Working well

Reliability analysis techniques for intelligent wells

Temperatures well over 100 °C, high pressures, heavy-duty steel valves and casings – inside an oil or gas well is not where most electronic design engineers think of their circuit boards ending up. But for some ABB designers, putting complex electronics downhole has become a routine business.

With more and more Intelligent Well (IW) systems being deployed, the technology is clearly becoming widely accepted. A sign of this is the now almost standard requirement that subsea control systems and tree systems be compatible with IW technology.

IW systems are nevertheless new, so too little field experience is available to allow the normal reliability predictions to be made. Since retrieval is next to impossible, just how do you ensure that the installed equipment is reliable?

The overriding reason for introducing the IW system for well control and operation management is to improve the overall net value of a field development. But this can only happen when the system meets the customer's expectations in terms of in-service reliability and operability. Any potential economic gains are illusory unless the equipment proves reliable in service. When determining the desired reliability of an IW system, many different variables need to be considered, such as equipment capital costs, available technology and the consequences of system failure. Obviously, these can vary considerably from one reservoir and field application to another.

Systematic component criticality assessments and reliability performance simulations support decisions during the design process, ensuring that the end design is 'reliability driven'.

The ABB approach

The only way to ensure high reliability levels is to establish a thorough quality and reliability management program for the entire life cycle of the intelligent well products. Reliability analysis alone is less than likely to provide a reliable product, unless it is integrated in an overall reliability and quality framework.

A reliability management program for new products should incorporate a whole range of activities, from conceptual design, through detailed design, manufacturing and testing, to installation and operation. It is of paramount importance that reliability assessments are a multi-disciplinary and integrated activity, providing decisions support on reliability issues throughout the entire project. Making reliability analysis a separate 'add-on' at the end of the design process is very likely to have no or only minor impact on the in-service performance. Furthermore, the feedback of experience gained during design, installation and operation into the organization is a critical element of continuous reliability improvement.

The aim of ABB's IW reliability project is to ensure the provision of satisfactory system reliability and operational performance on a long-term basis for all well applications, including high pressures/high temperatures (HP/HT). To achieve this objective, systematic component criticality assessments and reliability performance simulations are applied as decision support tools during the design process. This ensures that the end design is 'reliability driven' and that any 'reliability killers' have been eliminated.

ADMARC™ – a reliability analysis case study

Since 1997 ABB has been developing a downhole Intelligent Well system called ADMARC™ (Advanced Downhole Monitoring and Reservoir Control) 1. The reliability analysis techniques applied during development of ADMARC are used to guide the development process,

Intelligent wells

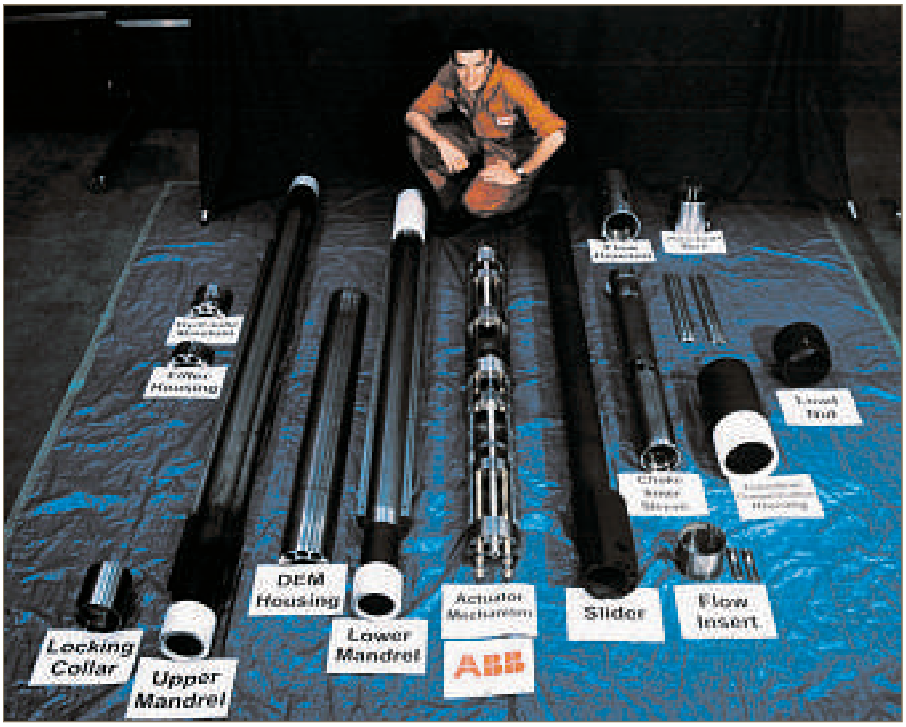
A widely accepted definition is that an intelligent well is one that has the following capabilities:

- *Flow segregation:* Individual zones/laterals in a well are isolated from each other and flow out of or into them can be remotely controlled by means of a downhole flow control device (FCD).
- *Well parameter monitoring:* Well bore and/or reservoir characteristics can be remotely monitored in real time.
- *Well performance optimization:* FCDs can be adjusted as a result of the knowledge gained from evaluating the well bore characteristics, in order to maximize the overall performance of the well.

It is also widely accepted that an intelligent well can add value in a number of areas. The benefits may include one or more of the following:

- Increased recovery
- Reduced well construction costs
- Accelerated production profiles
- Reduced well intervention frequency and costs
- Improved operational safety

1 The main ADMARC™ modules



ie they do not just constitute a methodology to be used on completion of development work in order to come up with a reliability prediction that satisfies client processes.

One of the basic problems when assessing the reliability of Intelligent Well systems is the limited field experience, which makes relevant input data difficult to obtain. Consequently, there is a certain risk of wrong conclusions being drawn if the focus is on absolute reliability predictions only. ABB therefore chose to focus on comparative rather than absolute reliability measures when providing decision support for the ADMARC development.

The ADMARC intelligent well control and monitoring system is based on an architecture which utilizes dissimilar redundancy and fault-tolerant design features to enhance system reliability. It is applicable to both production and injection wells. The downhole Flow Control Devices (FCD) can be operated by electrical, hydraulic or electro-hydraulic means. A secondary mode is chosen as back-up in the event of the primary actuation system failing.

The analysis process

To provide unambiguous reliability predictions, first of all important boundary definitions were set to establish, amongst other things, required functions, operational time and a mission profile. An iterative reliability assessment process was integrated right from the conceptual stage. Generic analysis techniques and activities were then applied, culminating in simulation runs and the feedback of results. This approach also required analysis of a large number of system configurations to address the need for varying the number of flow control devices involved. The simulation models also had to be sufficiently flexible and modularized to enable rapid handling of altered configurations.

> The reliability assessments clearly demonstrated the benefit of designing a highly fault-tolerant system through a so-called ‘feature benchmark exercise.’

Survivability

The process predicted reliability figures for a ‘high-end’ IW system operating at 150 °C in terms of a survival probability after one and five years of approximately 98 percent and 81 percent, respectively. Operating the same system at reduced temperature is anticipated to improve the overall reliability considerably, increasing the five-year survival probability to some 88 percent. The reliability assessments have clearly demonstrated the benefit of designing a highly fault-tolerant system through a so-called feature benchmark exercise, quantifying the gain of including reliability enhancing features such as redundancy and high-temperature electronics 2, 3.

Gathering data

The reliability assessments were performed in view of shortcomings in the input data that were due to the limited field experience with intelligent well equipment. Nevertheless, it is ABB’s firm belief that the assessments, performed as an integral part of the development work, contribute to reliability growth and the elimination of bottlenecks prior to testing and manufacture of the equipment.

As more systems are actually deployed, industry databases such as ICON (Intelligent Completions On the Net) will grow and be able to feed back more meaningful data to reliability analysis techniques. As a result, reliability predictions can be used for more than comparative evaluation techniques and facilitate greater acceptance of intelligent well technology.

2 High-temperature electronics

3 High-temperature circuit-boards: downhole electronics module and receiver/transmitter