QUANTITATIVE OPERATIONAL RISK MODEL APPLICATION TO WELL INTEGRITY

Luiz Fernando Oliveira[1], Joaquim Domingues[2] (DNV)
Danilo Colombo[3] (PETROBRAS/CENPES)

ABSTRACT

Almost all O&G companies have a well integrity management system based on a well failure model. Until now they are mostly based on qualitative risk models with only very few claiming to use quantitative risk methods. The objective of this paper is to present a production well integrity system based on a different type of quantitative risk model. Traditional risk assessment methods were developed to be used in design stage (when you can only conjecture about what will actually happen to the asset). Unlike such models, our quantitative risk/reliability model has been developed to be specifically used during the operational phase of a well. A unique time-dependent "in-time" reliability model was developed to solve the problem from an operational viewpoint. The basic indicator of the risk of loss of well integrity is the instantaneous frequency of an uncontrolled leak but it also calculates the cumulative risk of failure with time. It properly controls the age of all barrier elements and considers all past operational events that are relevant to describe the current conditions of each barrier element; it uses this information to calculate the current risk. The future evolution of risk is then calculated based on current conditions of barrier elements, their scheduled tests, and existing well monitoring capabilities. Through a two-control-line risk management and a criterion for incremental cumulative risk of uncontrolled leak (concept borrowed/adapted from the nuclear sector), the results provide objective guidance for key operational decisions, the risk increase caused by a detected failure of a barrier element, whether it is acceptable or not to continue operating with the failed barrier element, and for how much time. The latter question is answered by calculating the number of days until the well risk reaches the unacceptable risk control line or the incremental cumulative risk limit.

1. INTRODUCTION

One of the most important management actions of an O&G producing company is to ensure the integrity of its wells throughout their life cycle from design and drilling to final abandonment, passing through its operating life. Maintaining well integrity during its operating life means to keep its ability to contain the reservoir fluids inside the pressure containment envelope of the well, thus avoiding the occurrence of uncontrolled leaks to the environment, that is, avoiding the occurrence of blowouts. All components or parts of a well which play a role in avoiding such undesired blowouts are called well barrier elements. Therefore, one of the most important aspects of well integrity management corresponds to managing the integrity of its well barrier elements. This can be achieved by incorporating monitoring devices, performing tests of barrier elements that cannot be monitoring and conducting repair and replacement activities when degradation or failures are detected.

In the Norwegian standard Norsok D-010 [1], well Integrity is defined as:

> "the application of technical, operational and organizational solutions to reduce risk of uncontrolled release of formation fluids throughout the life cycle of a well".

In the announcement of the organization´s "Principles of Well Integrity", OGUK [2] states that:

1 PhD U.C. Berkeley, Vice-Presidente – DNV
2 DSc, COPPE/UFRJ, Senior Principal Consultant - DNV
3 MS, UFF, Well Engineer – PETROBRAS/CENPES

> "Well integrity is defined to be the application of technical, operational and organisational solutions to reduce the risk of uncontrolled release of formation fluids throughout the life cycle of a well".

Still within the "Principles of Well Integrity", OGUK [2] further states that:

> "There should be at least two well barriers available throughout the well life cycle. The removal, or degradation, of a well barrier should be carefully considered to ensure that well integrity risks remain ALARP".

In Brazil, ANP published Resolution No. 46/2016 [3] which created the Regime of Operational Safety for the Integrity of Oil and Gas Wells. In § 2º of Art.1 it is stated:

> "In the Regime of Operational Safety for the Integrity of Oil and Gas Wells, are considered responsibilities of the companies retaining the rights of exploration and production of oil and natural gas:
> I – to implement a management system that conforms with the requirements of the Technical Regulation of the Well Integrity Management System – SGIP instituted by ANP".

There are also international standards, such as ISO 16530-1 [4] that sets down requirements for the implementation of integrity of oil and gas wells. As a result, nowadays almost all O&G operating companies in the world have a well integrity management system (WIMS), most of which are based on a well failure model. Until now, they are mostly centered around qualitative risk models [5 - 8] with only very few claiming to use quantitative risk methods [9, 10]. In this paper, we present a new web-based computational system named MyBarrier Integrity which has been developed through a research collaboration agreement between DNV and Petrobras. This system is based on a risk-based quantitative model of well integrity which has been specifically designed and developed to be applied during the operational phase of a well. It is aimed at serving as a complementary tool to existing WIMS of oil companies.

2. OBJECTIVES OF THIS PAPER

The objective of this paper is to present a production well integrity system (named MyBarrier Integrity) based on a different type of quantitative risk model. Traditional risk assessment methods were developed to be used in design stage (when you can only conjecture about what will actually happen to the asset). Therefore, they are not really adequate to manage operational risks during the production phase because they cannot take into account the operational history and the true current asset conditions. Unlike such models, our quantitative risk/reliability model has been developed to be specifically used during the operational phase of a well.

A unique time-dependent "in-time" reliability model was developed to solve the problem from an operational viewpoint. The basic indicator of the risk of loss of well integrity is the instantaneous frequency of an uncontrolled leak but it also calculates the cumulative risk of failure with time. It properly controls the age of all barrier elements and considers all past operational events that are relevant to describe the current conditions of each barrier element; it uses this information to calculate the current risk. The future evolution of risk is then calculated based on current conditions of barrier elements, their scheduled tests, and existing well monitoring capabilities.

Through a two-control-line risk management and a criterion for incremental cumulative risk of uncontrolled leak (concept borrowed/adapted from the nuclear sector), the results provide objective guidance for key operational decisions, such as the continuation of operation with a failed barrier element by calculating the number of days until the well risk reaches the unacceptable risk line or the incremental cumulative risk limit. The system gives correct answers to questions such as: what is the risk of loss of integrity now/today under the past operational history and current conditions of the well? What is the safety impact of a detected failure of a barrier element on the current and future well risk? Is it safe to continue to operate with a degraded safety barrier element? For how long?

3. BRIEF DESCRIPTION OF THE MODEL

3.1 Overview

The model uses a leak path diagram developed from schematic barrier diagrams available for most production wells. This information is then used to construct a directed graph connecting the reservoir cavity to the environment, passing through the internal cavities of the well (see example in Figure 1). Graph theoretic algorithms are then used to determine all minimal leak paths going from the reservoir to the environment. The barrier elements which have to fail for the fluid to go from one cavity to the other are then allocated to each connection between cavities. The leak paths are then expressed as sets of barrier element failures leading to an “Uncontrolled oil leak to the environment”. This procedure is similar to the construction of a fault tree and then determining its minimal cut sets.

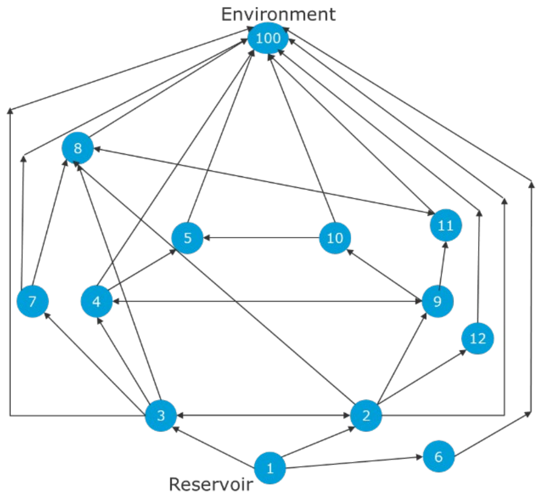

Figure 1 - Example of Graph Constructed for the Determination of All Minimal Leak Paths from the Reservoir to the Environment

In Brazil, the first efforts to evaluate the probability of loss of well integrity using fault tree analysis were those of the pioneering works by Takashina [11] and by Moreira [12]. The procedure outlined before is similar to that proposed by Korneliussen [13], that has also been adapted/used by several authors in different applications (Fonseca [14], Alves [15], Zanetti [16], Bouças [17], Colombo [18]).

But the similarities between this work and the cited previous applications stop here: while all previous works solve the problem from t = 0 (a design-type perspective) we develop a solution that looks at the problem from t = t. This means that the model developed here solves the reliability problem from the point of view of an observer that is following the performance of the well with time during its operational phase and is therefore solving the problem from t = t and not from t = 0, as done in all design-type reliability applications. By adopting such point of reference, the model can explicitly take into account all operational conditions that are known at t = t, including the known history of the barrier elements from 0 to t and consequently their respective ages at t.

Again, differently from the previously referred papers, we consider that since the elements of the well primary barrier and some of the secondary barrier are under continuous demand to fulfil their safety function of containing the oil, such well barrier elements are subject to a condition of high/continuous-demand mode, as defined in IEC-61508 [19]. Therefore, the quantitative risk indicator to be evaluated for the well barrier is the frequency of failure, which corresponds in this case to the instantaneous frequency of an uncontrolled leak from the well. A detailed time-dependent reliability model is constructed to provide this evaluation at all times during the production phase of the well (see Section 3.4).

Another important difference from previous models is that the current model is not restricted to using constant failure rates, but it is capable of handling time-dependent failure rate distributions, such as the Weibull distribution with increasing failure rates. This means that the model is capable of properly take into account the process of aging of the barrier elements which occur during the well lifetime.

The bases of the quantitative reliability assessment performed here are the sets of leak paths generated from an analysis of a well leak path diagram. The way they are organized and used in this paper are also presented in this section.

3.2 Well integrity and well barriers

The basic concepts of well integrity and well barriers as utilized in this paper are presented in this section. Well integrity is related to the containment and the prevention of the escape of fluids from the well to the environment. From the point of view of well integrity, the most important risk throughout the whole lifecycle of a subsea oil well is the occurrence of an “uncontrolled oil leak from the well to the environment”. This is the event of interest considered in this work. In addition, we are here only concerned with the occurrence of this event during the production phase of the well, as explained in Section 2.

To accomplish the well integrity function indicated above, the well is equipped with well barriers which are defined in ISO 16530-01:2017 [4] as: “systems of one or several well barrier elements that contain fluids within a well to prevent uncontrolled flow of fluids within or out of the well”. In the same reference [4], a well barrier element is defined as “a combination of one or several well barrier elements that contains fluid within a well to prevent uncontrolled flow of fluids within, or out of, a well”. In NORSOK D-010 [1], well integrity is defined to be “the application of technical, operational and organizational solutions to reduce risk of uncontrolled release of formation fluids throughout the life cycle of a well”. The subject of this paper is restricted to the presentation of a technical solution which provides a way of following the condition of the well barriers by assessing their reliability indicators at all times and reassessing their values as any new information related to failures of barriers elements is detected.

The NORSOK D-010 standard [1] requires that a well-barrier schematics (WBS) be drawn for each well activity and operation. WBS is a drawing illustrating the limits of the primary and secondary well barriers and their corresponding well barrier elements. Initially, each Norwegian operating-company worked independently to fulfil this requirement but later they decided it would be better to have a standardized way of developing the WBS and this was accomplished with the publication of OLF 117 [20].

3.3 Cavities, well barriers and leak paths

The cavities existing in the well and the barrier elements that separate them can be derived from the WBS referred in the previous section. A method was proposed by Korneliusen [13] to identify all possible leak paths from the reservoir to the environment passing through the various cavities. To pass from one cavity to another it is necessary that the barrier elements separating the two cavities fail by failure modes that allow fluid movement between the two cavities.

Following the above suggestion, a graph, named leak paths diagram, can be constructed showing the identification of the cavities that the fluid must pass by to go from the reservoir to the environment. A graph algorithm is then used to identify all possible minimal paths from the reservoir to the environment. By including the associated barrier element failure modes between the cavities, then sets of barrier elements failure modes can be identified that constitute the various minimal failure combinations that are needed for the fluid to reach the environment from the reservoir. Such minimal combinations are the equivalent of minimal cut sets in a fault tree, the top event of which can be thought as “uncontrolled leak from reservoir to the environment”. Once all minimal combinations of barrier failure modes, the leak paths, are determined, then reliability methods can be used to calculate the cited reliability indicator (instantaneous failure frequency or intensity) to provide appropriate decision support to the well integrity management problem. A summarized description of the reliability model used in this paper is provided in the next section.

3.4 The time-dependent reliability model: a brief description

Consider a well leak path, *Pi*, formed by a set of *{N}* barrier elements (actually, we should say, failure modes of barrier elements, but we will refer only to barrier elements for simplification). The instantaneous leak frequency, $W_{Pi}(t)$, for this cut set is given by:

$$\boldsymbol{W_{Pi}(t) = \sum_{n=1}^{N}\left[w_{Pi,n}(t) * \prod_{\substack{m=1,\\ m\neq n}}^{N} P_{Pi,m}(t)\right]} \qquad (1)$$

where:

$w_{Pi,n}(t)$ is the instantaneous frequency of the *n-th* barrier element of *Pi*, $n \in N$, and

$P_{Pi,m}(t)$ is the probability that the m-th barrier element of *Pi*, $m \in N$, has failed before *t*.

In the model, Equation (1) is evaluated from time $t = t$ and not from time $t = 0$ as is the case of reliability models used for design. Its predictions for times after *t* are valid as long as no new information is detected by the operators. Therefore, its assessment from *0* to time *t*, is also conditioned on no new information other than those known at $t = 0$ being detected by the operator. This means that at a time t after $t = 0$, some of the barrier elements (those whose failures cannot be detected during operation) may have failed without this being detected by the operators. This uncertainty is evaluated by the probability of such components having failed before *t* and thus being in a failed state at *t*. The failure of the leak path (leading to a leak through the leak path) will occur within *t* and $t + dt$, if one of the barrier elements just fails within this interval while all the others are already failed, having failed before *t*. This is the meaning of the terms in Equation (1). It also derives from the assumption that two or more failure events do not occur within the same *dt*. Therefore, if a failure (an uncontrolled leak) occurs within *t* and $t + dt$, it can only be because one of the components was not failed at *t* but failed between *t* and $t + dt$, while all the others in the cut set had already failed before *t* and are failed at *t* (and this information was unknown to the operators). Typically in a model evaluated from $t = 0$ (typical reliability models used at the design stage), the frequency of occurrence of a failure of a component at *t* is evaluated by its instantaneous failure intensity, $w(t)$ given by Equation (2):

$$\boldsymbol{w(t) = A(t).\lambda(t)} \qquad (2)$$

where:

$A(t)$ is the availability of the component at *t* (instantaneous availability), and

$\lambda(t)$ is the failure rate of the component at *t*.

It is then necessary to evaluate $A(t)$ for each one of the three types of time-dependent components that are considered in the model: monitored (M), tested (T) or neither (N).

The terms $P_{Pi,m}(t)$ in Equation (1) are given by Equation (3):

$$\boldsymbol{P_{Pi,m}(t) = 1 - exp\left(-\int_{T_i}^{t}\lambda_m(t')dt'\right)} \qquad (3)$$

In Equation (3), T_i is the last time the component was known to be working, for example, after a test, if the test result indicated that the component was working, or after a repair that restored the component to a working state. Therefore, the interval $t - T_i$ is the failure exposure period since the last time the component was known to be working. What about the integration variable t' ? This variable represents the age of the component within the time interval $t - T_i$. Another important advantage of assessing from $t = t$ is that the whole history of each component up to t is known.

Working with varying failure rate distributions in a $t = 0$ model requires the analyst to specify a maintenance strategy that will be followed in operation, namely, good-as-new or good-as-old, and the results vary depending on which strategy is assumed. In our model, we do not need to fix such maintenance strategy because we are solving the problem at $t = t$, and we can use the strategy that is actually used at each situation. We can do that because we keep track of every test and repair actions (maintenance) associated with each component. We keep track of their times, their results and their resulting actions. Therefore, in a repair action, we know if the component was repaired to as-good-as-old or to as-good-as-new condition. Therefore, the correct age of the component is known at each time t and this allow us to use any type of varying failure rate models for the component. Compare this situation to that of a $t = 0$ model where the condition of an as-good-as-new repair model for a component with time-varying failure rate introduces the need to evaluate all possibilities for the age of the component in the failure exposure (integration) interval, simply because one cannot know the precise age of the component at a future time t.

For the calculation of the frequency of uncontrolled leaks for times ahead of t = t, that is, the future risk, we do the calculations considering that the present conditions are maintained in the future, that is, they are valid until a new condition is detected, for instance a new failure is detected. Of course, this is an approximation, whose validity lies in the fact that most failure rates of the barrier elements have low values compared to the time horizon of the calculations. The few cases of barrier elements that have failure rates that are not so low may introduce limitations to the calculations of future risks that, in such cases, may be good approximations to times that are up to ten or 15 years ahead. But even this limited time is enough to solve almost all operational times of interest to well integrity problems.

The barrier elements in our model can be of four types: 1) Monitored (named Type M), 2) Tested (Type T), 3) Neither Monitored nor Tested (Type N), and 4) Fixed Probability (Type P). Noticed that we referring to first type as “monitored” and not as “repairable” or “monitored repairable”. This is because the random repair process is not part of our model. Component failures are introduced when they actually happen (at t = t), and what the system does is to perform a Boolean reduction of the leak paths (or minimal cut sets) and continue the calculations with the failed component for all times in the future. Whenever the failed component is repaired or replaced (the latter is the dominant maintenance strategy in well integrity of offshore fields), the original cut sets are restored and the system continues the calculations with the new condition. The same strategy is followed for Type T and Type P barrier elements. For Type N barrier elements, normally their failures are not detected when they happen, but there may be cases, that their failures are detected during a workover and they may be repaired or replaced at that time. They may be also replaced because they are judged to be degraded (a kind of preventive maintenance). In the case of replacement of any component, its operational life (age) is assumed to start again from zero (as good as new). If they are repaired, their ages are resumed from the values they had prior to the repair (as good as old).

Once the instantaneous failure intensities are calculated for each leak path (or minimal cut sets), we do calculate the value of their instantaneous failure rates (see Vesely [21]) using the equation:

$$\boldsymbol{\Lambda_{Pi}(t)} = \frac{\boldsymbol{W_{Pi}(t)}}{\boldsymbol{A_{Pi}(t)}} \tag{4}$$

We are using the failure rate rather than the failure intensities of the leak path because we know that no leak path has occurred at t = t, otherwise a blowout would have already happened and the system would not be calculating. In this case, we are interested to know the probability of failure (occurrence) of the leak path between t and t+dt given that it is not failed at t, and this is given by the failure rate at t multiplied by dt.

We also use the expressions given by Vesely [21] to calculate the failure intensity and the failure rate of the well at t. With those we can calculate the Expected Number of Failure (ENF(t)) and the cumulative probability of having a blowout from 0 to t.

3.4 The Failure Frequency, the Cumulative Risk, and the Incremental Cumulative Risk

In our system, the main mode of controlling the risk of a blowout of the well is through the values of the frequency of uncontrolled leak at t given the well is not leaking at t, which is given by the instantaneous well failure rate at t. Typically this function is an increasing function with time (or a piecewise increasing function with time). The risk management control line (essentially the upper control limit line) is then used to calculate the limiting time that a barrier element can be in a failed state before the well has to be closed. Depending on the combination of failure rates of the barrier elements, this function may not increase too fast to reach the upper control limit within a reasonable time frame.

To circumvent the above mentioned difficulty we have implemented a second time limiting control by introducing the calculation of the "Incremental Cumulative Risk" caused by a given failure. We borrowed and adapted this concept from the nuclear sector where it is used as the limiting control for the so-called "Completion Time" used in nuclear power plants [22-23]. The completion time (CT) is the maximum time a failed safety system can be under repair (from the moment of occurrence of the failure) before the power plant has to be shutdown. It is calculated using the concept of incremental cumulative risk which is the amount of risk accumulated as result of the failure of the system compared to what would be accumulated without the failure.

In MyBarrier Integrity the Incremental Cumulative Risk (ICR(t)) after a failure can be calculated by:

$$\boldsymbol{ICR(t)} = \int_{t_f}^{t} \boldsymbol{F_{with\,failure}(t')dt'} - \int_{t_f}^{t} \boldsymbol{F_{no\,failure}(t')dt'} \qquad (5)$$

Each integral in Eq.(5) corresponds to the accumulated probability of blowout over the interval from t_f (time of occurrence of the barrier element failure) up to a time t in the future: the first integral is that calculated with the frequency of blowout with the detected failure and the second is the same but for the frequency of blowout without the failure.

Similarly as done in the nuclear sector, to use ICR(t) as a limiting function we had to establish a reasonable limit to it. In our case we use the following argument: the lower control limit of the frequency of failure graph is the upper limit of the SIL 3 range, namely, 10^{-7}/h. Considering that this is defined as the limit of the target region (acceptable region) of the frequency graph, the accumulated risk (the cumulative probability of failure) over the entire life of a well that continuously operates at this limit is equally acceptable. Such cumulative probability of a blowout over 30 years of well life is:

$$\boldsymbol{Cumulative\ Prob.blowout\ over\ 30\ y = 10^{-7} \times 30 \times 8760 = 2.63 \times 10^{-2}} \qquad (6)$$

Therefore allowing a certain percentage of this value to be incrementally accumulated at every barrier element failure is a very reasonable limit for the maximum time that the well is allowed to operate before the failed barrier element function is restored. In MyBarrier Integrity, this percentage is defined by the user company. In our examples, a value of 10% is adopted. This leads to an ICR limit equal to:

$$\boldsymbol{Maximum\ ICR\ Limit = 2.63 \times 10^{-3}} \qquad (7)$$

The use of a such a percentage (10%) for the ICR maximum value, means that even if the well suffers 10 barrier element failures and each one of them is allowed to use the ICR maximum value, the total accumulated probability of failure over the 30-year life of the well will only be equal to twice the acceptable value given by Eq.(6). This is a low variation considering that each SIL ranges correspond to a 10-fold variation of the frequency of failure.

4. PRESENTATION OF SOME RESULTS FOR AN ILLUSTRATIVE EXAMPLE

We present here some results for a hypothetical natural flow offshore well whose production starting date is April 01, 2018. The annulus pressure of this well is not constantly monitored but the failure modes of all barrier elements that can produce annulus pressure variation are tested every three years. It is also considered that the failure modes of DHSV, master and wing valves (failure to close and leak in closed position) are tested every three years.

Results of MyBarrier Integrity for the Example Well are shown below considering that no failure has been detected until today (15/11/21). The uncontrolled leak frequency graph (frequency of blowout) is shown in Figure 2 for the whole lifetime of the well. This graph is divided in three regions by two horizontal lines which are the two risk control lines:

1. The lower control line (the orange line) delimits the "acceptable region" or "target region" which is painted green in the speedometer to the left of the graph; this is the region where the operating company would like to keep the frequency of blowout during the whole life of the well.
2. The upper control line (the red line) marks the lower limit of the "unacceptable region" which is painted red in the speedometer; this is the region where the operator does not accept that the well is operated at any time (if the frequency goes above the red line, the well must be closed asap for restoration).
3. In between the lower and the upper control line lies the "tolerable region" where the operator does not wish to operate the well but tolerates that it is operated in this region for a certain time.

As can be seen from Figure 2, the frequency of blowout for the Example Well is predicted to be in the acceptable region for the first twelve years of operation of the well and gradually enters the tolerable region, although with periods of return to the acceptable region after performance of the periodic tests. On the other hand, the frequency of blowout is not predicted to reach the upper control line within the lifetime of the well, under the assumption that the today conditions are maintained throughout the period. Given the long time span until the end of life of the well there is a chance that some failure is going to occur within that period of time. Whenever that happens, the frequency graph will be updated to reflect the impact of such a failure event.

Figure 2 - Frequency of Uncontrolled Leak for Example Well without any Detected Failure

As indicated before, all leak paths are determined and their frequencies evaluated in MyBarrier Integrity where the relative contributions to the frequency of blowout of the well are also evaluated. The latter values are used to rank the leak paths according to their contributions. This is shown for the first three highest contributing leak paths where the highest contributor is that formed by combinations of failures of column and completion elements and annulus A elements. The second highest contributor is formed by the failure modes of the DHSV and those barrier elements immediately upstream from it.

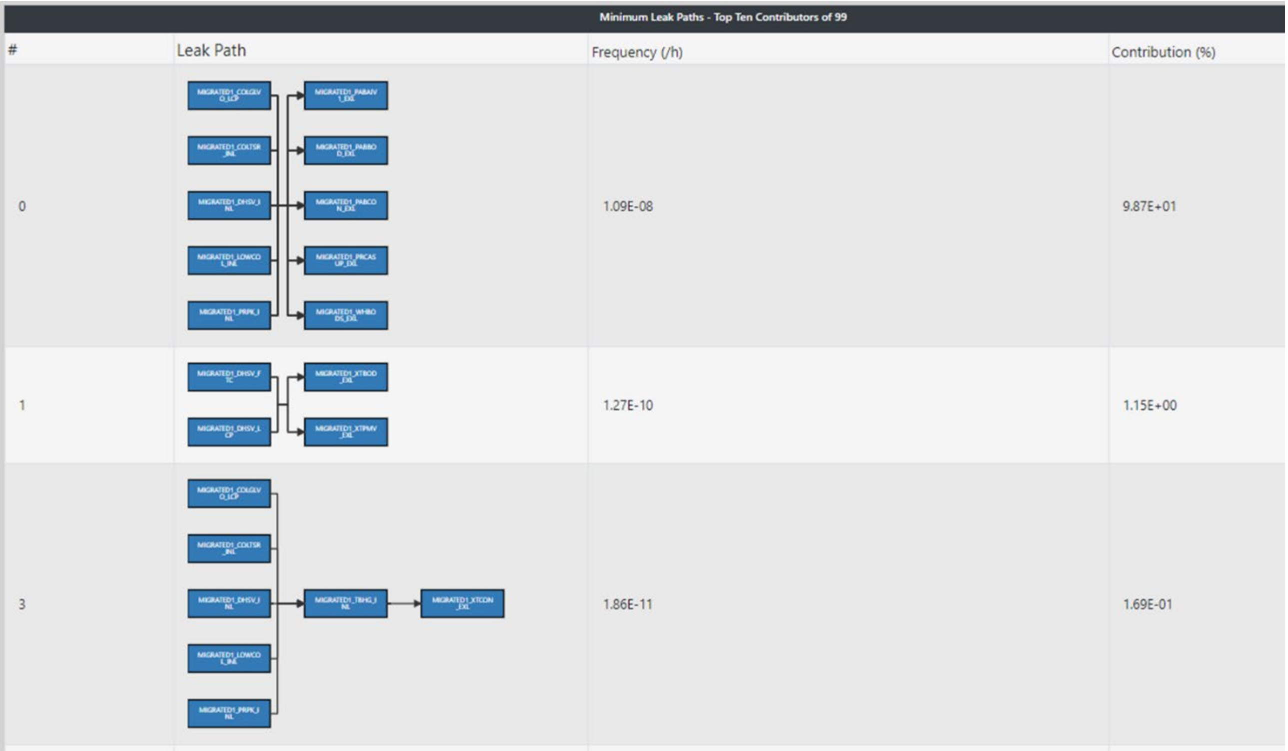

Figure 3 - The Three Leak Paths with the Highest Contributions to the Frequency of Blowout of Example Well

In Figure 4 we present the results for the frequency of blowout of Example Well before (green curve) and after the failure of the DHSV (blue curve). As can be seen, the failure of the DHSV assumed to have occurred on July 31, 2021, immediately causes the frequency of blowout to jump to the tolerable region and from that it will reach the upper control line in 8518 days from today as show in the Results Summary below the speedometer on the left.

Figure 4 - Frequency of Uncontrolled Leak for Example Well with Failure of dhsv on july 31, 2021

As can be seen from Figure 4, the frequency of blowout is slowly increasing with time for the case of Example Well. In principle, the operating company could consider that this is within the tolerable risk region and decide to run the well with the failed DHSV until, for example, an intervention in Example Well occurs for any other reason such that an opportunity is presented to fix the DHSV. In general, operational experience shows that well interventions occur at a rate of one every 10 to 15 years of well operation.

As indicated before, in MyBarrier Integrity another way to establish a limit for the maximum allowed time to operate the well with a failed barrier element is also provided which is that of the Incremental Cumulative Risk (ICR). Figure 5 shows the graph of ICR with time for Example considering the cited failure of the DHSV. The three curves in Figure 5 are: the green curve is the cumulative risk without the failure, the blue curve is the cumulative risk with the failure and the orange curve is the ICR which starts at the moment that the failure of the DHSV is detected and given as input to the system. The blue dot represents today (15/11/21) and the orange dot is the intersection of the ICR curve with the established risk limit of ICR. The frame on the left shows the number of days from the date of the failure to the ICR limit (729 days) and below that, the number of days from today to the ICR limit (621 days). In general, the maximum time obtained with the ICR tends to be lower than that obtained with the frequency of blowout limit, but this is not always the case.

5. FINAL COMMENTS

The novelty of this paper is the development of an in-time quantitative reliability model that can be used to calculate the risk of loss of well integrity at any point in time throughout the lifetime of the well. Future risks are approximately calculated under the assumption that current conditions (today) are maintained from now on. Whenever a new condition (a detected failure, for example) is detected, that information is passed to the system which will then recalculate the results taking into account the effect of the detected failure. One of the main advantages of this model is that the ages of all components are known at any time and this allows the calculation with time-varying failure rate distributions to be performed in a much simpler way. This allows MyBarrier Integrity to take into account the ageing effects of all well barrier elements, in addition to assessing the proper effects of repairs and replacements of elements throughout the lifetime of the well. It can also evaluate the effects of different testing policies for whole groups of tested barrier elements (barrier elements that are tested at the same time and with the same frequency) on the risk of loss of integrity. It can also assess the mean remaining time to a heavy or a light workover, thus providing significant planning support to upcoming interventions. This paper contains only a demonstration of a few of its main functionalities.

We do not think that MyBarrier Integrity is a substitute to most of the well integrity management systems already in use by oil companies, and it is not intended for that. But we are sure that it represents a very nice addition to the existing WIMS tools, because it adds several new elements to facilitate well integrity decision making that do not exist in the existing tools.

6. ACKNOWLEDGEMENTS

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