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(54) **WELL CONTROL MEANS**

(76) Inventors: **Philip Howe**, Winscombe (GB); **Christopher Richard King**, Stoud (GB)

Correspondence Address:
James E. Bradley
BRACEWELL & PATTERSON, L.L.P.
P.O. Box 61389
Houston, TX 77208-1389 (US)

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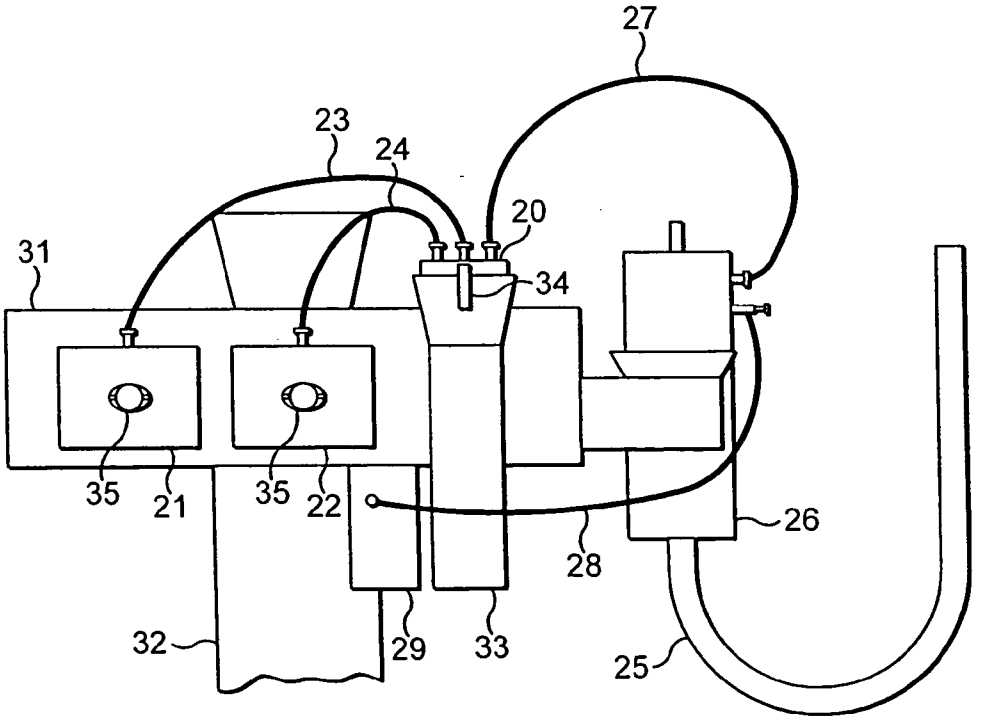
(57) **ABSTRACT**

A controller for a well facility has at least one electronic control module (**20**) and at least one power switching module (**21, 22**). The power switching module may provide either a wholly hydraulic or wholly electrical output. The distributed electronic and power switching controls facilitate their removal and replacement by a remote operating vehicle. The modules are preferably housed on a subsea well tree (**31**).



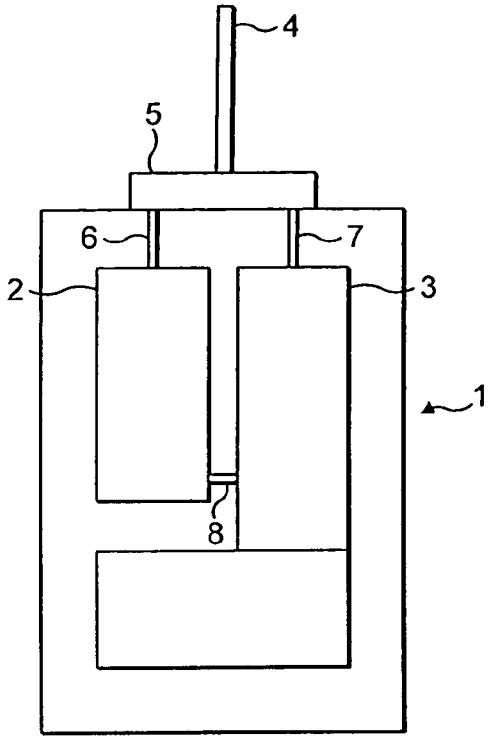


FIG. 1

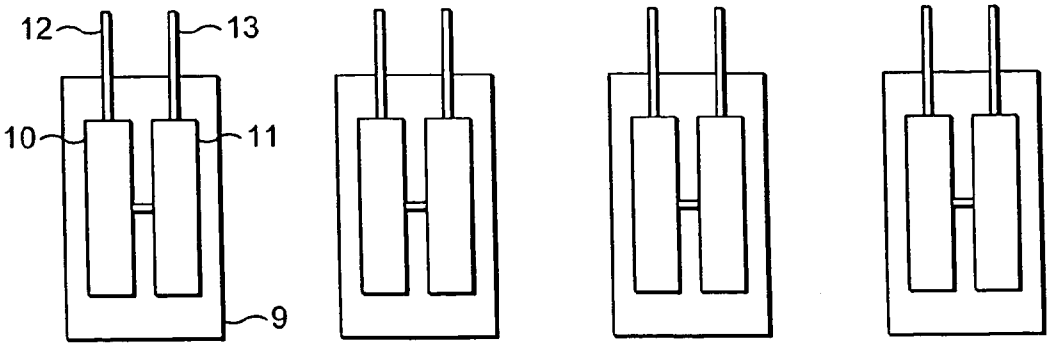


FIG. 2

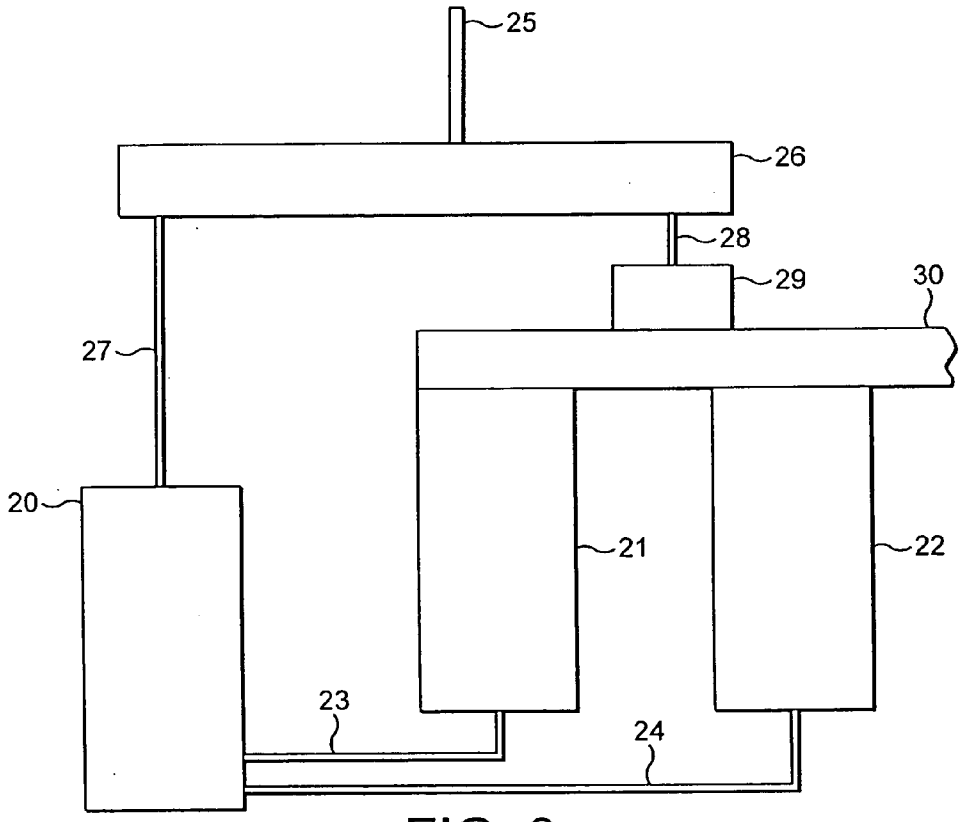


FIG. 3

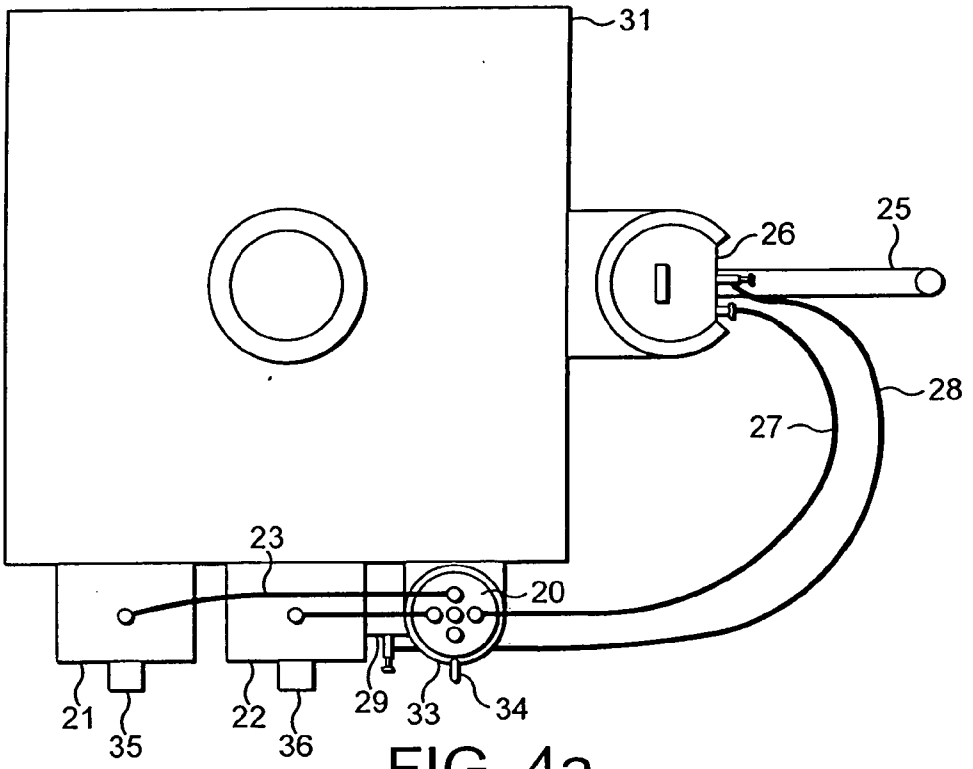

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FIG. 4a

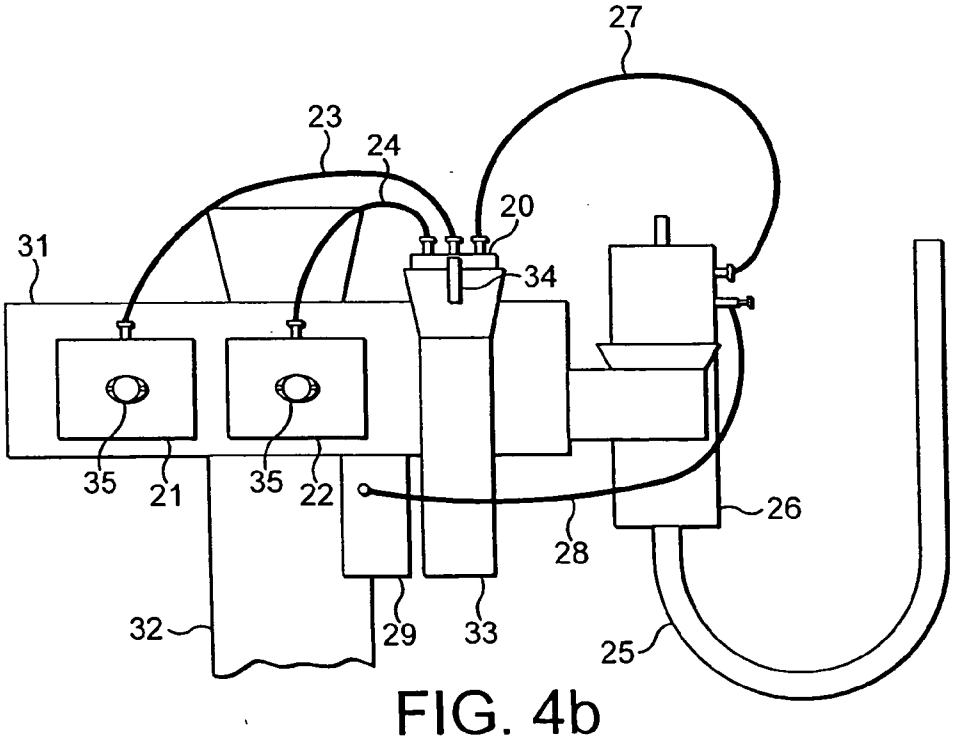
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FIG. 4b

WELL CONTROL MEANS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of United Kingdom Patent Application No. 0319622.7, filed on Aug. 21, 2003, which hereby is incorporated by reference in its entirety.

TECHNICAL FIELD OF THE INVENTION

[0002] This invention concerns the control of well facilities, for example underwater hydrocarbon extraction wells.

BACKGROUND OF THE INVENTION

[0003] A subsea well is conventionally controlled by equipment mounted on a structure known as a tree, which is typically located on or below the sea bed above the well bore. The tree houses a subsea control system, normally within a subsea control module (SCM) which comprises a subsea electronic module (SEM) and a hydraulic control module (HCM). The SCM is normally fed by an umbilical line from a surface station, e.g. from a surface platform, with electric power, control signals and hydraulic power. The control signals are processed by the SEM which then controls electrically operated, hydraulic directional control valves (DCV's) in the HCM, which in turn operate the multiplicity of hydraulic devices such as actuators, controlling the well.

[0004] The subsea control system is centralised within the tree, as illustrated diagrammatically in **FIG. 1**. The SCM **1** houses the SEM **2** and the HCM **3**. The SCM **1** is connected to the umbilical **4** via a distribution unit **5** which provides electric power and control signals to the SEM **2** via a cable **6** and hydraulic power to the HCM via a feed **7**. The SEM **2** controls the DCV's in the HCM **3** via a cable **8**. Although there are generally back-ups of the major functions of the system, any further failure requires the removal of the SCM **1**, which, since its weight is substantial, requires the use of heavy lifting equipment, resulting in a very expensive operation for the well operator.

[0005] A prior art attempt to decentralise the control system is described in GB 2 264 737 (ECA). Here the concept is to combine a limited electronic and hydraulic function within a small and light module, as schematically illustrated in **FIG. 2**. Thus the SCM ceases to exist in itself and is replaced by a multiplicity of integrated electronic and hydraulic functions in modules **9** by smaller and dedicated electronic units **10** and hydraulic units **11**, fed with electric power and control signals via an interface **12** and hydraulic power via an interface **13**. Four such modules only are shown for simplicity although there may be as many modules as hydraulic devices requiring to be operated. Other attempts include relocating the DCV's from an HCM onto the hydraulic devices themselves. In such systems, failed individual control units can be replaced without the use of heavy lifting equipment, by employing a remotely operated vehicle (ROV). EP 0 704 779 describes a development of the system of GB 2 264 737.

[0006] However, such prior systems have the major disadvantage of a substantially increased number of interface connections, both electrical and hydraulic, resulting in a reduction of the system reliability and availability. Furthermore, although failed individual control units are light enough to be within the handling capability of, and can be recovered by an ROV, it is time consuming to recover and replace the multiplicity of such units often required to clear a fault.

[0007] Various subsea well control systems are also described in U.S. Pat. No. 6,216,784, U.S. Pat. No. 4,120,362, US 2002/011286 A1, U.S. Pat No. 4,174,000, U.S. Pat. No. 4,378,848, U.S. Pat No. 4,497,369, U.S. Pat. No. 6,644,410, U.S. Pat No. 6,102,124, GB 2 194 980, EP 0 545 551, EP 0 627 544 and FR 2 574 849.

[0008] U.S. Pat No. 5,249,140, EP 0 247 335, EP 0 240 965 and EP 0 272 397 disclose distributed electro-hydraulic control systems.

SUMMARY OF THE INVENTION

[0009] The present invention enables decentralisation of a well control system in new configurations whilst maintaining system availability.

[0010] In accordance with a first aspect of the present invention there is provided control means for a well facility, comprising an electronic control module and a power switching module, said electronic control module being configured to provide a wholly electronic output and said power switching module being configured to provide a power switching output using said electronic output.

[0011] The power switching module may provide either wholly hydraulic or wholly electrical output.

[0012] The electronic control module and the power switching module could be arranged to be removably mounted on a well tree.

[0013] Preferably, jumpers are used for carrying control signals from said electronic control module to said power switching module.

[0014] The control means may further comprise an umbilical termination unit. This may be arranged to be removably mounted on the well tree. A jumper may be used for connection between the electronic control module and the umbilical termination unit. A hydraulic feed for feeding hydraulic power from the umbilical termination unit to a hydraulic power switching module (or an electrical feed to an electrical power switching module) may also be provided.

[0015] Preferably, at least one of the electronic control module, the power switching module, the umbilical termination unit, the hydraulic feed, the electrical feed or the jumpers is adapted for removal and fitting by a remotely operated vehicle.

[0016] A plurality of power switching modules may be provided, each connected to said control module. At least one of them could produce wholly hydraulic output and at least one of them could produce wholly electrical output.

[0017] In accordance with a second aspect of the present invention, there is provided a well tree comprising the above control means.

[0018] In accordance with a third aspect of the present invention there is provided a well facility comprising the above control means.

[0019] In accordance with a fourth aspect of the present invention, there is provided a method of controlling well operations using an electronic control module to produce a wholly electronic output, which output controls a power switching module to produce a power switching output.

[0020] The electronic control module may receive control signals from a remote station, preferably via an umbilical termination unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The invention will now be described by way of example with reference to the following figures, in which:

[0022] **FIG. 1** shows a conventional subsea control system;

[0023] **FIG. 2** shows a prior art decentralised control system;

[0024] **FIG. 3** shows a schematic diagram of a control system according to the present invention;

[0025] **FIG. 4***a* shows a plan view of a well tree using a control system according to the present invention; and

[0026] **FIG. 4***b* shows a side elevation view of the well tree of **FIG. 4***a*.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] Referring firstly to **FIG. 3**, a control system in accordance with the present invention comprises a subsea electronics module **20** containing control circuitry and hydraulic power switching modules **21** and **22** which contain equipment to effect limited hydraulic functions, such as the control of DCV's, actuators etc. One of the hydraulic modules could be a relatively low pressure hydraulic module and the other a relatively high pressure hydraulic module. Both the SEM **20** and hydraulic modules **21** and **22** are mounted on a well tree (not shown). SEM **20** sends control signals to hydraulic modules **21** and **22** via electrical jumpers **23** and **24** respectively. Electrical power, control signals and hydraulic power are fed to the tree from a remote station via an umbilical **25** to an umbilical termination unit (UTA) **26**. Electrical power and control signals are fed from the UTA **26** to the SEM **20** via a jumper **27**. Hydraulic power is fed from UTA **26** via a hydraulic feed **28** to a tree distribution unit **29** which feeds hydraulic fluid to a manifold **30**. The manifold **30** provides distribution of the hydraulic fluid to the hydraulic modules **21** and **22** through channels within it with an arrangement of self-sealing hydraulic coupling on both the modules **21** and **22** and the manifold **30**. The manifold **30** is capable of carrying more than just the two hydraulic modules **21** and **22** shown. The SEM **20**, hydraulic modules **21** and **22**, jumpers **23**, **24** and **27**, UTA **26** and hydraulic feed **28** may all be removed and replaced by using an ROV. Thus the number of interfaces is substantially reduced compared to the prior art, and ROV replacement of a module replaces a significant proportion of the system, thus keeping the number of ROV recovery operations in a fault situation to a minimum.

[0028] **FIGS. 4***a* and **4***b* show a plan view and side elevation view respectively of a lightweight well tree **31** provided with a specific implementation of the above. Where possible, the reference numerals used in **FIG. 3** have been retained for corresponding features. Developments in hydraulic systems have permitted the elimination of heavy hydraulic accumulators thus allowing elimination of a large and heavy mechanical structure to support the subsea control module. An accumulator-free control system is light enough to be mounted on production tubing **32**, particularly if the functions of the control modules are limited to the essential requirements rather than the fitting of a standard control system designed to be compatible with all of the requirements of any well.

[0029] The lightweight well tree **31** is attached to the production tubing **32**. Umbilical **25** carries hydraulic power, electrical power and control signals from a surface platform to the UTA **26**. The UTA **26** is housed in a receptacle, facilitating its removal and replacement by an ROV. Electric power and control signals are fed to the SEM **20** via jumper **27**. The tree **31** also functions as a hydraulic manifold which is fed from a tree hydraulic distribution unit **29**, to connect hydraulic fluid to the hydraulic modules **21** and **22** and to provide outputs from the hydraulic modules to hydraulic operated devices such as actuators (not shown). The UTA **26** is connected by a hydraulic feed **28** to the tree hydraulic distribution unit **29**.

[0030] The SEM **20** is located in a receptacle **33** attached to the tree **31**, and is fitted with a handle **34** so that the module **20** can be removed from the receptacle **33** by an ROV. Jumpers **23** and **24** connect control signals from the SEM **20** to the hydraulic modules **21** and **22**. All three jumpers **27**, **23** and **24**, as well as hydraulic feed **28** are designed to be removable and replaceable by an ROV. The hydraulic modules **21** and **22** are secured to the tree **31** by a locking screw arrangement, for example arrangements **35** and **36**, such that an ROV can engage with the arrangement and detach each module from the manifold. The process of detaching the module causes the hydraulic feeds at both the manifold and the module to be automatically sealed. Likewise, replacement of the module by an ROV re-opens the feeds.

[0031] A major advantage of the ROV replaceable hydraulic modules is that they can be made truly standard so that the specific requirement of each well can be accommodated by fitting further hydraulic modules to other faces of the tree manifold, the number fitted being dependent on the complexity of the well. This not only saves the operator costs in that he does not have to fit a subsea control system which of itself provides all electrical and hydraulic functions to a low-complexity well, but also reduces hardware delivery time as "standard" units can be held in stock by the supplier. Each hydraulic module, being small and light, has a limited function capability. Typically each module contains seven DCV's along with hydraulic fluid supply filtration and pressure transducers. A further advantage is that variants can be provided of the standard, with lower component populations to further reduce costs.

[0032] During installation and workover, it is necessary to exercise the well operating devices such as valves and chokes before the umbilical is installed. Another advantage of the inventive system is that hydraulic power and electrical control can be connected to the tree via temporary workover "mini-umbilicals" connected to the SEM **20** and the tree distribution unit **29** during these non-production phases.

[0033] Although the invention has been described with reference to the embodiments above, there are many other

modifications and alternatives possible within the scope of the claims. For example, the modules could be mounted on other than a well tree (for example on a subsea manifold, subsea template or subsea pipeline structure); there could be other electronic modules other than the electronic control module (for example for controlling or monitoring various downhole functions); and the invention may be applied other than in an underwater well facility; and at least one of the hydraulic power switching modules could be instead an electrical power switching module producing wholly electrical output and ROV replaceable.

1. A controller for a well facility, comprising an electronic control module and a power switching module, said electronic control module being configured to provide a wholly electronic output and said power switching module being configured to provide a power switching output using said electronic output.

2. The controller according to claim 1, wherein said power switching module produces wholly hydraulic output.

3. The controller according to claim 1, wherein said power switching module produces wholly electrical output.

4. The controller according to claim 1, wherein said electronic control module and said power switching module are arranged to be removably mounted on a well tree.

5. The controller according to claim 1, comprising a jumper for carrying control signals from said electronic control module to said power switching module.

6. The controller according to claim 1, further comprising an umbilical termination unit.

7. The controller according to claim 6, wherein said electronic control module and said power switching module are arranged to be removably mounted on a well tree and wherein said umbilical termination unit is arranged to be removably mounted on said well tree.

8. The controller according to claim 6, comprising a jumper for connection between said electronic control module and said umbilical termination unit.

9. The controller according to claim 6, wherein said power switching module produces wholly hydraulic output, the control means further comprising a hydraulic feed for feeding hydraulic power from the umbilical termination unit to the power switching module.

10. The controller according to claim 1, wherein at least one of said electronic control module, said power switching module, said umbilical termination unit, said hydraulic feed and said jumpers is adapted for removal and fitting by a remotely operated vehicle.

11. The controller according to claim 1, comprising a plurality of such power switching modules, each connected to said control module.

12. The controller according to claim 11, wherein at least one of said power switching modules produces wholly electrical output and at least one produces wholly hydraulic output.

13. A well tree comprising the controller according to claim 1.

14. A well facility comprising the controller according to claim 1.

15. A method of controlling well operations using an electronic control module to produce a wholly electronic output, which output controls a power switching module to produce a power switching output.

16. The method according to claim 15, wherein the electronic control module receives control signals from a remote station.

17. The method according to claim 16, wherein the control signals are received at the electronic control module via an umbilical termination unit.

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