

### **Onshore Pipeline Overpressure Protection System (LVI) Reliability**

- An independent verification report (to confirm the SIL rating of the onshore pressure limitation system – the LVPLS (Landfall Valve Pressure Limitation System)) was commissioned by Mokveld Valves bv. The company chosen to carry out the verification was Safety Solutions Consultants B.V. Apeldoorn Netherlands (“SSC”). The analysis was carried out in September 2009 and reviewed by JP Kenny in February 2010. A revised report incorporating the latest design changes has been issued in August 2010.
- The method used to carry out the verification analysis is in accordance with both IEC 61508 and IEC 61511.
- The conclusion of the verification is that the LVPLS meets the SIL 3 requirements. This conclusion is based on a proof test interval of 12 month (inclusive complete tightness test of the Mokveld valves) and an overhaul of the Mokveld valves after 15 years.
- The following components are included in the verification performed by SSC:
  - EJX pressure transmitters - certified by TUViT
  - Yokogawa Logic Solver ProSafe - SLS - certified by TUV
  - Shut-off valve RZD-X-SAV-2 - certified by TUV
  - Solenoid valves Maxseal ICO4S - certified by SIRA (Cologne)SSC’s verification report had regard to the certification of the above.
- The SIL verification of the LVPLS has made use of the failure data from component SIL certificate reports. (Note that a reliability certification for the system is generally not produced and not required by the IEC codes (IEC 61511:2003 and even IEC 61508:2010)
- The verification of the LVPLS has been performed by Herman Jansen of Safety Solutions Consultants BV. He is certified by TUV in 2005 for Functional Safety (certificate number TUVFSEng 0227/05).

### **Offshore Pipeline Overpressure Protection System (Wells Isolation System) Reliability**

- The wells isolation system has been designed such that the offshore pipeline MAOP of 150 barg will not be exceeded. This system has been modified since the 2009 submission such that it now has a similar PFD to that of the LVI.
- The main modification was composed of adding an additional means of shutting down all the subsea actuated valves by fitting a high reliability automatic subsea hydraulic pressure release system at the terminal.
- DNV Energy were tasked to carry out an independent analysis of the Wells Isolation System.
- DNV Energy used a Failure Mode and Effects Analysis (FMEA) to identify the relevant modes of failure and a Fault Tree Analysis (FTA) to calculate the probability of ‘Failure to Isolate One or More Wells’. DNV Energy have utilised Excel spreadsheets (with transparent calculations) for both the FMEA and FTA. This independent verification confirms the reliability of the pressure protection system. (Further information on the FMEA and FTA can be found in Appendix Q4.6).

- All the base data used for calculations within the FMEA are from industry standard auditable sources (e.g. OREDA) and the references are provided in the FMEA worksheets. Specifically, failure rate of mechanical/electrical/instrument components were obtained from the following sources:
  - the Reliability Analysis Center (RAC) Nonelectronic Parts Reliability Data 1995 (NPRD-95)
  - OREDA (Vol 2- Subsea)-2009
  - ABB In-house data
  - SIL 3 Verification Report (45337-906 Dated 29 September 2009)
- A number of standards are available to specify the approach and format to be used for FMEA or FMECA. The function based method as specified within the British/European Standard BS EN 60812:2006 was implemented, using the quantitative approach. This approach enables specific values for probability of occurrence for all failure modes to be quantified numerically.
- DNV Energy concluded that the calculated probability for 'One or More Wells Not Isolated' is  $4.5 \times 10^{-4}$  (0.00045), Table 1-1 shows the comparison between probability of failure on demand and integrity levels. The value calculated for this analysis lies within band 3 or less than one occurrence in two thousand years.

• **Table 1-1, Integrity Level Comparison**

<b>Integrity Level (IL)</b>	<b>Probability of Failure on Demand (PFD)</b>	<b>Risk Reduction Factor (RRF)</b>
4	0.00001 to 0.0001	10,000 to 100,000
<b>3</b>	<b>0.0001 to 0.001</b>	<b>1,000 to 10,000</b>
2	0.001 to 0.01	100 to 1,000
1	0.01 to 0.1	10 to 100
A	0.1 to 1	1 to 10

- This independent verification of the Probability of Failure on Demand (PFD) of the offshore pipeline overpressurisation protection system was performed by Roger Allen, Principal Engineer with DNV Energy, with expertise in Reliability, Maintainability and Safety engineering.