Field experience with a novel pipe protection and monitoring system for large offshore pipeline construction projects

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Subsea, offshore gas pipeline construction, logistics, pipe protection, safety, security, no-surprise load-out, corrosion protection, third party damage protection, cutback protection, high performance polyurethane elastomers, polyurethane recycling, wireless sensor network, surveillance system, pipe laying time cycle, pipe tracking, RFID, condensation prevention, self-sufficient router, central control room, monitoring software, continuous monitoring.

Contents

1. NordStream: Logistics and construction of a very long subsea gas pipeline

The 2 parallel Nord Stream pipelines will connect the world's largest gas reserves with the European gas pipeline network. This will make these pipelines a cornerstone of European gas supply and of energy partnership between the European Union and Russia.

Number one of the lines has come on stream in 2011; number two is under construction now and nearing completion. Each line has a length of approximately 1,220 kilometres with a transport capacity of approx. 27.5 bcm per year. Full capacity of about 55 bcm / year will be reached once both lines are operational.

Despite the huge logistical challenges this project posed, pipe laying is on schedule. To ensure the most efficient pipe laying process possible, a customised logistics infrastructure in the Baltic Sea region was established. Weight coating plants, interim stock yards and trans-shipment facilities were strategically placed in 3 countries around the Baltic Sea to minimise cost, time required, and environmental impact. Nord Stream is the largest offshore gas-pipeline project ever.

5 logistics locations were identified and established along the Baltic Sea coast. This has lead to a strong positive impact on the local and regional economies around these logistics centers, boosting local business and employment.

Figure 1: Baltic Sea Logistics

2. Requirements for a pipe protection system

2x 1'220 km of subsea pipeline required storage of approx. 110'000 concrete-coated pipe joints in 5 marshalling yards, thousands of kilometers apart from each other. Two concrete-coating plants in Finland and Germany produced pipe joints (48", 12 m long) up to a year ahead of the start of pipe laying. These pipe joints could not just be stored outside for 1-2 years without protection for the following reasons:

For load-out, the pipe joints need to be

a. Clean on the inside, free of dirt, excessive amounts of water, animals, etc.;
b. Free of corrosion on the cutbacks (uncoated areas) at both pipe ends;
c. Free of defects caused by mechanical damage (or from fire) during storage;
d. Individually marked and identifiable in the shortest possible time.

At a pipe laying speed of 2.4 km per day, the cycle time for handling each pipe joint is just a few minutes. This means that quayside , there is almost no chance to "repair" any pipe joint that does not match conditions a) through d). If a pipe is not in condition for load-out, it can only be set aside and taken care of later.

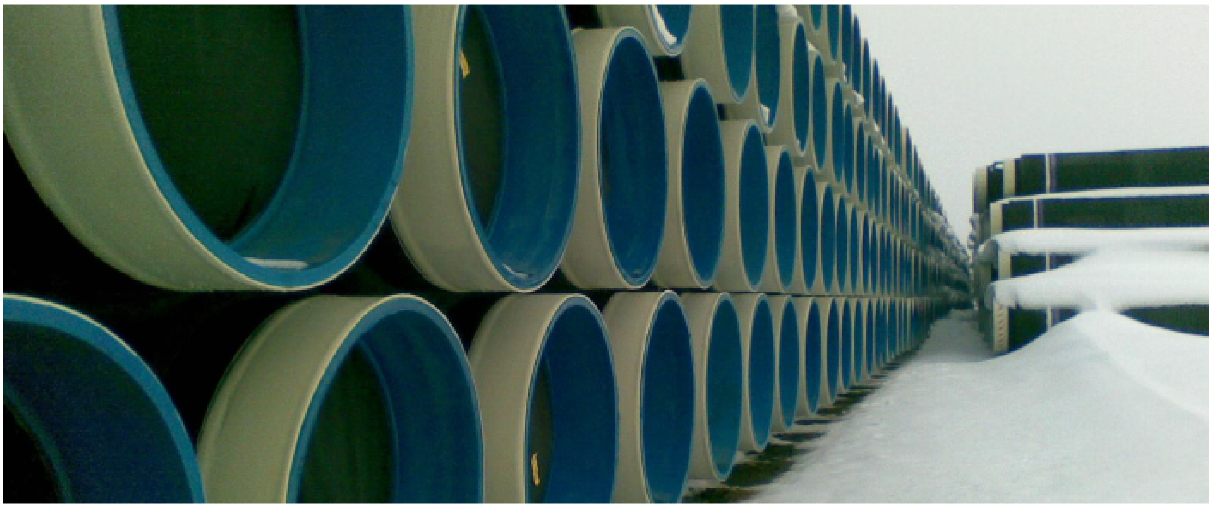
Therefore, a "no-surprises" solution was mandatory that guarantees that all pipe joints arriving quayside match conditions 3.1. a) through d).

To guarantee that the pipes are not damaged mechanically, there would have to be physical barriers as well as a rather large security personnel detail.

To prevent the pipes from becoming dirty or corroded, some kind of caps or closures need to be applied to each end of each pipe joint.

To allow complete tracking and identification of each pipe, a system was required allowing to read pipe numbers on capped pipes. A barcode or embossing solution was therefore not feasible.

Figure 2: 110’000 pipe joints stored in 5 outdoor yards



3. A new concept for pipe protection

NordStream and the in-line inspection technology provider ROSEN discussed implementing a load-out inspection of each pipe at the point of load-out. These pipes would have come to the quay from marshalling yards that would have been fenced and guarded by high-security equipment and personnel. This inspection (e.g., by pulling a wire line MFL or optical inspection tool through each pipe) would have needed to be done quayside. A “cycle time” of only 3-4 minutes would have been available per pipe joint. This very short cycle time would include bringing a pipe to the inspection station or setting up and removing inspection equipment at pipe stacks.

Before inspection, each pipe would need to be cleaned to remove dirt, debris, water and even desiccant packs (in case hermetically sealing pipe caps would have been used). Any varnish or dope to protect inner and outer pipe cutbacks from corrosion would need to be removed at this stage as well.

Particularly the preparatory steps and cleaning would have been prohibitively expensive. An alternative solution was conceived:

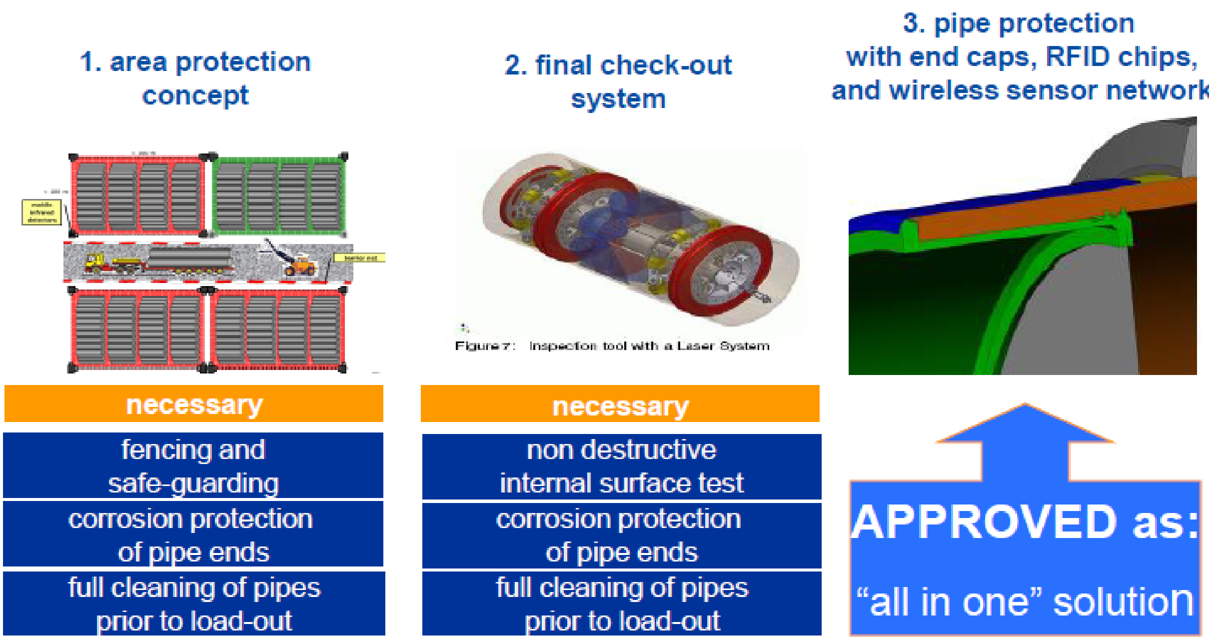
Only six months before startup of the first concrete coating plant, both partners conceived idea to protect the pipe joints from dirt, corrosion, and third party damage throughout the entire storage process from concrete coating to load-out. In a one-system solution combining physical protection by pipe caps as well as damage and tamper protection by a wireless sensor network.

RoPlasthan® high performance elastomers manufactured by ROSEN`s subsidiary ROPLAST were chosen as extremely sturdy material for pipe caps. Combined with this, an electronic system to allow pipe joint tracking and detection of third party damage was included in these caps. In addition, features like prevention of water accumulation inside the pipe, tprevention of outer cutback corrosion, and wireless data transmission were included. The cap system was designed to be re-used for protection of the second pipeline. A newly developed recycling process enables ROPLAST to employ the duromeric material of used pipe caps for the manufacturing of PUR products that retain a very high share of the high performance elastomer's superior mechanical properties. Thereby, the environmental footprint of using high performance PUR elastomers can be reduced significantly.

Within three months of conception of the idea, manufacturing equipment for the cap system, including moulds, polyurethane casting machinery, electronic boxes were constructed. By the same time mounting machines to mount the caps onto the pipe joints (controlled automated process) have been developed.

After six months, commercial cap delivery and cap mounting on a large scale started. Wireless data transmission and central control systems came on stream. Before this, the system had been audited by the operator and by third parties.

Figure 3: Options for pipe joint protection



4. The pipe protection system

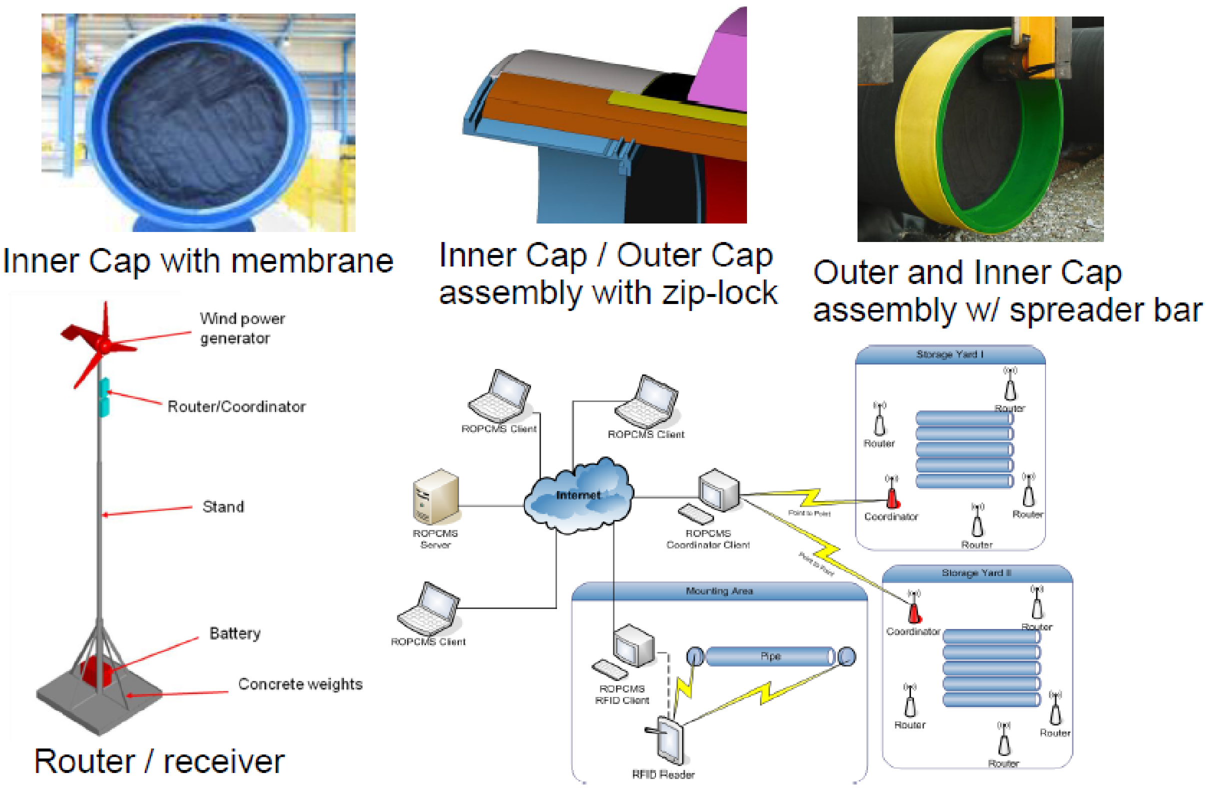
The system as described consists of

- a two-part cap system ("inner and outer cap") made from high performance polyurethane elastomer. Inner and outer cap interlock by a zip lock system. Towards the pipe cutback, the inner cap seals by a number of oversized sealing lips, thereby accommodating heat expansion/cold shrinkage over the entire possible operating temperature range. The outer cap seals by its elasticity; it is undersized; the mounting machine expands it and pulls it over the pipe cutback. These elastomers exhibit elongation-at-break values in the range off 400% and above.

- a membrane as part of the inner cap surface to allow passage of evaporated water while preventing passage of liquid water or dirt. The membrane is molded firmly into the PUR inner cap and sports high UV resistance as well as tear resistance to withstand even hurricane strength winds.
- an electronic box mounted to the inside of the inner cap containing all sensors, an RFID chip for pipe joint identification, an energy storage device, and a wireless transmitter. The sensors detect any tampering with the pipe (e.g., accidental hits by construction equipment), removal or damage of the cap, and fire.
- a wireless data transmission network with energy- self sufficient repeaters and a central control system. The central control system receives information on all capped pipe joints in or near real-time. Alarms are raised whenever
  - a sensor reports an incident;
  - an electronic box fails;
  - a router/repeater fails.

In case of a router/ repeater failure, other routers / repeaters automatically take over its function. In all of the cases above, alarms are analyzed by the ROPCMS software and security personnel is dispatched to the respective pipe joint if the analysis verifies the alarm received.

Figure 4: the Pipe Cap System



5. Experience to date

The NordStream project is nearing the end of the laying process. Pipe caps and protection system have proven to work reliably over several years. The re-use of the pipe caps for the second pipe string gave no additional issues and worked well.

Two very cold and snowy winters followed by a winter with gale force winds, the pipe cap system has proven its viability in a Nordic maritime environment. Even under sometimes very harsh weather conditions, load-out is progressing smoothly.

Audited quality systems were establish and contribute to functioning and reliable product.

Overall, this system means significant cost savings for the operator compared to conventional protection and surveillance systems.

The NordStream Logistics System has won the German Logistics Award; the pipe protection system made a significant contribution to this success.

The successful and timely execution of this project is a prime example how innovation, logistics planning, and applied best practice in all operations can lead to strong cost reduction and a large step forward in offshore gas pipeline construction technology.

Figure 5: The photos below show examples from the field.

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