Vessel Internal Electrostatic Coalescer (VIEC)

Novel oil-water separation technology

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In offshore oil production, the well output is a mixture of oil, gas and water. Gas is released as pressure decreases along process stages but water-oil separation, especially in high viscosity crude oils is much more difficult.

Water droplets are dispersed forming water-oil emulsions which can be extremely stable due to surface-active molecules and particles attaching themselves to the water-oil interface.

Typically, a multi-stage separation process is employed and the first stage separation vessel is one of the largest pieces of equipment on the platform. In many cases, to achieve a separator output with 5–10 % water is time consuming and requires an injection of chemical demulsifiers.

ABB has significantly improved this process by successfully employing what is known as the electrocoalescence technique to the first stage of the separation process. This has led to the development of a modular device known as a Vessel Internal Electrostatic Coalescer (VIEC). The VIEC has reduced the troublesome emulsion layer in the first stage separator and has also reduced the required injection of demulsifier from 10 to 2 ppmv.

ABB's VIEC is a modular device suitable for new installations and retrofit projects. Its development is a follow on from the initial concept of a novel device (with impressive emulsion breaking capabilities) that combines the functions of a mechanical flow straightener (a perforated barrier in the first stage separation vessel) and an electrostatic coalescer [1].

Technology description

The application of electrostatic force to break oil-water emulsions and increase water droplet size is an old and proven technology [2]. Traditional electrocoalescers however, must be the last elements in the separation process, as a high percentage of water will create a short circuit between the electrodes.

For many years, offshore production facilities all over the world have used electrostatic coalescers to ensure the maximum allowable water content in oil of 0.5%. A coalescer forces small water droplets to merge and form larger and thus faster sedimenting drops. Therefore, the settling velocity of water droplets in oil not only depends on viscosity and density, but also on the droplet radius squared. If the average droplet size is doubled, separation time decreases by a factor of four. Increasing droplet size is exactly what an electrocoalescer does.

Coalescer performance theory

The main feature of electrostatic coalescers is the effect its electrostatic field strength has on the conductive droplets (water) in an insulating media (oil). In the presence of an electric field, the water droplets become dipoles whose electric charges, in a sufficiently high field strength, can overcome the repulsive surface-surface interactions, resulting in oil film drainage and consecutive coalescence.

The coalescence of droplets depends primarily on the electrostatic induced forces, film rheology, collision frequency (depending on turbulence level), and concentration. The forces are proportional to the electrostatic field squared and inversely proportional to the surface-surface distance to the power of four. This means the distance between the water droplets, and thus water concentration, plays a central role in the electrocoalescence process. If the distance between droplets exceeds one droplet diameter, electrocoalescence cannot, in practice, be achieved because the field strength required exceeds practical limits. The facts presented above point out that the higher the water concentration the better the performance of the electrocoalescer. This explains why the electrocoalescer was developed for the first stage of the process.

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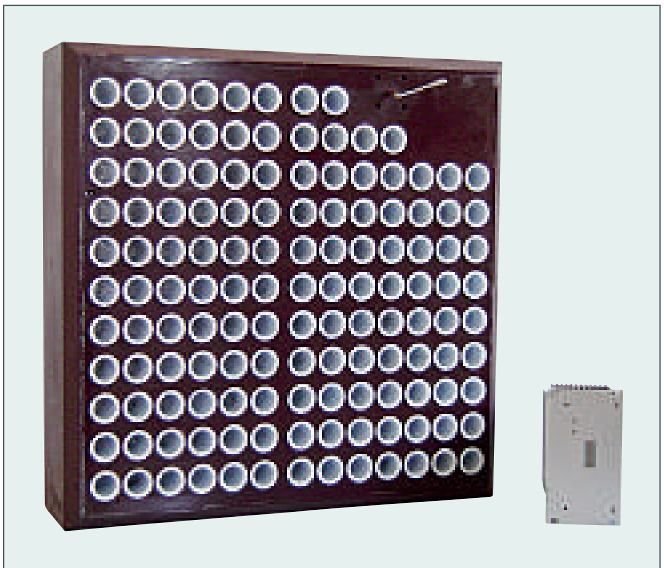
All oils are characterized by a critical field strength which may vary between 0.2 and 2 kV/cm, and heavy oils require the highest field strength [3].

The introduction of an electric field to a water-oil emulsion in this range may create salt water bridging between the electrodes. As bare steel plates (requiring tens of kV potential difference between them) have traditionally been used as electrodes, there is a high probability of short-circuiting. This, in a nutshell, has been the main obstacle to the use of electrocoalescers in the first stage. The use of dielectric material between the electrodes and the fluid can eliminate this effect. But insulating the electrodes is a challenging task as the material required to do this must be able to withstand the harsh environment of the first stage separator interior.

1 ABB's VIEC module and frequency converter.



Mechanical and electrical design of the VIEC

The mechanical design of traditional coalescers consists of a bare metal grid suspended horizontally in a large liquid-filled pressure vessel. The grid is suspended in isolators and attached to a 50/60 Hz transformer located at the top of the vessel. With the imminent threat of short-circuiting and other problems, some vendors use isolated or composite electrodes to offset some of these weaknesses.

From an electrical point of view, the use of insulating plates forms a connection similar to that of two capacitors in series: one capacitor is formed by the insulation layer on the plates whereas the second one is represented by the emulsion between the plate surfaces. The emulsion is characterized by a high dielectric loss factor making the construction of an insulated coalescer operating at 50/60 Hz difficult. The reason being that the low impedance of the emulsion results in a high voltage drop across the insulation layer.

To overcome this, the VIEC uses a dedicated frequency converter to shift the operating frequency into the kHz region. The combination of high frequency and thick insulation helps the VIEC to better tolerate, and in fact make use of the harsh first stage separator conditions.

The VIEC module resembles epoxy encapsulated medium voltage apparatus produced by ABB, such as voltage and current transformers. It is comprised of electrodes that are powered by transformers which are moulded into a perforated epoxy wall inside the separator. Teflon tubes are used in the mould to create holes for the turbulent fluid flow. The turbulence increases the collision rate of water droplets, and thus increases performance. The tubes also work as miniature separators allowing the droplets to settle into a liquid film.

The time the fluid spends inside the VIEC element depends largely on the oil properties and on the physical layout of the entire installation and is generally of the order one to three seconds.

The size of the VIEC module is such that it can be carried into the separator through a service manhole. Each epoxy VIEC module is connected to an individual frequency converter, 1, which is controlled from an operator station using of dedicated VIEC control software. The converters generate a sinusoidal voltage using the Pulse Width Modulation (PWM) principle. The Digital Signal Processor (DSP)-based generator permits on-line adjustments of frequency and amplitude so that the optimal operating point can be maintained. This technology has made it possible for individual modules to consume no more than 50 W, thus making the total typical power consumption of an installation consisting of 40 modules smaller than 2 kW. Compared with traditional electrocoalescers using heavy 50/60Hz power transformers, the VIEC power supply is quite a miniature device.

VIEC installation on the TROLL C platform

The Troll C platform (see title picture) was commissioned by Norsk Hydro in 1999 to exploit the thin oil layers below the Troll field gas cap. The Troll field is currently the largest oil producer on the Norwegian continental shelf. The Troll C platform itself produces 220,000 barrels of oil per day.

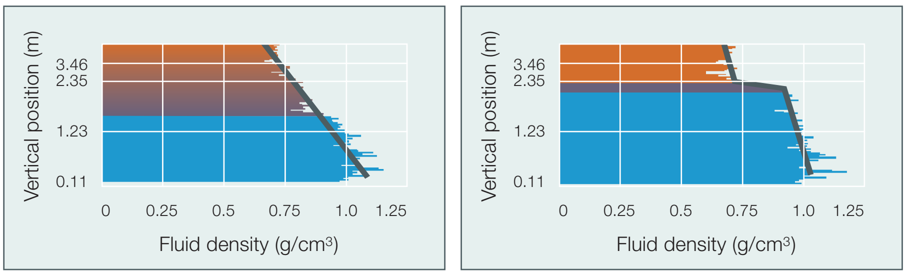
The separation process in the first stage separator on Troll C, however, suffered from reduced capacity and poor water level monitoring. Consequently, the water content in the oil at the separator outlet exceeded 10%. A solution was therefore urgently required.

2 Troll C platform: First stage separator with VIEC installed.

A pilot installation of ABB's VIEC on the TROLL C platform [4] was commissioned in June 2003. The installation, 2, consists of 36 modules (located in the first stage separator) connected to the driving unit which houses 36 frequency converters. The complete system is divided into two sections, each of which is powered from a separate DC power supply.

Since turning it on, the average oil quality from the first stage separator in late 2003 was shown to be three times better: water content was reduced to between 3 and 5%. Operating conditions have significantly improved and this is clearly illustrated by a reduction in the emulsion layer as shown by the separator density profile in 3. With the VIEC

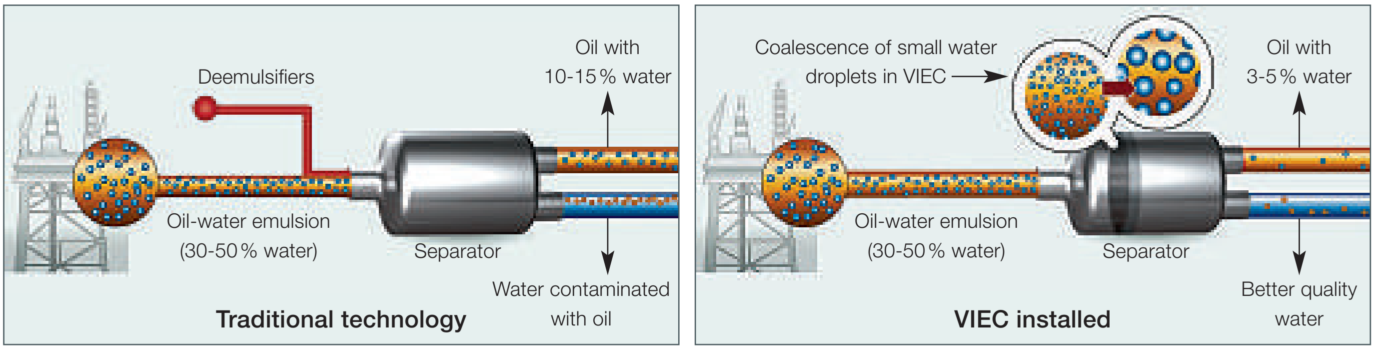
3 Density profiler screen showing the improvement in phase separation.



VIEC off

VIEC on

4 Separation technology improvement with VIEC.



off, the profile shown indicates a very gradual vertical density change. This means that most of the process fluid in the separator is still the emulsion, while thin oil and water layers occupy the top and bottom areas respectively.

After the VIEC is turned on, clearly defined interfaces become visible. The top section of the vessel contains the oil phase and water is present at the bottom. The emulsion layer lies between the oil and water phases. The thickness of the inner layer is well defined making the control of the interface level and thus the oil/water residence time accurate. The emulsion layer is reduced to a third of the height when VIEC is turned on. In fact, since installing the VIEC, the demulsifier injection level has been reduced from 10 ppmv to 1.5 ppmv and further trial reductions are planned.

The tests have shown that improved separation using VIEC can be used to either: reduce water content in oil; reduce demulsifier injection; or increase capacity to equal quality. One or all of these effects may dominate depending on the oil and other aspects of the separation process. A comparison between the traditional and the new separation technology using VIEC is shown in 4.

Conclusions

The successful pilot installation of ABB's pioneering VIEC system on the Troll C platform is the first worldwide application of active coalescence in first stage separators. This fact was recognized at the Offshore Technology Conference in Houston (OTC 2004), where VIEC received the prestigious technology award.

VIEC is a door-opener for other technologies requiring multi-channel electrical functionality inside process vessels.

Further development of this new technology may soon result in subsea separation, in one step, to below 2%! This would help eliminate hydrate problems in subsea oil pipelines. As the water-oil separation problem is not restricted to the off-shore oil production, VIEC in on-shore process facilities is also being considered.

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