

AN ELECTRICALLY OPERATED VALVE OR DAMPER ACTUATOR HAVING AN ELECTRIC  
MOTOR DIRECTLY COUPLED TO THE ACTUATOR DRIVE SHAFT

FIELD OF INVENTION

This invention relates to electromotive prime movers and more particularly to electrically operated actuators for opening, closing and/or  
5 modulating valves and dampers to control the flow of fluids in pipework and ducts.

BACKGROUND ART

Automatic flow control of fluids in industrial pipework and ducts is widely used in areas such as power generation, petroleum, oil and gas  
10 refining, pulp and paper, chemical, food and beverage, petrochemical processing, water and wastewater treatment industries. Hitherto, such actuators have utilised fixed speed alternating current induction motors which are coupled to an actuator through a worm/wormwheel gearbox drive, integral to the actuator.

15 One of the disadvantages of such prior art systems is that a combination of different motors and gearboxes is required to provide the required output speeds which results in high inventory. Furthermore, usually a change of components or a model change is required to effect a speed change as each combination of motor and gearbox has a constant  
20 output speed.

Another disadvantage of prior art systems is that to maintain a given output torque across a wide speed range requires a wide range of motors. To reduce costs, it is a standard practice to limit the number of motors used and this results in a reduction of torque with an increase of speed.

25 A further disadvantage of the prior art systems is that the gearbox introduces wearing surfaces (and thus frictional power losses) between the motor and the output drive shaft.



Prior art actuators have varying degrees of electronic and mechanical functions within the system and for setting up the equipment and making adjustments in the field. However, these functions present some problems including dismantling to effect physical adjustment causing process time delay and all intrusive work requires clearance to power down equipment for safety and access permits.

Most prior art machines have provision for manual operation during electrical power failure periods. During these periods it is essential to sense and monitor these manual operations to ensure position indication is maintained so as not to lose initial calibration. Some standard existing actuators are fitted with complex gearing to provide such position indication.

#### SUMMARY OF THE INVENTION

According to one aspect of the invention there is provided an electrically operated actuator for operating a valve or damper having an actuating shaft that has an operational torque requirement greater than 10 Nm, said electrically operated actuator comprising:

- (i) a housing having an interior,
- (ii) a drive shaft rotatably mounted within the housing and having a first end which extends from the housing for coupling to the actuating shaft of the valve or damper,
- (iii) an electric motor having a rotor and a stator, the electric motor being capable of developing a torque greater than 10 Nm and being mounted within the housing with the rotor co-axially mounted on the shaft and the stator fixed to the interior of the housing, and
- (iv) means for controlling the operation of the motor.

In a preferred form of the invention, there is a sole means of connecting the electric motor to the drive shaft which may suitably comprise a clutch.

Preferably, the variable speed, permanent magnet, constant torque  
5 electric motor is a high torque, direct current motor operated by pulse width modulation (PWM).

The PWM operated permanent magnet direct current motor provides an infinitely variable output speed (in steps of one RPM) over the minimum/maximum speed range. Thus, one embodiment of the invention  
10 can cover 6 to 12 different actuators of the AC motor and gearbox assembly combinations of the prior art. By changing the setting of the PWM duty cycle (via a keypad mounted on the equipment, or a hand held unit, or from a remote down the line position) the speed of the motor can be changed over a set range. Two embodiments of the present invention  
15 can replace 24 different AC motor and gearbox assembly combinations of the prior art (one supplier's range), which results in low spares inventory and foregoes the need to change the model to alter the speed/torque combination.

The permanent magnet direct current motor provides a constant  
20 torque over the full speed range.

The axially mounted motor and directly coupled shaft eliminate the wearing surfaces of the gearbox required in the prior art systems. This invention provides improved mechanical efficiency as the inherent frictional power losses in the integral gearboxes of the prior art systems are  
25 eliminated. A further advantage of the invention is that position sensing and monitoring during manual operations are achieved without complex gearing.

The electric motor consists of a stator and rotor. The stator is connected to a three phase, solid state, semi conductor switching device which is supplied with a dc voltage from a three phase rectifier unit. By switching the solid state device, the motor is driven as an AC motor. Thus  
5 the switching device is acting as an inverter.

By controlling the operation of the solid state switching device with a Pulse Width Modulated (PWM) signal the speed of the motor can be varied infinitely between given minimum and maximum values. The motor can be designed to give a specified range of speed at a required torque.

10 A microprocessor controls the PWM signal for given speeds that are set in the operational control parameters and maintains these speeds by reference to the rotor position sensor.

Should the speed start to fall due to a load imposed on the shaft, then the microprocessor will ramp up the PWM signal which will result in a  
15 larger voltage being switched to the stator allowing for the required speed correction and the greater torque requirement to be maintained at set constant speed.

When using this motor as the basis for an actuator it allows for one specifically designed unit to give a required output torque across a range of  
20 output speeds.

The actuator of the invention incorporates a motor drive control and a human interface microprocessor control. The motor drive control contains all the circuitry necessary to drive and protect the motor.

The microprocessor is programmed to control the motor pulse width  
25 modulation unit thus enabling the motor speed to be varied across its complete range. The microprocessor also carries the programme that will

allow all operational control parameters to be set and to give a particular alarm when any setting is exceeded.

In one embodiment of the invention, the actuator includes a human interface control that comprises circuitry that allows all parameters to be set from a local or remote position. This control connects into the microprocessor for the basic operation of the actuator to match the requirements of the control system in which it is a functional element. Field bus operations are also managed through this circuitry, via a matching interface.

#### 10 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of an electrically operated valve actuator according to one embodiment of the invention,

Fig. 2 is a view taken along lines II-II of Fig. 1,

Fig. 3 is a view taken along lines III-III of Fig. 1,

15 Fig. 4 is an enlarged side elevational view of the declutching cam and latch with the drive dogs or pins of the drive sleeve engaged with the drive pins of the rotor,

Fig. 5 is a view similar to Fig. 4 with the drive dogs or pins of the drive sleeve disengaged from the drive pins of the rotor,

20 Fig. 6 is block diagram of a first control system for operating the actuator of Figs. 1 to 5, and

Fig. 7 is block diagram of a second control system for operating the actuator of Figs. 1 to 5.

#### MODES FOR CARRYING OUT THE INVENTION

25 The actuator 10 of the embodiment of the invention shown in Figs. 1 to 5 includes a main housing 11 which defines a shaft compartment 12, a terminal compartment 13 closed by a terminal cover 14, a control

compartment 15 closed by a control cover 16, an auxiliary compartment 66 (see Figs 1 and 3) closed by a cover 67, and an encoder compartment 68 (see Figs 1 and 3) closed by a cover 69. A shaft 17 is supported by means of a bearing 18 at the lower end of the housing 11 and a bearing 19 at the upper  
5 end of the housing 11.

The shaft 17 is rotatable by an electric motor 21 having a stator 22 fixed to the housing 11 and a rotor 23. The rotor 23 is couplable to the shaft 17 by  
✓ clutch 24.

The shaft 17 may also be rotated by a hand wheel 20 for manual  
10 operation when the electric motor 21 is not operable, for example in the event of failure of the electric power supply.

The shaft compartment 12 is closed by a top cover 25 and a drive base 26. The top cover 25 has a central aperture which receives the hub 28 of the hand wheel 20. The downwardly extending skirt 27 of the top cover 25  
15 supports the bearing 19a. The hub 28 has a central aperture which receives the shaft 17 with bearing 19 therebetween. The hub 28 is sealed with respect to the shaft 17 by seal 29 and with respect to the top cover 25 by seal 30. In this instance, the hand wheel 20 is secured to the hub 26 by pin 31.

The drive base 26 has a central aperture for receiving the end of the  
20 shaft 17 which is supported by bearing 18. The drive base 26 is sealed with respect to the shaft 17 by seal 34. The drive base 26 is secured to the housing 11 by screws (not shown).

As can be seen in detail in Figs. 3, 4 and 5, the electric motor 21 is located above the drive base 26 with the stator 22 secured to a downwardly  
25 depending skirt 35 of the housing 11. The stator 22 is secured to the skirt 35 by screws 65. The rotor 23 is rotatably mounted on the \_\_\_\_\_

shaft 17 by bearing 36. The hub 37 of the rotor 23 has a plurality of upwardly extending drive pins 38 adapted to engage drive lugs 39 on the drive sleeve 40 which is slidably mounted on the shaft 17 by keys 41.

5 The drive sleeve 40 incorporates a cam ramp 43 on its lower face which is engaged by a cam 46 that is secured to the declutching shaft 47. A latch 44 which is pivotably mounted about axis 45 on cam 46 is biased by spring 48 secured to the cam 46 by screws 49. The declutching shaft 47 is biased by return spring 50. In Fig. 4, the actuator is shown in the motor drive mode.

10 The declutching shaft 47 is rotated by hand lever 54 (see Fig. 1) to enable the drive lugs 39 to disengage the drive pins 38 as shown in Fig. 4 for manual operation of the shaft 17.

15 In Fig. 5, the actuator is shown in the manual mode with the drive lugs 39 of the drive sleeve 40 held clear of the drive pins 38 of the rotor hub 37 by the engagement of the tail 51 of the latch 44 with the shoulder 52 of the rotor hub 37 and the head 53 of the cam 46 with the cam ramp 43 of the drive sleeve 40.

20 The shaft sensor wheel 55 is mounted on the shaft 17 above the drive sleeve 40. Between the wheel 55 and the drive sleeve 40 there is a spring 56 which drives the drive sleeve 40 downwards when the tail 51 of the latch 44 is removed from the shoulder 52 upon rotation of the rotor 23. The shaft sensor wheel 55 is aligned with a shaft sensor cartridge 58 secured in an opening in the housing 11 by screws 59.

25 As can be seen in Fig. 3, the power compartment 13 has a terminal block 60 which is secured to the housing 11 by screws 61. The control cover 16 has a display window 62 and switches/buttons 63.

The Power control operation and indicator systems for the actuator of Figs. 1 to 5 are shown in Figs. 6 and 7. Three phase mains supply is provided by lines 100 to a power switching unit 101 which in turn supplies inverter 102 through line 103. The inverter 102 provides power to the motor 21 which rotates the shaft 17.

In the event of no power and manual operation, a battery backup is provided to supply power to the shaft position sensing circuit 117, thus enabling the recording of any shaft rotation (manually) during periods of no power. The battery shut down switch 118, shuts down the battery supply if no shaft rotation is sensed for a given time period. Any manual operation of the shaft will automatically reactivate the battery circuit through the switch 118.

The microprocessor 104 receives signals representing the temperature of the motor 21 via line 105, the position of the shaft 17 via line 106, the temperature of the inverter 102 via line 107 and rotor speed via line 115.

All control functions are handled by the microprocessor 104 which in turn feeds speed requirements and torque settings to the programmable logic device (PLD) 113.

In Fig. 6, local control is via keypad 117 and remote control via 111.

The following parameters are set via the keypad 117 prior to the putting into service of the device:-

- Preferred access code number
- Mode: OFF - LOCAL - REMOTE - CALIBRATE
- Inching or Latching operation mode
- Emergency shutdown requirement Close, Open or Stop
- "Close on Torque" or "Close on Limit"

- Opening Speed RPM
- Closing Speed RPM
- Opening Torque Setting Nm
- Closing Torque Setting Nm
- 5     • Open Limit of travel (Number of Turns to fully Open) 100%
- Close Limit (fully closed) 0%

For local control there are two dedicated keypad buttons for open and close operation when selected to LOCAL or CALIBRATE mode.

All prompts and settings read out on the Liquid Crystal Display 110.

- 10   With these controlling parameters in place the device can be operated safely.

In Fig. 7 local control is via the hand held unit (infra-red emitter) 108 and remote control via 111. For local control and indication 112, there are two switches mounted on the control port of the device - one selects control either side of OFF for Local or Remote Operation and the other  
15   selects either side of STOP the Close or Open commands.

The following parameters are set via the hand held unit (infrared emitter) 108 prior to the putting the device into service:-

- Preferred access code number
- 20   • Inching or Latching operation mode
- Emergency shutdown requirement Close, Open or Stop
- "Close on Torque" or "Close on Limit"
- Opening Speed RPM
- Closing Speed RPM
- 25   • Opening Torque Setting Nm
- Closing Torque Setting Nm
- Open Limit of travel (Number of Turns to fully Open) 100%

- Close Limit (fully closed) 0%

All prompts and settings read out on the Liquid Crystal Display 110.

With these controlling parameters in place the device can be operated safely.

- 5            Local indication (116 in Fig 6 and 112 in fig 7) is by three light emitting diodes (LED) and a sixteen pixel alpha/numeric liquid crystal display (LCD) 110. The LED signals are CLOSED - ALARM - OPEN.

The LCD 110 displays all settings during On-line interrogation when pre-set values are requested, plus

- 10            • Position indication 0-100% increasing and decreasing during operation, together with the words Closing or Opening depending on direction and Open or Closed at the end of each travel.

The following alarm indication will be displayed for:-

- 15            • Torque Trip Opening (apply abbreviation to fit 16 pixels)
- Torque Trip Closing
  - Motor Temperature
  - Electronics Temperature
  - Battery Low

- 20            With remote control and indication 111, the standard control functions are Open-STOP-Close as with the local control. Indication is for:

- Fully Closed
- Fully Open
- Remote Selected
- 25            • Voltage OK
- Fault
- 4-20 mA Position Indication

Optional remote control is offered for:

- Analogue position control (used for modulating devices)
- Field Bus interface connection for remote calibration, control and On-Line interrogation.

5 All control parameters are stored in the microprocessor circuit 104.

Customised software has been written to handle all operational and procedural functions as are required to operate the device in accordance with specification for functional requirements.

10 The programmable logic device (PLD) 113 is programmed to operate the switching unit when receiving a signal from the Rotor Sense Circuits via line 114. The switching unit in turn operates the inverter which drives the motor 21. The duration of the switching pulse is determined by the pulse width modulating (PWM) signal received from the microprocessor 104. The longer the pulse the faster the motor speed.

15 The PWM speed signal is controlled by the pre-set parameters in the microprocessor 104 for the required speeds opening and closing.

Various modifications may be made in details of design and construction without departing from the scope or ambit of the present invention.

CLAIMS:

1. An electrically-operated valve or damper actuator, said valve or damper having an actuating shaft that has an operational torque requirement greater than 10 Nm, said electrically-operated actuator comprising:

- (i) a housing having an interior,
- (ii) a drive shaft rotatably mounted within the housing and having a first end which extends from the housing for coupling to the actuating shaft of the valve or damper,
- (iii) an electric motor having a rotor and a stator, the electric motor being capable of developing a torque greater than 10 Nm and being mounted within the housing with the rotor co-axially mounted on the shaft and the stator fixed to the interior of the housing, and
- (iv) means for controlling the operation of the motor.

2. An actuator according to claim 1 wherein the electric motor is a variable speed, permanent magnet, constant torque electric motor.

3. An actuator according to claim 2 wherein the electric motor is a high torque, direct current motor operated by pulse width modulation.

4. An actuator according to claim 3 wherein the electric motor is adapted to provide an infinitely variable output speed of the drive shaft over a predetermined speed range.

5. An actuator according to claim 3 wherein the electric motor is adapted to provide a constant torque over a predetermined speed range.
6. An actuator according to claim 1 wherein the rotor is rotatably mounted on the drive shaft and wherein the actuator further includes a clutch for coupling the rotor to the drive shaft.
7. An actuator according to claim 6 wherein the clutch includes a drive sleeve slidably mounted on the drive shaft but not rotatable with respect to the drive shaft, drive pins on the drive sleeve, drive pins on the rotor and spring means for normally biasing the drive sleeve-towards the rotor so that the drive pins are engaged.
8. An actuator according to claim 7 and further including cam means adapted to engage the drive sleeve and move the drive sleeve away from the rotor against the action of the spring means to disengage the drive pins.
9. An actuator according to claim 8 wherein the other end of the drive shaft is connected to a hand wheel adapted to rotate the drive shaft when the drive pins are disengaged.
10. An actuator according to claim 1 wherein the means for controlling the operation of the electric motor is a motor drive control comprising circuitry to drive and protect the motor and a human interface control adapted to set the operational parameters of the actuator.

11. An actuator according to claim 10 wherein the control means includes a microprocessor programmed to allow the operational parameters to be set and to generate an alarm when any setting is exceeded.

12. An actuator according to claim 10 wherein the human interface control allows the operational parameters to be set from a local or remote location.