REDUNDANCY FOR SUBSEA ELECTRICAL ACTUATOR CONTROL

Field of the invention

The invention relates but is not limited to subsea control systems. More specifically, the invention relates to subsea hydrocarbon production systems comprising several subsea Xmas trees with valves or other subsea equipment controlled by actuators.

Background of the invention and prior art.

Existing subsea actuators for Xmas tree or process control are generally hydraulically controlled. These are normally reliable, however, they can be slow in response, especially in deep water or with long subsea step-outs through long umbilicals.

The accepted next step is to move to electrically driven actuators which can be faster to control especially over very long step-out distances. Due to the difficult location of subsea actuators, system reliability is of prime importance as a failure of a key module or valve could stop production for a long period of time before a replacement part can be installed. Electrical actuators can have lower mean time between failures (MTBF) compared to hydraulic actuators, due to the larger number of components in the design. This is normally addressed by building in additional levels of system redundancy. More specifically, two electric actuator controllers are as a standard solution implemented for each subsea Xmas tree valve. This additional redundancy adds cost and increases the package envelope and number of electrical connectors. As a result, an installation using electrical actuators will be larger, more complex and more expensive than the equivalent hydraulic system. The additional redundancy will not be required on every actuator so the system will be carrying duplication of functionality that may never be required. In addition to this, the packaging of typically two electric actuators together on each valve or device to be controlled can make retrieving single or multiple failed electrical units a complex and time consuming task, increasing service time and cost and reducing production.
delivery. A demand exist for technology that is favourable compared to the prior art technology described above.

Background art or related art are described in the patent publications WO 201215113A1, GB 2364396A and WO 2011159405A1. None of said publications describes a centralized actuator controller module comprising a number of controllers larger than the number of actuators to be controlled simultaneously.

Summary of the invention
The invention provides a subsea system for production or processing, comprising several valves or other units controlled by electrical actuators, distinctive in that each valve or unit actuator is operatively connected for power and control to a centralized actuator controller module comprising a number of controllers larger than the number of actuators to be controlled simultaneously.

Preferably, the central actuator controller module comprises inverters for power and controllers providing control of actuator position all within a single module. For redundancy the number of inverters for power and controllers are larger than the number of actuators to control. Preferably each valve and unit contains one actuator with an electric motor operatively arranged, the electric motor is connected to an inverter which is connected to a controller which is connected to a supervisor controller, the actuator is connected to the centralized actuator controller module for feedback on position and other convenient operation parameters or/and algorithms are used to control position and operation parameters of the actuator including the actuator motor. Accordingly, the power and control electronics of the actuators are centralized in the actuator controller module, with or without feedback connections.

Compared to earlier solutions, the specific redundancy as found required can be built into the system at a reduced cost. By including a selected number of controllers and power inverters larger than the number of actuators, a higher level of redundancy can be provided, and several faults can be handled without stop of production. With the prior art solution, two faults could stop production.
Further, there is no longer a duplication of power and control electronics, of which most will never be used and therefore contribute little or nothing to the redundancy of the system. A further advantageous difference, providing further simplification and cost, operation and maintenance benefit, is that both power and control signals are routed directly to the controller module, contrary to the standard subsea solution of having power and control routed separately.

Preferably, the actuator controller module comprises a switcher device, such as a rotary or linear switch mechanism, for switchable connection between power inverters, controllers and actuators.

Preferably, the actuator controller module is arranged on a stab type plate, accessible and readily retrievable as a unit and individually with respect to power inverters and controllers. Preferably the module has controllers and inverters each replaceable individually with an ROV (Remotely operable Vehicle), with adapted size, weight and handle for ROV operation. Preferably the system comprises subsea mateable connectors, such as stab type connectors for handling and mating by an ROV.

The system of the invention preferably comprises an actuator controller module with \( N + 1 \) redundancy, more preferably \( N + n \) redundancy, where \( N \) is the number of actuators and \( n \) is larger than 1. Accordingly, 1 or more preferably \( n \) relates to the selected level of redundancy, relating to the additional number of controllers and power inverters over the number of actuators. Preferably each valve or other equipment controlled by an actuator has one single actuator arranged, however two actuators or more can be an option for enhanced redundancy.

In a preferable embodiment the system of the invention is a subsea petroleum production system comprising several Xmas trees with valves with actuators.
Some other system embodiments are subsea manifold systems, subsea separation systems and subsea processing systems or combinations thereof.

The invention addresses all the deficiencies of the standard electrical actuator by reducing package space for each actuator, reducing system cost while still providing a level of redundancy, reducing installation complexity and reducing system down-time when the module or units thereof are replaced. In addition, the invention will also allow a number of electrical actuators to be driven by a single controller / inverter if actuators are not required to run simultaneously.

Provision can be made in the system for future expansion needs or additional spare outputs while still costing less than dual redundancy on every actuator.

Figures

The invention is illustrated with 4 figures, of which:

Figure 1, 2 and 3 illustrate embodiments of a centralized actuator controller module of a system of the invention, and
Figure 4 illustrates a typical rotating electrical actuator and prior art valve,

Detailed description

Reference is made to Figure 1 illustrating a centralized actuator controller module 1, with basic switching arrangement, of a system of the invention. More specifically, three valve actuators are illustrated; the actuators are for example arranged to production Xmas tree valves, not illustrated. Contrary to prior art solutions, only one actuator with one electric motor is arranged for each valve, as shown in figure 4. Each of the valve actuators has in principle two types of connections to the actuator controller module, namely power connection of the motor phases, p1, p2, p3 respectively and signal connection comprising motor and actuator position feedback, f1, f2, f3,, respectively. The motor phases comprise typically 3 phases per motor. Note that the three individual motor phases are not shown for clarity. The motor and actuator position feedback may
be omitted for some embodiments, since position control can be provided alternatively or additionally by for example current or logic control algorithms.

The illustrated subsea controller module comprises a supervisor controller C, four motor controllers c1, c2, c3, c4 respectively and four inverters i1, i2, i3, i4 respectively. More specifically, the figure illustrates a subsea controller module (1) containing a supervisor controller (2): \((N+1)\) motor controllers (3); \((N+1)\) power Inverters (4); 3-phase, two way switching elements (5); and \((N)\) electrically actuated valves (6). The number of controllers and inverters is larger than the number of actuators, namely 4 compared to 3, thus providing \(N + 1\) redundancy. The subsea controller module also comprises a switching device (5, 7) controlled by the supervisor controller C, such as a rotary switcher, arranged to switch controllers and inverters interchangeably to actuators. Each switching element may be configured as three pole (or phase) two throw (3P2T) as shown in figure 1, allowing for \(N+1\) controller and inverter redundancy. Alternatively each switching element may be configured as 3PxT as shown in figure 2 and figure 3, where x may be chosen to provide the desired level of redundancy.

Figure 2 illustrates: Subsea Controller Module (1) containing a supervisor controller (2): \((N+n)\) Motor controllers (3); \((N+n)\) Power Inverters (4); 3-phase, multi-way switching elements (7); and \((N)\) electrically actuated valves (6).

Figure 3 illustrates: Subsea Controller Module (1) containing a supervisor controller (2): \((N+n)\) Motor controllers (3); \((N+n)\) Power Inverters (4); 3-phase, multi-way switching elements (7); \((N)\) electrically actuated valves (6); spare output for ROV connection (12).

To the contrary, Figure 4 illustrates a Typical prior art Rotating Electrical Actuator coupled to a rotary valve, which is an embodiment not of the invention.
More specifically, Figure 4 illustrates Electric motor (8) and gearbox (9) within a common retrievable housing, coupled (10) to a typical control valve (11). The present invention can be implemented with any motor design (brushless DC, permanent magnet, switched reluctance, inductive, etc.) The motors used would generally be of the same type however this is not essential if the control system is capable of controlling multiple motor types. The illustrated design assumes a single motor winding however significant additional redundancy may be added using two windings and a duplicated control module.

The supervisor controller C takes the demand from the process control as a valve / actuator position demand. It directs the motor position feedback to the appropriate controller unit along with the torque and direction request. Each controller unit uses the motor position feedback and the current measurement (direct, indirect or inferred) from its associated inverter to match the demand from the controller. In the event of an inverter or controller fault the supervisor simply switches the actuator over to an alternate controller. Actuator absolute position can be measured or inferred from the motor movement; however since this can be determined by the supervisor controller there is no requirement for this to be passed over to the controller unit.

Further, an A-B type redundancy can be achieved at any level by duplicating the supervisor controller or the complete unit with dual-wound motor assemblies. A duplicate supervisor controller would be able to take control of all actuators and controllers in the event of a failure of the active controller. The control system implemented will determine if the actuator positions need to be re-learnt or are continuously updated. The actuators can be connected using jumpers to a single connection plate or connected through the pre-wired XMT. This design is usable where the actuators are located in close proximity to each other and the central controller. Generally the motor phase connections may not be more than 10 metres long otherwise the additional resistance & inductance of the harness will affect motor performance. However, using DC or low frequency of AC will allow longer distances. Since identical inverter units are used, they must be sized for the largest motor demand. If all the motors are of
similar size then actuator movement speed or force needs may be achieved using mechanical gearing. This design does not require all the actuators to be of the same type – linear or rotary, fractional or multi turn actuators may be mixed as the control system sees all actuators as motor drives with position feedback. Constraints for individual actuators may be programmed into the supervisor controller, e.g. torque or speed limits. The supervisor controller will then control each actuator to its calibrated limits regardless of which inverter is being used as the power driver. Integrating this system into the CPDU can reduce the number of external connectors used in the system.

If only one actuator is required at any one time, a single motor controller may be used with a multi-position rotary switch to control which actuator motor is connected, reducing the number of control and inverter modules to fewer than the number of actuators while still maintaining a level of redundancy.

If several actuators are to be used simultaneously, this will drive the number of inverter units fitted. Actuator sequences for process control may be handled by using the rotary switch and a single inverter. The central controller module allows a number of different features to be included, such as actuator sequencing for process or power limiting needs, or controlling multiple actuators from a single inverter.

The supervisor controller will determine the most appropriate switch configuration in the event of failure(s) through a look-up table or algorithm. More than one switching element may need to be switched to allow the failed controller / inverter to be isolated. Replacing the 3P2T (3 pole, 2 throw) rotary switch with 3PnT gives an increase in redundancy of controller and inverter units. In addition it would be possible to provide additional outputs (12) on the
controller as shown in figure 3 to allow ROV connection using a jumper harness in the event of harness or connector failure.

Some advantages of the invention are as follows:

- With a central controller and inverter unit it is a single retrieve and replace operation for all electronic modules, reducing production downtime and service cost
- Lower initial investments:
  - Fewer electrical connections
  - Less duplication of electronics for redundancy
  - Simpler installation with a significantly smaller actuator package
- Lower cost actuator assembly
- Lower running costs
- Fast switch-over in the event of a single electrical failure
- Enhanced functionality
- Ability to control an actuator sequence even with multiple electrical failures
- Ability to add positions for future expansion / replacement of hydraulic actuators with electrical override

The system of the invention may comprise any feature as described or illustrated in this document, in any operative combination, each such combination is an embodiment of the present invention.
CLAIMS

1. Subsea system for production or processing, comprising several valves or other units controlled by electrical actuators, characterized in that each valve or unit actuator is operatively connected for power and control to a centralized actuator controller module comprising a number of controllers larger than the number of actuators to be controlled simultaneously.

2. Subsea system according to claim 1, wherein the central actuator controller module comprises inverters for power and controllers, providing power and control of actuator position with a single module, for redundancy the number of inverters for power and controllers are larger than the number of actuators requiring simultaneous actuation.

3. Subsea system according to claim 1 or 2, wherein the actuator controller module comprises a switcher device, such as a rotary switch mechanism, for switchable connection between power inverters, controllers and actuators.

4. Subsea system according to claim 1, 2 or 3, wherein the actuator controller module is arranged on a stab type plate, accessible and readily retrievable as a unit and preferably individually by an ROV with respect to power inverters and controllers.

5. Subsea system according to any one of claim 1-4, wherein the actuator controller module comprises \( N + 1 \) redundancy, more preferably \( N + n \) redundancy, where \( N \) is the number of actuators and \( n \) is larger than 1.

6.
Subsea system according to any one of claim 1-5, wherein the system is a subsea petroleum production system comprising several Xmas trees with valves with actuators.

7. Subsea system according to any one of claim 1-6, wherein the system comprises assemblies and units with dual wound windings, for enhanced redundancy.