Deep Sea Hybrid Power Systems (Initial Study)
Subcontract 07121-1902

Functional Requirements – Basis of Design

Deep sea hybrid power systems may enable cost effective offshore oil and gas exploration and production. Advanced deep-ocean drilling operations, locally powered, may provide access to oil and gas reserves otherwise inaccessible and could decrease the air emissions associated with offshore operations. Such technology will therefore enhance the energy security of the United States. There is a strong driving force for the development of subsea capabilities on the ocean floor. Such facilities will require ample supplies of local power to operate machinery on the floor, ranging from control modules to pumps and compressors to supplying power for an entire drilling vessel.

This initial study will systematically screen several potential systems for energy generation and storage technologies for unattended environmentally-friendly deep-sea applications. To begin the screening process, a definition of systems requirements and the establishment of quantitative and qualitative selection criteria are required. These criteria will be used to guide the development of subsea hybrid power system suitable for powering oil and gas equipment. The existing knowledge base of high-performance energy conversion and storage systems, appropriate for underwater applications, will be used as the basis of several conceptual designs, and then those conceptual designs will be systematically screened for the best hybrid system.

The systems requirements were defined through a series of meetings with the deepwater operators that are members of the research team. The requirements were then reviewed with service providers.

The vision is to locate the power system in remote deepwater production sites. The power system would supply all power needs for the location so that there would be no electrical umbilical from a ‘host’ platform. The power system would be sized to supply the site specific needs.

- **Low power**: trickle charging of battery packs for satellite well control modules
- **Mid-power**: small scale multiphase pumps
- **Large-power**: gas compression, satellite field installations
- **Mega-power**: cold-ironing of drilling vessel (for example, a semi-submersible drilling rig where the rig may shut down all power plants on the vessel after it plugs into the subsea power plant), large subsea facilities

Water depths for the location of the power system may range from 8,500 ft to 12,000 ft. At these depths the water temperature is 39.4° F.

System redundancy and reliability of the subsea power supply may also be critical. Small equipment must be able to withstand a shock load of up to 3g. Larger equipment must be able to withstand a shock load of 5g.

Additional functional requirements are summarized in the following table.
<table>
<thead>
<tr>
<th>System</th>
<th>Output</th>
<th>Redundancy/Reliability Issues</th>
<th>Comments</th>
</tr>
</thead>
</table>
| Low Power  | Less than 5kW (potentially DC) | • Prefer 100% backup or hot standby.                                                         | • May be able to cover control modules for a cluster of wells (6 – 8 trees that are of a typical electrical-hydraulic type).  
• May be able to trickle charge control modules.  
• May be able to handle small chemical injection pumps.  
• Multiphase flow meter would need 30 to 100 watts.  
• Overall – not of much interest. |
| Mid Power  | 1 to 10 MW (AC)             | • Prefer 100% backup or hot standby.                                                          | • Small scale multiphase pumps (up to 3 MW each).  
• Small wet gas compressor (approx. 5 MW)  
• Direct electric heating of flowlines and jumpers (approx. 10 MW)  
• Example: BP King Booster Station (1 MW for each pump, 6.6 kilovolts) |
| Large Power| 10 to 30 MW (AC)            | • Prefer 100% backup or hot standby.                                                          | • Larger compression (20 MW each)  
• Example: Ormen Lange (60 MW total, 20 MW for each compressor)  
• Currently require 6.6 kV. Future requirements could be 13.8 kV or higher.  
• Prefer to be modular in concept (smaller units connected in parallel). |
| Mega Power | 30 to 200 MW (AC)           | • Prefer fail-safe system  
• Greater than 25 year life                                                                   | Prefer 100% backup or hot standby.  
Could serve as a subsea utility hub.  
As a stretch target, could consider a drilling vessel coming to location under its own power, then, cold-ironing into subsea power plant for drilling operations. A drilling vessel could require a maximum of 50 MW, including  
• 8 x 4 MW for thrusters  
• Approx. 5 MW for draw works (6,900 HP)  
• Approx. 7 MW for mud pumps (4 x 2,200 HP)  
• Two pedestal electric cranes and two electric knuckle boom cranes.  
• Prefer to be modular in concept (smaller units connected in parallel). |
Vision of Power Generation Systems
The vision is to have a range of sizes of various power generation systems. Based on the discussions held with operating companies, it is desirable to have systems that are sized on a fit-for-purpose basis.

A summary of subsea processing power requirements was published in March 2008.¹ Power requirements for multiphase pumps are illustrated in the graph while the table on the next page summarizes the various installed systems along with the power requirements.

Based on the information gathered from interviews with operators, a review of the current systems installed and a review of the literature, the recommendation is made to focus on three ranges of power requirements: mid, large and mega. The low power range (less than 5 kW) is adequately handled through technology currently available today.

Mid-Power Vision
An example of a mid-power requirement is the BP King Project as discussed in the sidebar.²

The mid-power vision is to supply power to remote subsea facilities. Facilities could include multiphase pumping units, water injection units, small wet gas compressors, direct electric heating of flowlines or jumpers.

---

| PROCESSING DISCIPLINE | COUNTRY | FIELD OR PROJECT | COMPANY | COMMENTS | YEAR | OWNER/FIELD OPERATOR | REGION | WATER DEPTH | TIPBACK DISTANCE | SYSTEM LIQUID THROUGHPUT | DIFFERENTIAL PRESSURE | FUEL OR GAS | % GP VOL | COMPANY | MC, @ WHR | PUMP TYPE | PUMP MANUFACTURER |
|----------------------|--------|----------------|--------|----------|------|----------------------|--------|-------------|-----------------|-------------------------|---------------------|------------|----------|--------|---------|-----------|-----------|----------------|-----------------|
| SUSSEA GAS COMPRESSION | | | | | | | | | | | | | | | | |
| 1 | | Dehlin K-Lab Test | | | 2001 | Norway | | | | | | Framo Engineering | | | | | | |
| 2 | | Deepwater | | | 2001 | Norway | | 850 | 2,289 | 139 | 188 | 529 | 79 | 60 | 67 | 80 | Aker Kvaerner | 4 | | | | | |
| 3 | | Aquila | | | 2010 | StatoilHydro | | 256 | 6,020 | 63 | 85 | | | | | | | Aker Kvaerner/GE | | | | | |
| 4 | | Belt | | | 2010 | StatoilHydro | | 243 | 1,176 | 4 | 6 | | | | | | | TBA | 2 | | | | |
| 5 | | Britannia | | | 2000 | StatoilHydro | | 355 | 1,518 | 36 | 93 | 209 | | | | | | | TBA | | | | | |
| 6 | | Smeltred | | | 2000 | StatoilHydro | | 514 | 3,402 | 165 | 285 | | | | | | | TBA | | | | | |
| 7 | | Risør | | | 1999 | StatoilHydro | | 341 | 1,322 | 147 | 239 | | | | | | | TBA | | | | | |
| | | Total | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| FULL WELL/STREAM BURSTING & DIVERTING | | | | | | | | | | | | | | | | | | | | | |
| 1 | | Shihua ZF1 Field (H15) | | | 2019 | Sinopec | | 15 | 212 | 0 | 0 | 40 | 80 | 0.1 | | | Sinopec Engineering | | | | | | |
| 2 | | Norwegian Field (EM Project) | | | 2019 | Norwegian Shell | | 207 | 630 | 8 | 37 | 183 | 29 | 53 | 173 | 75 | Framo Engineering | | | | | | |
| 3 | | Gullfaks Field | | | 1996 | JIP ESP | | | | | | | | | | | | | | | | | | |
| 4 | | Lehn_mZF1 Field (K16) | | | 2019 | Shell | | 154 | 476 | 9 | 56 | 73 | 113 | 35 | 98 | 13 | | TBA | | | | | |
| 5 | | Murchison Field (ESP Project) | | | 2019 | Shell | | 142 | 419 | 11 | 68 | 63 | 120 | 30 | 90 | 10 | | TBA | | | | | |
| 6 | | Tassos Field | | | 2002 | Shell | | 272 | 740 | 7 | 45 | 72 | 189 | 36 | 60 | 10 | | TBA | | | | | |
| 7 | | Cell C and 03 | | | 2000 | Shell | | 247 | 738 | 11 | 63 | 100 | 200 | 40 | 60 | | | TBA | | | | | |
| 8 | | Cell 3 (ESP) | | | 2000 | Shell | | 250 | 721 | 7 | 47 | 74 | 188 | 36 | 60 | | | TBA | | | | | |
| 9 | | Mutarak | | | 2017 | Shell | | 136 | 409 | 4 | 25 | 64 | 128 | 20 | 30 | 10 | | TBA | | | | | |
| 10 | | Ethanol | | | 2017 | Shell | | 136 | 409 | 4 | 25 | 64 | 128 | 20 | 30 | 10 | | TBA | | | | | |
| 11 | | ESF Tackback | | | 2015 | Shell | | 136 | 409 | 4 | 25 | 64 | 128 | 20 | 30 | 10 | | TBA | | | | | |
| 12 | | Jobete | | | 2017 | Shell | | 136 | 409 | 4 | 25 | 64 | 128 | 20 | 30 | 10 | | TBA | | | | | |
| 13 | | Subsolubilization 2 Systems | | | 2005 | Shell | | 200 | 591 | 8 | 53 | 75 | 113 | 35 | 98 | 10 | | TBA | | | | | |
| 14 | | in King (7) | | | 2017 | Shell | | 170 | 517 | 20 | 10 | 500 | 80 | 0 | 72 | 100 | Aker Kvaerner | 2 | | | | | |
| 15 | | North Field | | | 2017 | Shell | | 143 | 417 | 11 | 50 | 89 | 178 | 33 | 53 | 10 | | TBA | | | | | |
| 16 | | Novy Field (17) | | | 2007 | Shell | | 169 | 514 | 8 | 40 | 80 | 160 | 32 | 63 | 10 | | TBA | | | | | |
| 17 | | Vigo 1 | | | 2016 | Shell | | 157 | 468 | 7 | 45 | 72 | 189 | 36 | 60 | | | TBA | | | | | |
| | | Total | | | | | | | | | | | | | | | | | | | |
**Large-Power Vision**

An example of a large-power requirement is the Ormen Lange Project. Specifics about the Ormen Lange field are discussed in the sidebar.

Subsea gas compression would require total installed power in excess of 50 MW to handle the large throughput (60 Mcm/d). The system under development includes the following:\(^3\)

- Long step-out power supply (120 km offset, 70 MVA, 120 kV)
- Subsea power distribution to 22-kV level (circuit breakers, variable speed drives)
- Four off 12.5 MW centrifugal gas compressors with gas-filled, high-speed motors and magnetic bearings
- Four off liquid pumps
- Four off separators
- Other equipment (coolers, control system, instrumentation, valves, process piping, various connections)

A generic system arrangement for the subsea compression system is illustrated to the right.

The large-power vision is to supply power to remote subsea developments that include large gas compression requirements.

---


Mega-Power Vision
There are three different scenarios related to the mega-power vision:
- Large subsea development in remote location
- Centralized subsea utility hub
- Any subsea development that would incorporate cold-ironing of drilling vessel

Large Subsea Development
An example of a large subsea development is the Shtokman field, located 342 miles from the Kola Peninsula in the Barents Sea in 1,148 feet of water. Initial gas in place is estimated at 134.2 Tcf and at full field development is expected to produce 3.2 Tcf/year in 2028. The development will have three subsea production facilities and three production platforms. Phase one will include 20 wells arranged over three subsea templates. If subsea compression is used at Shtokman, power requirements will be significant.

Centralized Subsea Utility Hub
A centralized subsea utility hub, supplying power, chemicals (corrosion inhibitors, methanol, etc.), water injection, gas compression, etc. could be located in a deepwater remote site to service various subsea developments that are within a certain distance, for example, perhaps a 200 – 250 km radius. This subsea hub vision is similar to that described in the sidebar. Although the figure illustrates only the compression, the hub could include other power requirements such as multiphase pumps and water injection facilities.

Cold-Ironing of a Deepwater Drilling Vessel
Cold ironing is a cost effective method currently used to reduce shipping emissions in port for container, cruise and reefer vessels. The vision is to enable a deepwater drilling vessel to arrive on location under its own power. Once at the drill center, the vessel would be able to hook up to the subsea power generator facility and shut down the vessel’s power plant. Turning off engines and plugging into the subsea facility would eliminate all

emissions associated with power generation on the vessel. The vessel would have its own power plant system as a back-up. Power requirements could require a maximum of 50 MW, including

- 8 x 4 MW for thrusters
- Approx. 5 MW for draw works (6,900 HP)
- Approx. 7 MW for mud pumps (4 x 2,200 HP)
- Two pedestal electric cranes and two electric knuckle boom cranes.

The mega-power vision would be to enable the option of cold-ironing of the drilling vessel at the various drill centers that are located at various reservoirs that are tied to a central utility hub, or the various drill centers associated with a large subsea field development. The mega-power vision would include powering of all subsea facilities associated with the utility hub requirements. To enable back-up systems for reliability/redundancy the vision would be to have multiple subsea power generation facilities that are tied together to create the mega-power facility. For example, a 200 MW facility could consist of four 50 MW facilities that are tied together in a common control methodology.