Power Solutions for Multiphase Boosting in a Subsea Environment

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The MBS-Project

The MBS-Project (Multiphase Boosting Systems) is part of the joint research project ISUP (Integrated Systems for Underawater Production of Hydrocarbons). In the context of the research initiative "Go Subsea" ISUP is sponsored by the Federal Ministry of Economics and Technology supported by Project Management Jülich. Subject of this R&D project is the whole system around the actual subsea pump, especially under the aspect of power. In detail that means power generation, power transmission and power enhancement as presented in the following chapters.

Interaction of Subsea Environment and Subsea System

Design criteria for subsea systems are substantially determined by the surrounding environment. Therefore a study was conducted to evaluate the impact of the subsea environment on the Multiphase Boosting System on the one hand and on the other hand the impact of the system on the environment.

71% of earth's surface are covered by oceanic water. Since hydrocarbon reserves are only found in continental shelf regions and the conditions in shallow water are well known due to decades of experience in oil and gas production in this regions, this study concentrates on the deep sea below the continental shelf regions in 1000 to 3000 m water depth.

Contrary to shallow water, the conditions in the deep sea are more stable because of a lack of weather influences. Temperatures in this depth are between –3 °C and 7 °C. The oxygen concentration in the water is always close to saturation, the salinity varies from 0.5 to 4.5 in different regions. These conditions are essential for the choice of materials and coatings.

The current speed is normally in the range of 3 cm/s to 8 cm/s. Only temporary, during so called benthic storms, the current speed can rise up to 36 cm/s, which is fast enough to bring fine particles from the deep sea floor into suspension. This can perhaps lead to sedimentation or erosion at the subsea system. In addition, hot surfaces of the system can start precipitation of calcium carbonate out of the sea water which can reduce the cooling capacity of the heat exchanger.

Hazards from living organisms are considered as small. Fouling organisms are very rare in the deep sea and the few whale and squid species that can dive to these depths will rather avoid than attack a subsea system.

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For the protection of the sensitive ecological equilibrium of the deep sea it is crucial to study the impact of a Multiphase Boosting System on the surrounding environment. When the system is launched to the seabed, it will compress the sediments and therewith the fauna and flora living in and on the seafloor. Any leakages off process or lubrication medium during the whole life cycle can cause severe damage to the environment and the organisms living there. In operation, the system emits heat and noise. The heat may kill some plankton organisms that come in touch with hot surfaces (up to 60°C). Apart from that, the warmth is diluted in the ocean in short distance to the system. More impact on the environment has the noise that is created by a running system. Most marine mammals can hear noise in a range of 20Hz to 200kHz. Some of the animals react very sensitive to increasing noise. It can affect the abilities of hearing, communicating and orientating. These effects are enhanced by the good spreading of sound in water.

The MBS Test Stand

Overview

To verify the theoretical research results, a special closed loop multiphase test facility was developed. The basic idea of this facility was to built one flexible test stand that can easily be adjusted to the individual test requirements of the different research topics. The basic components are:

- Separator and header system (300lbs)
- Synchronous electric motors / generators (25, 50, 100kW)
- Various twin screw aggregates
- High dynamic VFD with 3 axis in parallel, speed and torque operation, energy recovery
- Low voltage distribution
- Instrumentation, PLC and additional software for unmanned automated test runs

Hardware and setup

The main part of the test bed is the 3.8 cubic meter separator connected with the header system. The mixture control section provides defined liquid-gas-mixtures with GVFs from 0 to 100% for the motor and pump tests. The test aggregates are connected to the headers via hoses to enable flexible test assemblies. Electric motors and pumps are installed on base frames to raise them to one common shaft height and thus provide free combination of electric and hydraulic components. To gain measuring data, various pressure, temperature and flow transmitters are installed. As they are not hardwired but connected with plugs, the measuring points can easily be adjusted to the actual assembly.

Figure 1: MBS test facility

At the moment, all tests are executed with air and water. But most of the test facility is designed for explosion proof operation. Thus it would be possible to conduct tests with real multiphase media, which behaves different from air and water.

Control System

To fit the flexibility of hardware and transmitter arrangement, the analog inputs of the PLC can be configured by the operator. All transmitters have 4 to 20 mA output signals. Each analog input can be configured in tag name, range, unit and setpoints for alarms and shut-downs to guarantee safe operation. The PLC also operates the actors, namely the flow control valves and the electric motors respectively generators. All actors have three operation modes: in manual mode the operator enters fixed values e.g. motor speed. In semi automatic mode, the actors can additionally execute PID control functions. For example the opening of a valve is automatically adjusted to reach a certain flow defined by the operator. Furthermore for the automatic mode a simple script was developed to program automated test procedures. The script is based on the control functions of the actors which can be sequenced in any order. The execution of the programmed sequence is determined by different step enabling conditions, e.g. expiration of a certain time or excess of a defined measuring value. This script language in combination with the setpoints and an automatic data recording enables the execution of fully automated test procedures and long time tests without the continuous presence of an operator.

Long Distance Power Transmission

Overview

New subsea installations are often remotely located and thus have to be tied back over long distances to existing structures onshore or offshore which supply control signals, hydraulics and power. Especially the operation of variable speed electric motors is challenging. In addition to the ohmic drop, due to electric properties of long cables the quality of the sinus signal is affected too. In the following, the challenges resulting from long cable distances are described in detail and some concepts for solutions are presented.

Transmission concepts

The most effective way to transmit electric energy over long distances is high voltage direct current (HVDC). In the easiest concept, this would require a subsea DC motor. Today there are no contact-free DC-motors hat can run in a fluid filled environment for 5 years without maintenance. Therefore this concept cannot be put into effect. Another way to use the advantages of HVDC is to put either the whole variable frequency drive (VFD) or only the AC inverter on the seafloor near the motor. Today such subsea components with proven reliability are not available. But this will probably be a feasible solution for the future as the development in this field of technology is in progress.

These restrictions mean, that today HVDC is no option. Thus the conventional system which consists of VFD topside, long three-phase cable to the subsea installation and an asynchronous motor is applied. Still there are different possible improvements to this concept that will be discussed in this chapter.

Simulation Model and Results

To examine the system VFD – cable – motor a simulation model was developed for each component. The single component models were checked for plausibility and verified with real data as far as available. After that the single components were integrated to one comprehensive model.

A cable causes ohmic, capacitive and inductive losses, depending on design and length (Figure 2).

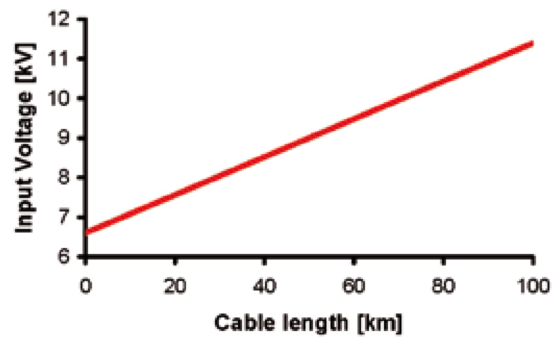

Figure 2: Input voltage depending on cable length

There are possibilities to lower the losses, like bigger profiles or higher isolation class, but these measures always have great effects on costs and flexibility.
Conventional VFDs supply a constant output voltage. For an application with a long cable between

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motor and VFD, the output voltage would be the voltage drop over the cable in addition to the motor voltage in nominal load operation. With constant VFD output voltage this causes overvoltages when the motor load is lower or an additional voltage drop when the load of the motor is higher. The difference to the nominal voltage depends on the length of the cable. According to this long cables, a sudden drop in load causes overvoltages that can damage the isolation in motor and cable. In case of a sudden rise of the motor load, the motor speed goes down or might even stop. Most critical are of course highly dynamic processes especially sudden load steps and the start up of the motor.

The start up of the motor is a critical process because it is dynamic and requires high torque. To achieve the maximum torque, a constant ratio between voltage and frequency at the motor is required. Up to 30 km cable length it is sufficient to fulfil this criterion with additional consideration of the voltage drop in the cable in the stationary nominal operation point. This voltage drop is calculated with a conventional cable equation. With longer cables it becomes obvious that the dynamic losses are even higher than the stationary ones. That means the VFD output voltage must be higher than calculated with the stationary cable equation. Along with this additional voltage the overvoltages in cable and motor rise until they get too high at 50 to 60 km of cable.

To avoid these effects and reach even longer distances the VFD-voltage has to be varied depending on the motor load. This requires real time data from the subsea system that has to be transmitted via fiber optics. With this data, a specially programmed controller can adjust the voltage to the load conditions of the subsea motor. Depending on speed and quality of the data this can extend the feasible tie-back distances substantially. But even with high data rates the range is limited because the reaction time between VFD-voltage and motor voltage increases with the cable length. So the next step to enable bigger step-out distances is the development of simulation models that can predict the behaviour of the load in the near future out of available data and thus compensate the long reaction times.

In any case one can see that it is a big advantage if the motor can start without load because this requires lower torque and thus a higher voltage drop over the cable can be accepted. An important design parameter for the motor is also its isolation and his ability to cope with temporary overvoltages.

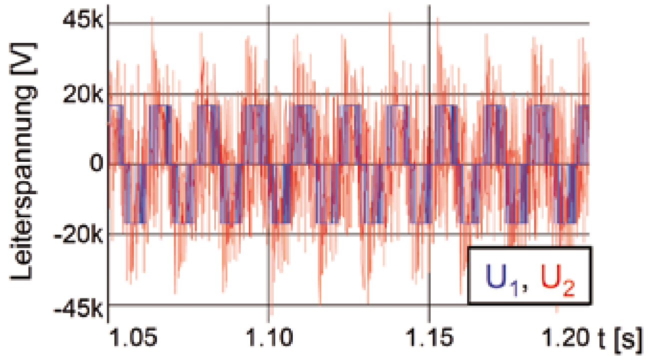

Figure 3: Overvoltages caused by travelling waves

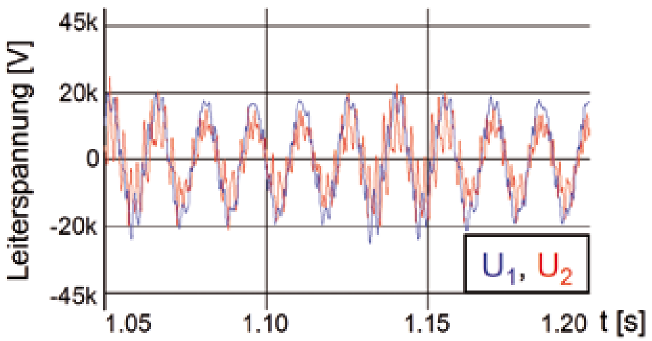

Figure 4: Dampening of travelling waves

Another effect that is enhanced by long cables is the formation of travelling waves in the cable (Figure 3). The waves are caused by the steep gradients of the PWM-signal of the VFD output voltage. Interference of the waves and their reflections can lead to significant overvoltages that cause damages in the isolations of cable and motor.
One way to reduce the effects of the waves is the installation of an electric filter at the VFD output to dampen the high frequency waves (Figure 4)

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Another way to achieve a smoother sinus signal is to put a transformer at each end of the cable to raise the voltage in the cable independent of VFD and motor. This measure requires a reliable and pressure resistant subsea transformer, but otherwise, the higher voltage in the cable reduces the losses. One challenge here is variable frequency operation. As transformer performance depends also frequency, further examinations have to be conducted on this concept. To avoid variable frequency operation, hydraulic speed control, in connection with the application of transformers can be a viable solution.

Conclusion

For successful installation and operation of subsea systems supply and control play an increasingly important role with longer tieback distances. Not only the core subsea components determine the feasibility new subsea installations in great depth and step out distances. Advanced AC-supply with load controlled voltage and HVDC are the future technologies to enable the economic and safe operation of subsea equipment over long distances.

Hydraulic Speed Control

Introduction

The basic idea of hydraulic speed variation is to provide a coupling that enables variable output speed with constant input speed. In subsea applications, hydraulic speed control has two main advantages: the electric motor can run in constant speed so that the electric supply chain can be optimized for one frequency. In addition, hydraulic couplings enable an unloaded start up of the motor which is a positive aspect for the power supply over long cables. Onshore, hydraulic speed control can also be applied in combination with gas or diesel engines to increase their limited ability in speed variation. Another possible application is the independent variable speed operation of two pumps with one electric motor. This could be a solution for high differential pressures with two pumps in series.

Hydrostatic Transmission

For hydrostatic transmission, a hydraulic pump and a hydraulic motor are connected through an oil circuit. Both aggregates work after the positive displacement principle which provides fast reaction times of the system as the hydraulic fluid is incompressible. To provide speed variation at constant input speed, one or both aggregates can be executed with variable displacement volume. That means that the transmission ratio is determined by the ratio of the displacement volumes of hydraulic pump and motor. After a concept study it was decided that the combination of variable pump and constant motor with a closed oil circuit as displayed in Figure 5 is the most suitable for the application in multiphase boosting, especially subsea.

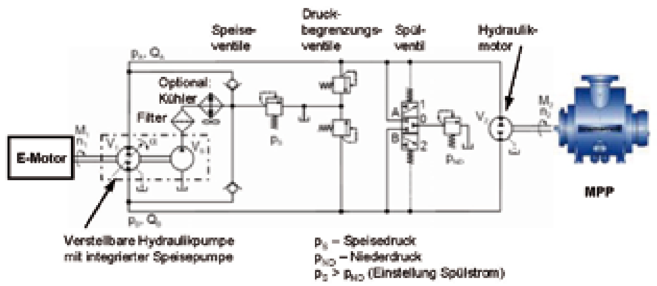


Figure 5: Closed loop system with variable pump

Figure 6: Closed loop system with variable pump

A fully submerged test system has been developed (Figure 6) to verify the applicability of hydrostatic drives in oil filled subsea systems.

Hydrostatic aggregates operate with high pressures, e.g. 350 bar which results in a very high power density. In addition to the compact construction, motor and pump are only connected through the oil circuit. This provides high flexibility in arrangement and system integration. As the single hydraulic components are limited in size and speed, it is also possible to design more complex systems with more than two aggregates. Hydraulic pumps are often available with power take off (PTO) so that several pumps can easily be driven by one shaft. Especially at a twin screw pump with for shaft ends, it is possible to apply several motors to one driven machine. To extend the operating range even more, gear boxes with fixed transmission ratio can be applied between driving motor and hydraulic pump or between hydraulic motor and driven machine.

Hydrostatic drives are a proven robust technology e.g. as pump drives on ships or as mobile application in construction and farming machines. Their modular conception and absence of a mechanical shaft connection leads to great flexibility in application. To keep the complexity of the hydrostatic drive systems to a reasonable amount, a sensible limit for the application is around 1000kW driving power.

Hydrodynamic Transmission

Hydrodynamic transmission was examined on the basis of a torque converter. A torque converter is an integrated machine with a centrifugal pump and a turbine in a common oil circuit.

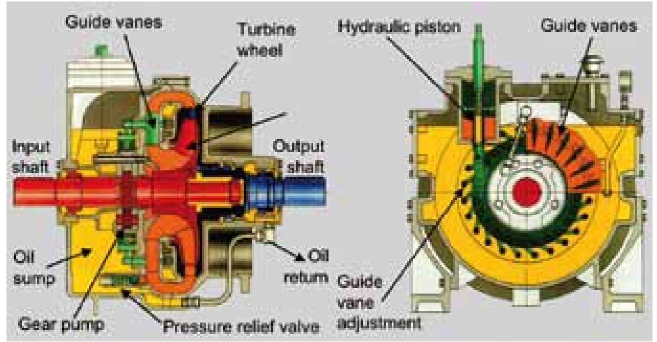


Figure 7: Torque Converter (Source: Voith Turbo AG)

The pump is driven by a motor while the turbine is connected to the driven machine. The speed variation is achieved by variable guide vanes which act as an adjustable hydraulic resistance in the oil circuit (Figure 7).

Because of the centrifugal pump principle, the torque converter has smoother operation characteristics and slower reaction times compared to the hydrostatic drive. This poses no problem because in multiphase boosting, no highly dynamic speed variation is required because of the large pipe volumes up- and downstream of the pump that respond slowly to an altered pump speed. This behaviour is an additional advantage regarding the long distance power supply: the torque converter absorbs sudden load changes of the driven machine and thus reduces electrical load steps and overvoltages in the now stabilized power supply chain.

The torque converter is an approved product with applications in oil & gas, industry and power generation. It has a very long lifetime because of the contact free pumping and turbine principle. Torque converters are build for high power applications (up to 60MW). Therefore this technology is best suitable to drive even the biggest multiphase pumps.

For testing, two aggregates were built. One with a newly developed concept was integrated in the MBS-Demonstrator (Figure 8). As measuring possibilities in the MBS-Demonstrator are limited, a conventional model in the same frame size was built for the MBS-Test Stand.

Figure 8: Integrated Torque Converter

Power Generation – Multiphase Twin Screw Motor (MTM)

In this chapter the generation of power out of an untreated high pressure well stream is examined. The idea is to use the approved twin screw technology in a multiphase motor instead of in a pump.

A typical scenario in oil production is a relatively fresh reservoir with a wellhead shut-in pressure of several hundred bar. From the wellhead the flow is throttled through a choke in the following pipeline system. The setting of the choke is determined by the target values for reservoir and flowline pressure.

The multiphase twin screw motor will be installed behind the choke. Now the choke is opened wider and the differential pressure from after the choke to the pipeline system is regulated by the multiphase motor. The hydraulic energy of the wellstream with this differential pressure is converted into mechanical power in the twin screws. This mechanical energy can either be used to drive a generator and generate electric energy or as a direct drive for another machine. The main advantage of the twin screw motor is the ability to cope with the variable composition of the hydrocarbon stream and thus the assurance of a stable power generation with up to 70% GVF at the inlet of the motor.

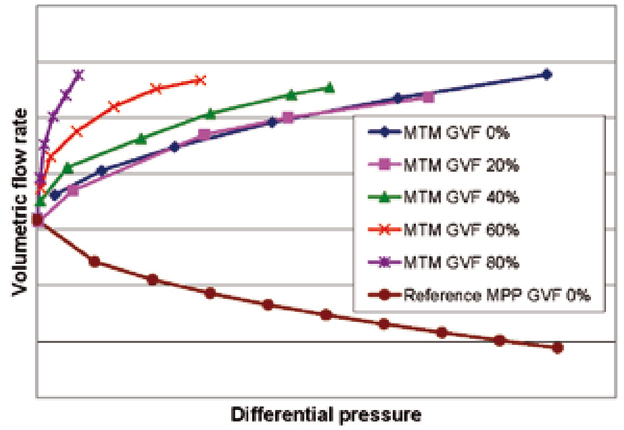


Figure 9: Test results multiphase motor

In Figure 9 some test results with the multiphase motor are displayed. Basically it has the same operating characteristics as a multiphase twin screw pump without the recirculation, meaning the generated power depends on flow rate and differential pressure. The volumetric efficiency depends mostly on the gas content. But as one has to compare the efficiency of the motor to that of the choke, the multiphase twin screw motor is an effective solution for the utilisation of otherwise wasted energy. Another way to look at the value of the multiphase motor is to compare the local subsea power generation against long distance power transmission with all its losses and high costs. Especially for the start up of a new remotely located field without existing infrastructure this is an interesting option.

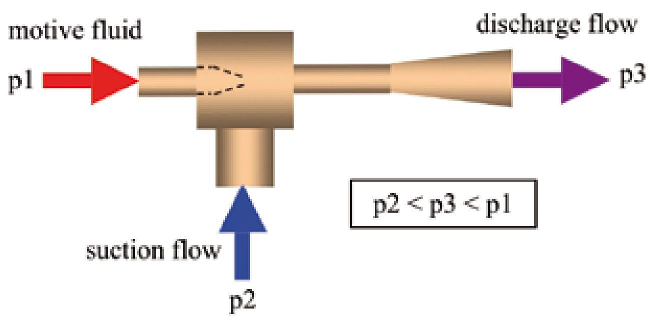
The full potential of the MTM technology is shown in the following calculation. In 2009 an average of 70,66 million barrel crude oil per day was produced [8]. With an average GVF of 50% and 40bar differential pressure throttled down at the choke that makes a total of 1GW hydraulic power available for power generation.

Power Enhancement in Wet Gas Compression – Multiphase Jet Pump

In this chapter, the use of a jet pump as pre-compressor to a multiphase twin screw pump is discussed. First the functional principle of the jet pump which is based on impulse transfer is illustrated. It is shown that under the right operating conditions the jet pump can enhance the capacity and efficiency of a boosting system substantially.

Jet Pump

The jet pump is a pump without any rotating parts. As shown in Figure 10, its power source is the high pressure motive fluid. This high pressure medium is injected through a nozzle into the head of the jet pump. With this conversion of potential energy to kinetic energy, the accelerated motive fluid creates a low pressure zone in the head so that the suction flow is drawn into the pump. During the mixing of the two fluids in the jet pump, impulse is transferred from the motive fluid to the suction fluid, so that the suction fluid gets accelerated. After this impulse transfer, the accelerated stream enters the diffuser where kinetic energy is converted into potential energy. This results in the pressure rise from suction inlet to



the discharge end.

Figure 10: Jetpump - functional principle

The extend of the pressure rise depends on different factors. The central process is the impulse transfer between motive and suction fluid. Therefore the determining physical factors are the differential pressure end the mass flow ratio between suction and motive fluid. The geometries of the jet pump are adapted to the actual process and medium conditions to make the jet pump process as effective as possible.

Wet Gas Compression

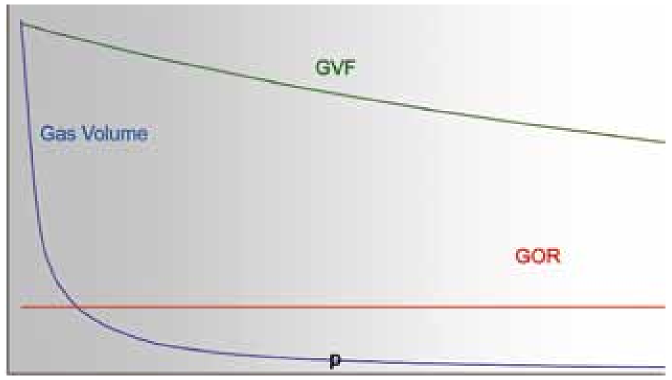


Figure 11: Gas characteristics in compression process

Wet gas is a mixture of hydrocarbons, mostly gaseous, with a certain amount of liquid. Pressure boosting of this medium poses a challenge because it contains too much liquid for gas compressors and too little liquid for a conventional pump. Even for a multiphase pump, wet gas demands special measures due to several process parameters: Especially at low inlet pressures, little changes in pressure will cause sufficient compression or expansion in gas volume (Figure 11). Exactly this expansion occurs when the wellhead pressure is drawn down to increase oil recovery. This bigger gas volume calls either for raised speed or for a larger pump. In both cases, this means an increase of the required drive power.

$$P = f(\Delta p, Q)$$

The second effect of a reduced inlet pressure is the increased compression ratio. A draw down from 2 bara to 1 bara e.g. means the compression ratio is doubled and may become critical for the multiphase pump.

Another topic of wet gas compression is always the heat removal. Because of it's low density, the absolute heat capacity flow through the pump is too small to take enough heat out of the pump system.

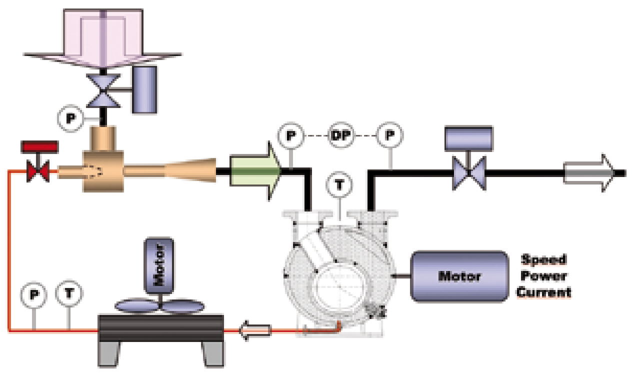


Figure 12: Two stage wet gas compression

To face all these challenges an improved two stage wet gas compression system has been developed (Figure 12). The low pressure wet gas is pre-compressed by a jet pump, so that the volume flow rate is reduced. The high pressure motive fluid is taken out of the separator casing of the multiphase pump and can be cooled additionally to regulate the system temperature. The spraying of the cool motive fluid through the nozzle provides optimal heat transfer in addition to the impulse transfer in the jetpump. The main pressure rise of the process is done by a twin screw multiphase pump. The improvement of the system results from the gas compression in the jetpump. The slight pressure rise in the jetpump causes a substantial compression ratio provided the process runs on a low pressure level (Figure 12). Therefore the operating conditions of the multiphase pump are considerably improved by the jet pump: The reduced volume of the gas flow mixed with the motive flow results in less drive power, lower compression ratio and lower GVF compared to the conventional system without jet pump.

Test Results

The jet pump is capable of handling multiphase flow in varying compositions including slug flow. Of course the best results are observed with liquid motive medium and gaseous suction flow. With a test pump and a motive pressure of 24 bar the system capacity of a multiphase pump could be raised by 50 % (Figure 13).

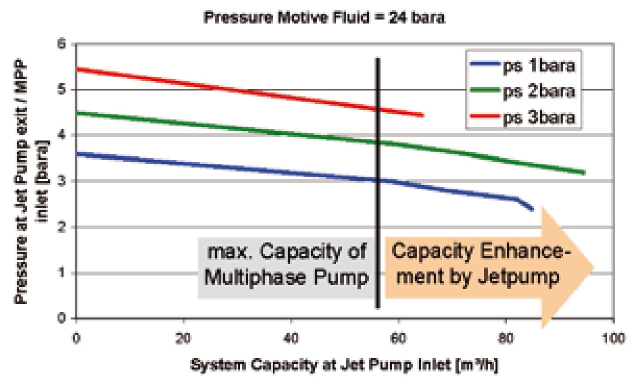


Figure 13: Capacity enhancement by jetpump

The main criteria for a successful application are low inlet pressure, high GVF and an adequate source for the motive fluid so that the volume flow rate at the exit of the jet pump is smaller than the suction flow rate.

Phase Behaviour of Hydrocarbons

Talking about multiphase boosting or power generation means to handle the untreated wellstream which can consist of different hydrocarbons, water and additional components like sour gas. Especially the phase behaviour of hydrocarbons depends on pressure and temperature.

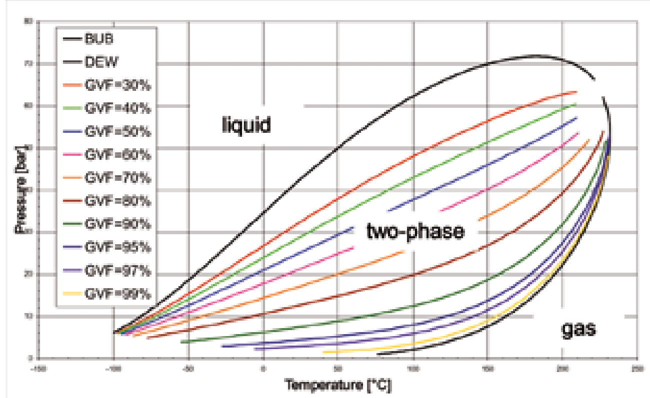


Figure 14: Phase envelope of a real reservoir fluid

As most multiphase tests are run with water and air, the practical knowledge about the effects of phase changes on the process is limited. Especially the jet pump process and the multiphase motor process are very sensitive to phase changes. In the jet pump its important to know whether the motive fluid stays liquid after the nozzle. In the multiphase motor its important to know if there is enough liquid for sealing the gaps even as the gas content may rise with the pressure drop. To predict the behaviour of the reservoir fluid, a tool based on standard software was developed. Depending on a given composition of hydrocarbons, the program can calculate phase envelopes (Figure 14) and flash compositions of liquid and gas phases at different pressures and temperatures. Even pseudo-components can be handled. The working principle of the program is the numerical solution of different equations of state in the thermodynamic equilibrium. Different models like Redlich-Kwong-Soave are applied. The required chemical data is store in an included data base.

Because of its simple software base and the easy usability, BorFlash is an efficient tool to calculate the phase behaviour of hydrocarbon mixtures. It helps to get a more profound understanding of multiphase processes and effects and its an easy way to deal with medium compositions given by customers. With its broad thermodynamic database, it also enables the calculation of heat balances in multiphase systems and thus helps in the design of the cooling systems.

Design Features of the Subsea Demonstrator

To the end of the research project a demonstrator subsea with some special new design features was built. Basically it follows the patented double pressure compensated cartridge design (DPC). The outer pressure vessel meets the required pressure rating of the system. The inner cartridge, which contains the whole drive train, is completely filled with oil. A special hydraulic system continually provides a defined overpressure of the oil against the discharge pressure. This function separation allows a simple design of the thick walled outer pressure vessel. The inner cartridge is only fastened at the lid of the outer vessel. This enables easy assembly, especially in vertical installation as realized here, and reduces the stresses resulting from thermal expansion. The lid is locked by a clamping collar. Combined with an intelligent redundant seal system, this avoids the high bending stresses which occur in the bolts of conventional flange connections and simplifies assembly and disassembly. The locking mechanism can even be adapted to ROV-operation.

Drive Train

The vertical drive train of the demonstrator consists of the twin screw pump, the hydraulic torque converter, the electric motor and a centrifugal pump for internal oil circulation (Figure 15).

The twin screw pump is equipped with the new high-dp-rotors including stronger shafts to reduce the bending and to allow smaller gaps. These rotors are the result of a development process started in the course of the BP-King Project and carried on in the MPT research project. It enables the pump for higher differential pressures up to 100 bar for low GVFs and up to 50 bar for higher GVFs. The discharge compartment of the pump is the outer pressure vessel, which provides an optimal separation chamber to hold back enough liquid for recirculation.

Figure 15: Drive train MBS-Demonstrator

The torque converter was specially designed for the subsea system. The turbine part is mounted directly on the drive shaft of the twin screw pump without additional bearings. The pump wheel of the converter is mounted on the motor shaft. The bearings of the pump wheel replace one radial and the axial bearing of the electric motor. This converter design without it's own shafts enables a drive train without mechanic couplings while the number of bearings stay the same. The electrical properties of the system are improved substantially as the motor can start up load free, operate at constant speed and gets no sudden load changes because of the damping effect of the hydrodynamic working principle of the torque converter.
The MBS-Demonstrator is driven by a submersible electric motor. Each of its single coils is separately isolated with polymer. This enables the motor to run either oil or water filled without short-circuit. It's slim design reduces the diameters of the pressure vessels and it has a second shaft end where the oil circulation pump is mounted to.

Cooler

All components of the drive train generate losses and heat up the oil circuit. Therefore an subsea heat exchanger hast to be added to the system. With the cold seawater all around, a lot of cooling capacity is available. It's more the opposite: After longer standstill of the system, the oil gets cold and thus very viscose. To cope with the sometimes too high cooling capacity of the surrounding seawater when the multiphase pump is not running at full load, a concept for an intelligent self-regulating cooler was developed. The concept displayed in Figure 16 shows a heat exchanger system with the main oil-seawater-cooler and after that an oil-oil cooler which pre-heats the cold oil coming out of the main cooler with the warm oil out of the pumping system.

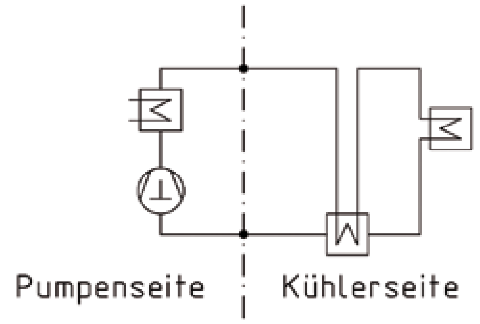


Figure 16: Self-regulating subsea heat exchanger

This pre-cooling / pre-heating in the oil-oil-heat exchanger provides the MPP-System with an almost constant oil inlet temperature under all operating conditions. Especially in partial load, the lower viscosity of the oil entering the pumps is a great benefit for the whole system. At the moment an actual cooler design is done, to realize the concept in a prototype.

Connectors

In the course of the vertical installation of the pump in the subsea frame all interfaces of pump

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and frame have to be connected. Practically, that means the system needs wet mateable connectors for power, signals, hydraulics and process.

Figure 17: Subsea connector interfaces with piping

The connectors are mounted in external arms fastened at the pressure vessel. This measure allows for more flexibility in positioning. (Figure 17)

The backside of the power connector has to be pressure resistant as it is connected to the oil filled motor cartridge. On the backside of the signals connector an encapsulated non-pressurized junction box is installed where the electronics of the pressure and temperature transmitters are located. After positioning, the electrical plugging is achieved simply by gravity.

The connectors for hydraulics have to be wet and leakage free mateable. This is achieved with a dual pressure compensated clean-break coupling for in- and outlet of the seal oil system. The locking mechanism can be ROV-operated.

The process connection must also be operable by ROV after positioning of the system. This is realised with single bolt clamp connectors.

Subsea Frame

The subsea frame was developed in cooperation with a Norwegian company. Together with the outer pressure vessel of the pump, the frame forms a self-aligning positioning system for the vessel (Figure 18). After the pre-positioning by ROV, the vessel is guided into position so that all are put together vertical.

Besides the actual pump, the frame provides slots for additional system components such as control pods or hydraulic accumulators and systems. The frame is the mechanical interface to the customers basic subsea structures.

Control Pod

In cooperation with a research partner out of the ISUP project a subsea control pod ("Orange Box") was developed and integrated in the system (Figure 18). It contains electronic modules for safe and reliable power supply, control and communication. The control pod is mounted on a stab plate with wet mateable connectors for analog signals, fiber optics and low voltage and is therefore easily interchangeable subsea. The control pod has proven its functions during the Demonstrator tests when it provided real time data over 200km distance between Hamburg and Obernkirchen.

Conclusion

Power transmission is a central topic when it comes to remotely located subsea installations. It is essential to examine the whole system to discover the optimization potential for the electric system. An actual example is the positive influence of the hydraulic torque converter on the whole electric energy chain. As the electric power supply has fundamental influence on CAPEX and OPEX there is also a big financial incentive to conduct further R&D-work to find new optimal power solutions.

One part of that can be local subsea power generation. The tests with a conventional pump running as a motor have proven its basic function. First results on its operational behaviour could be gained. A design study in which the conventional pump design is optimised for motor operation is in progress.

Figure 18: MBS-Demonstrator

With the MBS-Demonstrator, several new design features were implemented. The result is a vertical Multiphase twin screw pump with double pressure compensated cartridge design and integrated torque converter. The lessons learned from this research model are already implemented in the next generation subsea pumps. All in all, the MBS-Demonstrator is great step towards qualification as a supplier of whole subsea boosting systems.

Outlook

To increase the possible step out distances, it is necessary to send significant data back to the topside operation system. An approach for further examination would be to identify the needed data and examine the measure methods available for subsea application. The available data can then be used in a controller or even in a model to predict the future behaviour of the system and thus optimise the power transmission.

Regarding the multiphase motor (MTM), its basic function has been proven. In the next steps, a subsea power generation system has to be developed to realise local subsea power generation integrated in an electrical subsea grid. Apart from hardware and construction that also means going into hydraulic systems, control logics and the subsea electric infrastructure.

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