VERTICAL SUBSEA TREE ASSEMBLY CONTROL

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates in general to control of a subsea well completion and, in particular, to a system and method for subsea well control by landing a landing sub on a vertical subsea tree.

2. Brief Description of Related Art

[0002] Subsea wellhead assemblies are typically used in the production of hydrocarbons extracted from subterranean formations below the seafloor. Subsea wellhead assemblies generally comprise a wellhead housing disposed at a wellbore opening, where the wellbore extends through one or more hydrocarbon producing formations. Casing and tubing hangers are landed within the housing for supporting casing and production tubing inserted into the wellbore. The casing lines the wellbore, thereby isolating the wellbore from the surrounding formation. Tubing typically lies concentric within the casing and provides a conduit for producing the hydrocarbons entrained within the formation. Wellhead assemblies also typically include subsea trees, also known as christmas trees, connected to the upper end of the wellhead housing. The subsea trees control and distribute the fluids produced from the wellbore.

[0003] Subsea trees are installed on the wellhead housing, tubing head, or tubing hanger spool by latching a running tool either within the tree's main mandrel or to the external profile and attaching wire or drill pipe to the running tool for lowering the subsea tree to the wellhead housing. One or more umbilical lines may then be run from a working platform to the subsea tree where the umbilicals may be connected to the subsea tree by remotely operated vehicles. These umbilicals are used to provide power, both hydraulic and electric, to subsea control modules to control functions of subsea trees, such as flow control valves, chokes and other hydraulic devices during tree installation, re-entry, workover, or abandonment of the well. In addition, umbilicals may be used to receive information from tree sensors during operation of the subsea tree. Opposite ends of the umbilicals may be connected to devices at the surface platform or alternatively to other subsea devices that provide operational control of valves within the

subsea tree. These umbilicals may be disposed at subsea locations that are several miles below the surface of the sea. One or more umbilicals may also be used to function or pressure test the tubing hanger running too and landing string. This system is run through the drilling marine riser into either the wellhead or tree master valve block. Thus, the umbilicals may be constructed to withstand the temperature and pressures at such locations. In turn, this may cause the cost of such umbilicals to be incredibly steep, upwards of multi millions of dollars to construction an umbilical that is strong enough and long enough to be used at subsea locations exterior of a subsea riser.

[0004] These umbilicals may also be subject to spooling damage during operation. When the umbilicals are damaged operating costs go up significantly as the umbilical must be retrieved, repaired and rerun. Operators may maintain backup umbilicals and reels in order to address potential damage to the umbilical during run in and operation through the umbilical. Again, this can add significantly to the cost of the well operation as well as necessitate additional equipment to store the backup umbilical at the surface platform. Still further, where the rig may be removed from the wellhead location, additional management systems may be needed to maintain the umbilical. This can also add significantly to the costs of the operation of the well.

[0005] During workover operations a workover umbilical may be lowered from a floating rig or work boat and leads from the workover umbilical are connected to the tree. Additional umbilicals may also be lowered with workover and completion tools and devices. These umbilicals electric or hydraulic power to the tools and devices for operation within the wellhead and tree assemblies. Running of multiple umbilicals for subsea operations adds significantly to the costs of operation as additional spools and equipment are needed at the surface to support the additional umbilicals. Therefore, there is a need for a system or method to control a subsea tree using fewer umbilicals.

SUMMARY OF THE INVENTION

[0006] These and other problems are generally solved or circumvented, and technical advantages are generally achieved, by preferred embodiments of the present invention that provide a method for subsea well control through a vertical subsea tree.

[0007] In accordance with an embodiment of the present invention,. a method for controlling a subsea completion or workover assembly in a subsea well having a vertical subsea tree communicatively coupled with a subsea control module is disclosed. The method provides the vertical subsea tree with at least one master valve block passage leading from an inner portion of an upper mandrel of a master valve block to an exterior of the vertical subsea tree, wherein the at least one master valve block passage communicatively couples the vertical subsea tree with the subsea control module. The method also provides the master valve block of the vertical subsea tree with at least one penetration on the inner portion of the upper mandrel communicatively coupled to the at least one master valve block passage. Still further, the method provides a landing sub having at least one landing sub passage extending from a landing sub penetration on a lower portion of the landing sub and connecting the at least one landing sub passage to an umbilical. The landing sub is run subsea to land the landing sub on the master valve block and register the landing sub penetration with the master valve block penetration. The method then supplies at least one of hydraulic fluid pressure and electric potential to the subsea control module through the umbilical, landing sub passage, and master valve block passage. The method then performs at least one of subsea completion operations and subsea workover operations with at least one of the hydraulic fluid pressure and the electrical potential provided through the passages.

[0008] In accordance with another embodiment of the present invention, a method for controlling a subsea completion or workover assembly in a subsea well having a vertical subsea tree communicatively coupled with a subsea control module is disclosed. The method provides the vertical subsea tree with a plurality of master valve block passages leading from an inner portion of an upper mandrel of a master valve block to an exterior of the vertical subsea tree wherein the plurality of master valve block passages communicatively couple the vertical subsea tree with the subsea control module. The method also provides the master valve block of the

vertical subsea tree with a plurality of penetrations on the inner upper mandrel communicatively coupled a respective passage. Still further, the method provides a landing sub having a plurality of landing sub passages extending from a plurality of corresponding landing sub penetrations on a lower portion of the landing sub and connecting the at least one landing sub passage to an umbilical. The method runs the landing sub to land the landing sub on the master valve block and register the landing sub penetrations with the master valve block penetrations and supplies hydraulic fluid pressure, electric potential, and treatment fluids to the subsea control module through the umbilical, landing sub passages, and master valve block passages. The method then performs at least one of subsea completion operations and subsea workover operations with the hydraulic fluid pressure, the electrical potential, and the treatment fluids provided through the passages.

[0009] In accordance with yet another embodiment of the present invention, a subsea completion or workover assembly in a subsea well having a vertical subsea tree with a master valve block having an inner portion of an upper mandrel for receiving a landing sub is disclosed. The assembly includes at least one master valve block passage leading from the inner portion of the upper mandrel of the master valve block to an exterior of the vertical subsea tree, the at least one master valve block passage further communicatively coupled to a subsea control module. The master valve block includes at least one penetration on the inner portion of the upper mandrel communicatively coupled to the at least one passage. The assembly also includes a landing sub having at least one landing sub passage extending from a landing sub penetration on a lower portion of the landing sub, and an umbilical connected to the landing sub, the at least one landing sub passage in communication with the umbilical. The landing sub lands on the master valve block and registers the landing sub penetration with the master valve block penetration. At least one of hydraulic fluid pressure, electric potential, and treatment fluids are supplied to the subsea control module through the umbilical, landing sub passage, and master valve block passage to perform at least one of subsea completion and workover operations with at least one of the hydraulic fluid pressure, the electrical potential, and the treatment fluids provided through the passages.

[0010] An advantage of a preferred embodiment is that it provides a means to operate a subsea vertical tree through a subsea control module using a single umbilical run from the surface with a

landing sub. This eliminates the need for use of multiple umbilicals, one that runs separately with the landing sub for operation of the landing sub and one run directly to the subsea control module. In addition, the disclosed embodiments eliminate the need for additional backup umbilicals associated with the subsea control module umbilical. Still further, the disclosed embodiments eliminate the need to have ROVs unhook from other assemblies to install and disconnect a subsea control module umbilical. The disclosed embodiments also reduce the management requirements associated with umbilicals by reducing the total number of umbilicals needed in an intervention or workover operation, thereby reducing installation time and risk. All these factors contribute to a more efficient and safer system that has a reduced capital expenditure for use and a reduced operating expenditure due to the faster and more efficient installation method.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] So that the manner in which the features, advantages and objects of the invention, as well as others which will become apparent, are attained, and can be understood in more detail, more particular description of the invention briefly summarized above may be had by reference to the embodiments thereof which are illustrated in the appended drawings that form a part of this specification. It is to be noted, however, that the drawings illustrate only a preferred embodiment of the invention and are therefore not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

[0012] Figure 1 is a schematic representation of a subsea well completion in accordance with an embodiment.

[0013] Figure 2 is schematic representation of subsea well completion of Figure 1 illustrating flow paths through the subsea well completion.

[0014] Figure 2A is an alternative embodiment of the flow paths of Figure 2.

[0015] Figure 3 is a schematic representation of an alternative subsea well completion illustrating flow paths through the subsea well completion in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0016] The present invention will now be described more fully hereinafter with reference to the accompanying drawings which illustrate embodiments of the invention. This invention may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout, and the prime notation, if used, indicates similar elements in alternative embodiments.

[0017] In the following discussion, numerous specific details are set forth to provide a thorough understanding of the present invention. However, it will be obvious to those skilled in the art that the present invention may be practiced without such specific details. Additionally, for the most part, details concerning wellbore drilling, wellbore completion, drilling rig operation, and the like have been omitted inasmuch as such details are not considered necessary to obtain a complete understanding of the present invention, and are considered to be within the skills of persons skilled in the relevant art.

[0018] Referring to Figure 1, a subsea wellhead 11 is disposed within a wellbore 13 located at a sea floor location 15. The wellbore 13 may be lined or cased with a casing string 17 extending from the wellhead to a location subsurface. In addition, a tubing string 19 may be suspended within the wellbore for production of hydrocarbons from wellbore 13. In the illustrated embodiment, a vertical subsea tree 21 is landed on wellhead 11. A subsea riser 23 extends from vertical subsea tree 21 to a platform 25 located on a sea surface. Platform 25 may be a floating rig, a workover vessel, or the like. A landing string 26 may extend from the platform to vertical subsea tree 21 and support a landing sub 27 at vertical subsea tree 21. A person skilled in the art will understand that vertical subsea tree 21 includes production ports (not shown) and valves (not shown) that connect to subsea flowlines to allow flow of well fluid to additional production apparatuses located on the sea floor. A person skilled in the art will understand that the schematic representation of Figure 1 may comprise a workover, a well intervention, a well recompletion, or the like. A person skilled in the art will also understand that landing sub 27 may comprise a subsea test tree and blowout preventer assembly, an open water installation device, such as a tree running tool, handling device, a lower riser package, an emergency

disconnect package, or the like depending on the particular situational conditions under which the well is operating. For example, in alternative embodiments, riser 23 may not be used. In these embodiments, open water operations and devices may be used.

[0019] Referring to Figure 2, vertical subsea tree 21 is schematically shown disposed on wellhead 11. Vertical subsea tree 21 may include a tubing head spool 29 disposed on wellhead 11. Tubing head spool 29 will support a tubing hanger 31 on which a master valve block 33 will be disposed. A subsea blowout preventer 35 may be disposed on vertical subsea tree 21. As shown, landing sub 27 will be disposed within blowout preventer 35 to land on master valve block 33. In the embodiment of Figure 2, landing sub 27 may comprise a subsea test tree. The well completion will include a central bore 28 extending through vertical subsea tree 21, tubing head spool 29, tubing hanger 31, master valve block 33, and subsea blowout preventer 35. In addition, the well completion may include an annulus flow path 30 extending through vertical subsea tree 21, tubing head spool 29, tubing hanger 31, master valve block 33, and subsea blowout preventer 35. Fluid flow through central bore 28 and annulus 30 may be controlled by a plurality of valves 32.

[0020] Master valve block 33 will include a plurality of flow paths 37 extending from an inner bore (not shown) of master valve block 33 to a location external to the inner bore of vertical subsea tree 21. Flow paths 37 may comprise any suitable subsea communication lines that may accommodate flow of subsea materials, such as hydraulic fluid, electric potential, or chemical injection fluid. In the illustrated embodiment, there are five flow paths 37, first and second low pressure flow paths, first and second high pressure flow paths, and a chemical injection flow path. Each flow path 37 will include an isolation valve 39. Isolation valve 39 may be any suitable valve such that operation of isolation valve may permit and restrict flow through the corresponding flow path 37. For example, isolation valves 39 may comprise gate valves, ball valves, or the like. Flow paths 37 will terminate at penetrations 41 in an inner portion of an upper mandrel 34 of master valve block 33. Upper mandrel 34 may be a integral portion of master valve block 33 or, alternatively, upper mandrel 34 may be a separate member coupled to master valve block 33. In the illustrated embodiment, penetrations 41 In the illustrated embodiment, penetrations 41 comprise male and female portions. At least one of the male and

the female portion of each penetration 41 will be mounted to the inner upper mandrel of master valve block 33.

[0021] Landing sub 27 will include landing sub flow paths 43. Landing sub 27 may be the same landing sub used to install and test tubing hanger 31 in wellhead 11 or a tubing spool or landing sub 27 may have a different orientation method or number of functions. Landing sub flow paths 43 may be formed in any suitable manner within landing sub 27 and will extend from a landing sub umbilical 45 to penetrations 41 at a lower end of landing sub 27. As shown, each flow path 43 will correspond with a flow path 37 of master valve block 33. The opposing pair of each penetration 41 will be mounted to a lower end of landing sub 27 so that when landing sub 27 lands on master valve block 33, each penetration 41 will mate with its respective pair to allow for fluid communication between respective flow paths 37 and 43. Landing sub umbilical 45 will extend through blowout preventer 35 and riser 23 to platform 25. There, high and low pressure fluids, along with chemical injection substances may be supplied to landing sub umbilical 45 for communication with respective flow paths 37 through landing sub 27. In an embodiment, electric power and communication may be supplied through landing sub umbilical 45 to landing sub passages 45 and flow passages 37.

[0022] In the embodiment of Figure 2, a subsea control module 47 and a subsea tree stab plate 49 may be mounted to subsea vertical tree 21. Subsea control module 47 may be any suitable apparatus adapted to operate functions of subsea vertical tree 21 and other devices located in and around subsea vertical tree 21. Subsea tree stab plate 49 may comprise a plurality of hot stabs adapted to allow a remotely operated vehicle (ROV) to interface with and provide hydraulic power and chemical injection to subsea tree 21 and subsea control module 47. The hydraulic pressure lines of flow paths 37 will be communicatively coupled to both subsea control module 47 and subsea tree stab plate 49 through a plurality of tees 51. Hydraulic fluid applied at the surface through landing sub umbilical 45 may supply subsea control module 47 with hydraulic power for operation of subsea tree 21. In this manner, the necessity of a separate umbilical to be run from the surface to subsea control module 47 will be removed, allowing all control of subsea vertical tree 21 to be conducted from platform 25 through riser 23 and landing sub 27.

[0023] In an alternative embodiment, illustrated in Figure 2A, tees 51 are not inserted into flow paths 37. Flow paths 37 are in direct fluid communication with subsea tree stab plate 49. A hydraulic bridging plate 53 may be coupled to subsea tree stab plate 49. Hydraulic bridging plate 53 will provide fluid communication between the hydraulic flow paths 37 and corresponding hydraulic flow paths 55 extending from subsea tree stab plate 49 and subsea control module 47. As described above with respect to Figure 2, hydraulic power may be supplied to subsea control module 47 from platform 25 through landing sub umbilical 45, landing sub flow passages 43, flow paths 37, and flow paths 55. In an embodiment, electric power may be supplied to subsea control module 47 from platform 25 through landing sub umbilical 45, landing sub flow passages 43, flow paths 37, and flow paths 55.

[0024] Referring to Figure 3, in an alternative embodiment, landing sub 27 may comprise an open water installation device such as a tree running tool, a handling device, a lower riser package, or an emergency disconnect package. Landing sub 27 may be run on a wire line 57 to the location illustrated in Figure 3. As described above, landing sub umbilical 45 may supply landing sub flow passages 43 with hydraulic power, electric power, and chemical injection materials. Similar to the embodiment of Figure 2, hydraulic power, and electric power may be further supplied to subsea control module 47 through flow paths 37. A person skilled in the art will recognize that the embodiment of Figure 3 includes the devices of and operates in a manner similar to the embodiment of Figure 2 and Figure 2A.

[0025] Accordingly, the disclosed embodiments provide a means to operate a subsea vertical tree through a subsea control module using a single umbilical run from the surface with a landing sub. This eliminates the need for use of multiple umbilicals, one that runs separately with the landing sub for operation of the landing sub and one run directly to the subsea control module. In addition, the disclosed embodiments eliminate the need for additional backup umbilicals associated with the subsea control module umbilical. Still further, the disclosed embodiments eliminate the need to have ROVs unhook from other assemblies to install and disconnect a subsea control module umbilical. The disclosed embodiments also reduce the management requirements associated with umbilicals by reducing the total number of umbilicals needed in an intervention or workover operation, thereby reducing installation time and risk. All these factors

contribute to a more efficient and safer system that has a reduced capital expenditure for use and a reduced operating expenditure due to the faster and more efficient installation method.

[0026] It is understood that the present invention may take many forms and embodiments. Accordingly, several variations may be made in the foregoing without departing from the spirit or scope of the invention. Having thus described the present invention by reference to certain of its preferred embodiments, it is noted that the embodiments disclosed are illustrative rather than limiting in nature and that a wide range of variations, modifications, changes, and substitutions are contemplated in the foregoing disclosure and, in some instances, some features of the present invention may be employed without a corresponding use of the other features. Many such variations and modifications may be considered obvious and desirable by those skilled in the art based upon a review of the foregoing description of preferred embodiments. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

What is claimed is:

1. A method for controlling a subsea completion or workover assembly in a subsea well (13) having a vertical subsea tree (21) communicatively coupled with a subsea control module (47), the method comprising the steps of:

(a) providing the vertical subsea tree (21) with at least one master valve block passage (37) leading from an inner portion of an upper mandrel (34) of a master valve block (33) to an exterior of the vertical subsea tree (21), wherein the at least one master valve block passage (37) communicatively couples the vertical subsea tree (21) with the subsea control module (47);

(b) providing the master valve block (33) of the vertical subsea tree (21) with at least one penetration (41) on the inner portion of the upper mandrel (34) communicatively coupled to the at least one master valve block passage (37);

(c) providing a landing sub (27) having at least one landing sub passage (43) extending from a landing sub penetration (41) on a lower portion of the landing sub (27) and connecting the at least one landing sub passage (43) to an umbilical (45);

(d) running the landing sub (27) and the umbilical (45) from a floating platform (25) to land the landing sub (27) on the master valve block (33) and registering the landing sub penetration (41) with the master valve block penetration (41);

(e) supplying at least one of hydraulic fluid pressure and electric potential to the subsea control module (47) through the umbilical (45), landing sub passage (43), and master valve block passage (37); and

(f) performing at least one of subsea completion operations and subsea workover operations with at least one of the hydraulic fluid pressure and the electrical potential, provided through the passages (43, 37).

2. The method of Claim 1, wherein step (e) further comprises operating an isolation valve (39) on the at least one master valve block passage (37) to allow fluid flow through the at least one master valve block passage (37) to the subsea control module (47).

3. The method of Claim 1, wherein:

step (e) comprises supplying treatment fluids to the subsea control module (47) through the umbilical (45), landing sub passage (43), and master valve block passage (37); and

step (f) comprises performing at least one of subsea completion operations and subsea workover operations with the treatment fluids provided through the passages.

4. The method of Claim 1, wherein the at least one master valve block passage (37) and the at least one landing sub passage (43) comprise a plurality of corresponding passages in communication through corresponding penetrations (41) in the master valve block (33) and the landing sub (27), step (e) comprising supplying hydraulic fluid pressure and electric potential to the subsea control module (47).

5. The method of Claim 1, wherein the landing sub (27) comprises a subsea test tree and step (d) comprises running the subsea test tree through a riser (23) extending from the vertical subsea tree (21) to the platform (25), the umbilical (45) running through the riser (23).

6. The method of Claim 5, wherein the subsea test tree is run through a blowout preventer (35) interposed between the master valve block (33) and the riser (23).

7. The method of Claim 1, wherein the landing sub (27) is a lower riser package and step (d) comprises running the lower riser package and the umbilical (45) through open water.

8. The method of Claim 1, wherein the landing sub (27) is an emergency disconnect package and step (d) comprises running the emergency disconnect package and the umbilical (45) through open water.

9. The method of Claim 1, wherein a remotely operated vehicle may communicate with the at least one passage (37) through a hot stab plate (49) located subsea and adjacent the subsea control module (47).

10. The method of Claim 9, wherein the at least one passage (37) communicates with the subsea control module (47) through the hot stab plate (49) which is capped with a bridging plate (53) having flow passages communicatively coupling the master valve block passages (37) terminating at the hot stab plate (49) with the flow passages (55) extending between the hot stab plate (49) and the subsea control module (47).

11. A subsea completion or workover assembly in a subsea well having a vertical subsea tree (21) with a master valve block (33) having an inner upper mandrel (34) for receiving a landing sub (27), comprising:

at least one master valve block passage (37) leading from the inner portion of an upper mandrel (34) of the master valve block (33) to an exterior of the vertical subsea tree (21), the at least one master valve block passage (37) further communicatively coupled to a subsea control module (47);

at least one penetration (41) on the inner portion of the upper mandrel (34) communicatively coupled to the at least one master valve block passage (37);

a landing sub (27) having at least one landing sub passage (43) extending from a landing sub penetration (41) on a lower portion of the landing sub (27);

an umbilical (45) connected to the landing sub (27), the at least one landing sub passage (43) in communication with the umbilical (45);

wherein the landing sub (27) lands on the master valve block (33) and registers the landing sub penetration (41) with the master valve block penetration (41); and

wherein at least one of hydraulic fluid pressure and electric potential are supplied to the subsea control module (47) through the umbilical (45), landing sub passage (43), and master valve block passage (37) to perform at least one of subsea completion and workover operations with at least one of the hydraulic fluid pressure and the electrical potential provided through the passages (43, 37).

12. The completion of Claim 11, wherein treatment fluids are supplied to the subsea control module (47) through the umbilical (45), landing sub passage (43), and master valve block passage (37) to perform at least one of subsea completion and workover operations with the treatment fluids provided through the passages (37, 43).

13. The completion of Claim 11, wherein an isolation valve is located on the at least one master valve block passage (37) to allow fluid flow through the at least one master valve block passage (37) to the subsea control module (47).

14. The completion of Claim 11, wherein the at least one master valve block passage (37) and the at least one landing sub passage (43) comprise a plurality of corresponding passages (37,

43) in communication through corresponding penetrations (41) in the master valve block (33) and the landing sub (27).

15. The completion of Claim 11, wherein:

the landing sub (27) comprises a subsea test tree;

a riser (23) extends from the vertical subsea tree (21) to the platform (25); and

the subsea test tree and umbilical (45) are run through the riser (23).