and, because the brake is dealing with the lowest force at the input rather than the output end of the actuator, wear and tear on the brake is negligible through thousands of operations. Under normal torque switch control, the brake is never engaged. Independent adjustment of the open and close brake discs is easily achieved through access plugs on the actuator gear case and does not involve any dismantling. Swift and accurate adjustment can be further facilitated by means of a 'smart' valve stem and diagnostic plug fitted to the actuator.
Tests have shown that the adoption of the Torque Limiting Brake can eliminate the practise of over-sizing valve structures

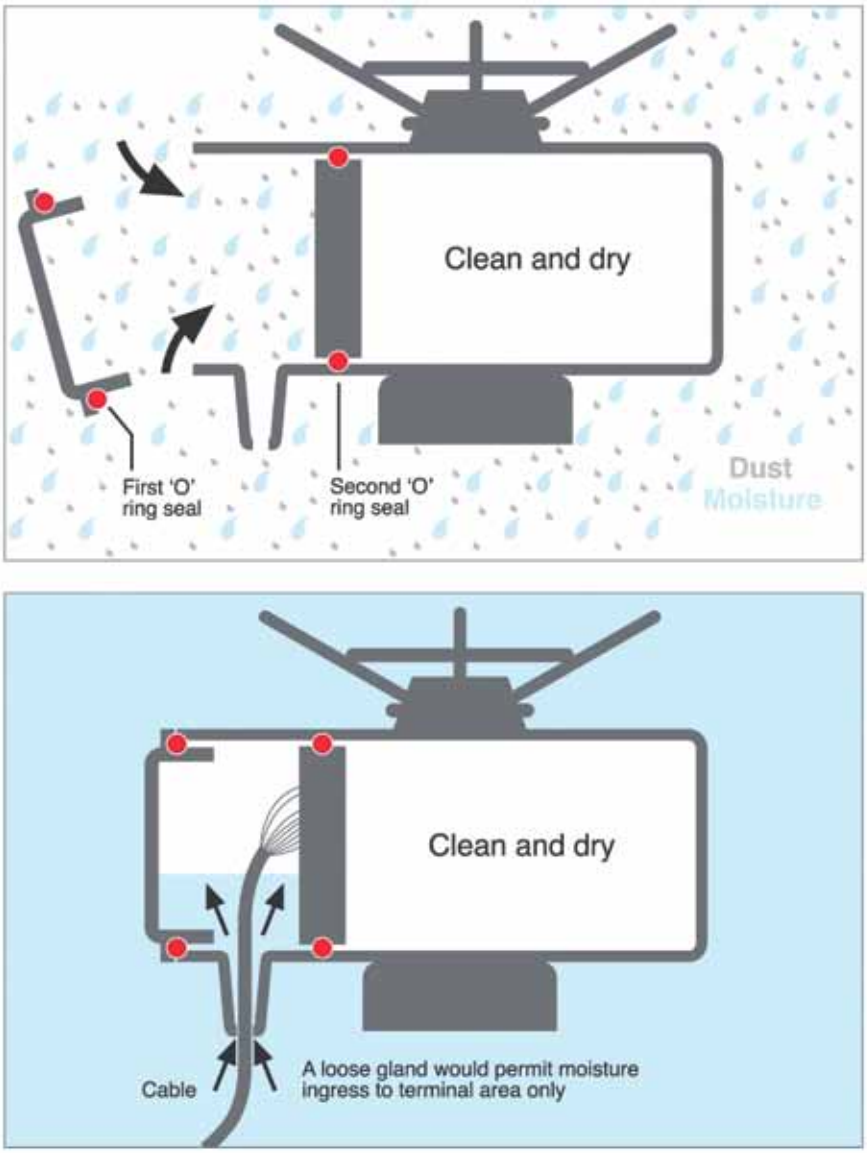

Fig 3 – Environmental protection provided by the Rotork 'Double Sealed' enclosure

Fig 4 – Plug and socket assembly for Rotork Type NE nuclear actuator.

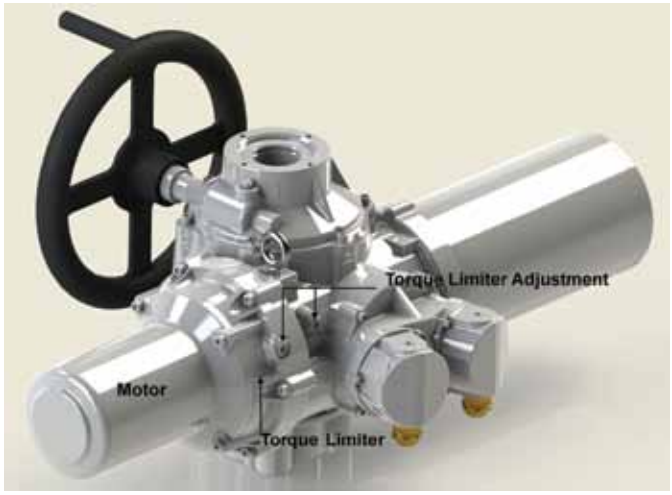

Fig 5 – Torque limiting brake configuration

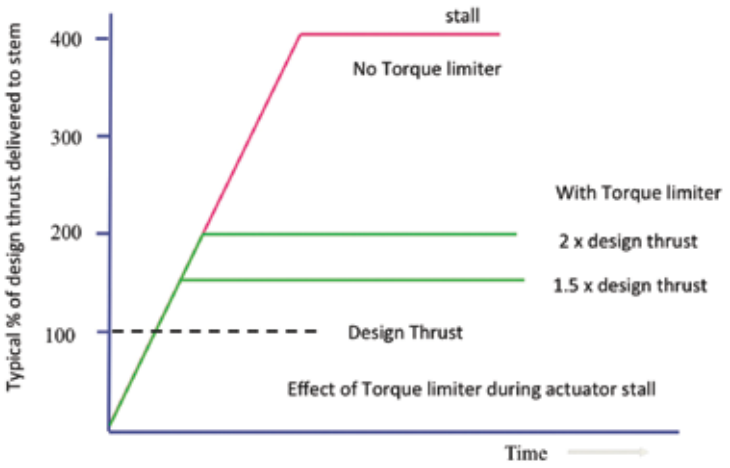

Fig 6 – Typical Torque Limiter Performance Curve

because of the risk of stall torque damage, particularly in high speed valve operating conditions.

The NE and ND actuator ranges are in the process of full qualification testing to IEEE 382-1996/2006 and to plant specific requirements. Rotork's established nuclear ranges of actuators have already achieved accreditation to IEEE 382-1996/2006 following the completion of testing in 2010, ensuring the continued support of existing installations and legacy product, and enabling controlled obsolescence management. A new generation of nuclear qualified gearboxes has also been designed, consisting of quarter-turn worm and multi-turn bevel and spur gear designs. Designed for manual or motorised operation, the new designs feature increased gear ratios, enabling the selection of economical and efficient gearbox and actuator combinations.

Fluid power actuators

Rotork has invested heavily in developing the actuators for main steam isolation valves (MSIV) and main feed water isolation valve (MFIV), replacing what was previously a customised solution for individual valve designs into a standardised range. The resulting NH range of gas charged hydraulic actuators retains all the features of the previous generation with a reduced number of components and reduced overall weight. A key feature is the ability to lock into position hydraulically, which prolongs the life of the equipment by eliminating extra cycles that would otherwise be needed to correct drift. MSIV actuators have recently been supplied to Hainan and Qinshan nuclear power plants in China and Mochovce in Slovakia

The development of the NH actuator has been comprehensively assisted by the engineering expertise available from Rotork Fluid Systems, the company's pneumatic and hydraulic actuation division. Rotork Fluid Systems has also successfully qualified a new range of quarter-turn pneumatic actuators to the requirements of IEEE382–1996/2006 for inside containment safety related duty and AP1000 PWR for the PV10, PV11 and PV41 packages. A range of linear actuators is qualified to the same levels. Continuing this work, a new range of linear pneumatic and hydraulic actuators for other locations and duties in nuclear power stations is also in an advanced stage of development.

About the Author

Mr Ivan Burnell works as Nuclear Engineering and Business Development Manager at Rotork Controls Ltd. He has over 30 years experience working in the nuclear power market with Rotork products. His current role is to ensure that Rotork has a complete offering of products from its electric, fluid power and gearbox divisions to meet the needs of the nuclear new build programme and interface with end users, valve makers and certifying/testing laboratories to ensure the correct standards and specifications are met.

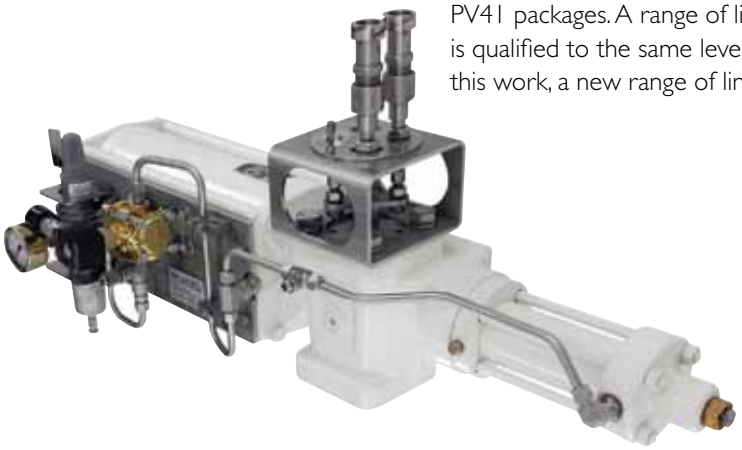

Fig 7 (left) Nuclear qualified quarter-turn pneumatic actuator; (right) MSIV actuator