Quest Journals
Journal of Research in Mechanical Engineering
Volume 8 ~ Issue 2 (2022) pp: 09-12
ISSN(Online) : 2321-8185
www.questjournals.org

Research Paper

The Impact of Equipment Failure on Hydrocarbon Production

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ABSTRACT
Oil and gas production problems associated with subsea control systems, flow line, manifold, riser, wellhead, Christmas tree etc have led to downsizing, halting and loss in investment. Productionengineers in the oil industry always have difficulties dealing with the inherent uncertainties. Oil and gas production has been modelled as a multi-period optimization case to incorporate the possibility of different demands, cost and overall time behaviour. Ortiz-Gomez et al. (2002) proposed a Mixed Non-Linear Programming (MINLP) to model these planning decisions for an oilfield production. More recently, the works by Barragán-Hernández et al (2005) have been used to improve the predictability of the model. Hydrocarbon production is limited by physical system such as pipe diameters and lengths, and pressure gradient between the wellbore pressure and surface pressure and surface equipment. The exploration and production of oil and gas are still a high-risk venture alongside several uncertainties in related areas. The impact of equipment failures on hydrocarbon production can be catastrophic. Production management is needed to assess all equipment for hydrocarbon production optimization.

***R**eceived 10 Feb, 2022; **R**evised22 Feb, 2022; **A**ccepted 24 Feb, 2022 © The author(s) 2022.*
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INTRODUCTION

Petroleum industry has advanced to the extent that many areas of engineering and related disciplines such as geophysics, petroleum geology, formation evaluation, drilling, economics, reservoir simulation, well engineering, artificial lift systems and facility engineering have been fully engaged.

Petroleum is essential for the world economic, since that this hydrocarbon is the principal source of energy for many industrialized civilizations. Oil is consumed around the world in a range of 30 billion of barrels per day and approximately 24 percent is utilized by United States. In BP' s publication it was found that Africa in 2010 consumed over 372.6 million tonnes, a 3.4 % increase from that of 2009 and 3.1percent of the total global consumption. It is expected that this figure will grow disproportionately in the coming years ahead. Thus, the optimization and accurate planning in the hydrocarbon production is of paramount importance.

Oil and gas production has been modelled as a multi-period optimization case to incorporate the possibility of different demands, cost and overall time behaviour. Ortiz-Gomez et al. (2002) proposed a Mixed Non-Linear Programming (MINLP) to model these planning decisions for an oilfield production. More recently, the works by Barragán-Hernández et al (2005) have been used to improve the predictability of the model. Hydrocarbon production is limited by the oil and/or water displacement in porous media inside the reservoir, physical system limitations such as pipe diameters and lengths, and pressure gradient between the wellbore pressure and surface pressure. Pressure gradient should include the extra energy incorporated into the system to achieve production such as gas lift, pumps. Although the simulation process is a known solution for the optimization of a hydrocarbon field, the exploration and production of oil and gas are still a high-risk venture alongside several uncertainties in related areas. For instance, geologic aspects of the reservoir simulation are uncertain with respect to structure, reservoir seal and hydrocarbon charge derived from its primary properties: permeability, porosity, natural pressures. Technological uncertainty is another aspect that must be canalized critically. Parameters related to the development and availability of the production system is the key piece to reduce equipment failures.

Edwards and Hewett (1994) formulated an approach to measure the financial risks involved in production optimization. In addition, a couple of works have been conducted by Aseeri et al. (2004) to propose a model for economic uncertainties. Aziz et al. (2004) presented a good approach combining geological uncertainties as well as risk of failure of the control devices.

The probability of an equipment being available or usable for a job on the rig is one of those parameters to take in account for failure risk in the optimization model of hydrocarbons production systems.

Challenges Associated with Equipment Failure

Project managers and designers in the oil industry always have difficulties dealing with uncertainties and coming up with the best choices for developing oil and gas fields. The expression, uncertainties refer to the failure criteria of long in-use subsea production control systems like the manifold, flow line, riser, wellhead, Christmas tree, etc.For the most part, the traditional methods used for making investment decisions like capital investment assessment tools such as net present value (NPV) do not take into account the unpredictability of certain variables that may exist in the future.They are also inadequate for making a good investment decisionparticularly in large projects. Oil and gas projects with inherent problems such as listed above have led to halting, downsizing and significant loss on investment.

Investors and shareholders have increased reluctance in releasing their capital due to loss of confidence in their operators; business risk is getting higher due to frequent operational failures and risk of recurrent problems.In the Nigerian oil and gas scene, this has been one of the contentions between the NNPC and other joint venture operators.Equipment uncertainty can be reduced significantly in petroleum production by predicting the probability of system failure through its lifetime. As well as, the type of failure, the time to repair and time of occurrence associated with each failure. This approach will have beneficial use in making financial risk decisions.

However, the current analysis only takes in account the subsea equipment availability. There are other sources of uncertainty, such as, geological and financial uncertainties, which have to be included in order to perform an integral analysis.

Process Simulation Modelling

Petroleum engineering comprises a complex system of three distinct but intimately connected sub-systems: the reservoir, the well and the surfaces devices. As defined by Nind (1981), the reservoir is a porous medium with particular rock and flow characteristics; the well subsystem includes drilling techniques and inflow performance; and the surface structures include: the surface gathering, separation and storage facilities.

One of the tools used and improved on by petroleum engineers in the past years is the process simulation modelling for hydrocarbon systems. It uses computer models to predict the behaviour of the flow of hydrocarbons through the porous media, well and surface equipment.

The software employed to perform the modelling task was provided by Petroleum Experts and the Integrated Production Modelling (IPM) includes: the reservoir model (MBALL), production modelling (PROSPER) and the gathering and surface device modelling (GAP).The success of petroleum production engineering lies in the suitable combination of the knowledge in the three major areas: reservoir engineering, production engineering and surface equipment technology.

Reservoir Modelling

Reservoirs are complex geological formations which may contain different rock type, stratigraphic interfaces, faults, barriers and fluid fronts, storing oil, gas and water. These reservoir conditions may influence the pressure transient behaviour affecting the reservoir performance. For the reservoir description purpose, well testing, well log, seismic analysis, PVT and rock properties, will be the key elements to the forecasting of reservoir performance. Horne 1990 added that, reservoir characterization is essential to achieve the production planning of petroleum systems.

Simulation is a common procedure in the reservoir analysis; predicting the behaviour of the flow of hydrocarbons through the porous media by computer models. The most common models are the classical material balance equation and the simulation, which uses the principal simulator models: black oil, compositional and thermal.

The material balance equation is zero dimensional models (0-D) which is considered as a homogeneous tank that does not require a geological model to be applied in the classical manner. The simulations can be 1-D, 2-D or 3-D; these consider the flow effects, mass balance and heterogeneous models. Smith et al (1992) suggested that material balance is a necessary step prior to perform a simulation study.

Well Modelling

Production engineering as a part of petroleum engineering has the principal objective to maximize the production in a cost-effective manner. The well is the conduit or connection between the reservoir and the surface equipment: gathering, separation and storage facilities. So, well modelling involves also reservoir model and the surface network system.

Network System (Surface Facilities)

This section is focused on the transport of fluid from the wellhead to surface facility. The surface facilities usually comprise two or three phase separators in an oil production system. If we are producing gas, the surface facility can be a gas plant or a compressor station.

Flow-lines from individual wells are interconnected through a manifold for commingling of fluids from several wells in a single pipeline. The hydrocarbon is finally transported to a storage or sale location. In an onshore facility, the wells are spread and the gathering lines usually are several kilometres length. In an offshore facility, the processing facilities are often situated adjacent to the wellheads at the manifold. For this reason, the gathering lines used are quite short.

Sizing of oil and gas pipelines and processing facilities is generally complex because the fluid rates and composition vary with respect of time. In general, hydrocarbon (oil and gas) production will be decreased over time and water rates will increase through the life of the field. Therefore, the initial facility design must be flexible enough to handle a very broad range of production rates and compositions.

Production Constraints

The production system consists of a given number of reservoirs where several wells have been drilled and are ready to produce. Manifolds allow interconnectivity of the wells to surface facilities and the produced oil/gas is sent to common sale and storage points. Once the process is defined, the next step is its optimization, where the objective function and constraints will be defined.In oil/gas production, the objective function is maximizing the production.

The principal constraints of the problem include the pressure decrease in wellbores and the resistance to flow from this point to the surface, because of the pipe characteristics and pressure at interconnectivities points. (Barringer, 2000).Focus on subsea equipment is pertinent because it has high risk on offshore facilities, and also due to the lack of information about the availability of petroleum equipment data in onshore facilities.

Control System

In the last years, the application of subsea systems for the production of oil and gas from subsea wellheads have been increased in an accelerated pace. A subsea production system includes several components, such as, x-mas tree, wellhead, riser, flow-lines, manifolds, structures, etc. In many instances, a certain number of wellheads have to be controlled from a single location. For this reason, a subsea control system is crucial part of a subsea production system to ensure a reliable and safe operation.

A subsea control system has to provide satisfactory operational and safety characteristics. The control system regulates choke and control valves on subsea completions, templates, manifolds and pipelines, as well as provide means for a safe shutdown on failures of the equipment or another safety features that prevent dangerous situations. The levels of redundancy throughout the system will ensure a satisfactory time response that may have a dramatic effect on reliability and safety of environmentally critical operations.

According to offshore reliability data, the subsea control system comprises: surface installed master control station, hydraulic and electric power units, static and dynamic umbilical, chemical injection unit, subsea control and distribution modules and the control equipment installed on the tree or the template. The control system manages daily production operations by a topside located computer. A control umbilical is the connection between the topside and subsea parts of the system. The principal unit is the subsea control module, which comprises electronic pieces and hydraulic instrumentation for efficient operation of subsea and downhole valves and also, provides interfaces for the communication with the topside for production process monitoring and optimization.

Manifold

A manifold is constituted by a complex of pipes, which interconnect several incoming lines with one or more outlets, providing an interface between the production pipeline, flow-line and the well. The manifold commingles produced fluid from wells, incorporating valves and instrument to monitor and control fluids flowing in individual lines and also allows injecting and distributing gas and chemicals to template wells or satellites. In a subsea production system, the manifold is housed in a manifold centre, bringing support and protection to all pipe work and valves. The manifold centre constitutes the gathering point in a subsea production system, into which wellhead cellars and other manifold centres are connected by flowlines. The oil from a manifold centreisconnected to a subset or fixed platform production station. The manifolds may vary considerably in design from large and complex multi-well template manifolds to simpler freestanding manifolds.

Flow Line

These pipes carry oil from wellheads to manifold and to production receiving terminal. The flow-line comprises flexible or rigid pipes from the sea floor up to and including the hang-off on the receiving installation belong to the riser equipment class.

Riser

The riser is constituted by flow linethat carry oil or gas from the base of a production platform to the processing plant. In offshore facilities, there are three different types of risers: rigid risers in shallow water, rigid risers in deep water and flexible risers. Rigid risers in shallow water are set of vertical steel pipes, which are extended between the seabed and the topside of the fixed platform. A fixed platform supports laterally this kind of risers. (Chakrabarti, 2005)

There are usually two types of rigid riser in deep water: Top Tensioned Risers (TTRs) that are subject to mechanical tension by a system on the platform; and Steel Catenary Risers (SCRs), which are connected to the platform piping through a flex joint forming an angle.

Flexible risers can adopt different shapes, such as, a catenary, an S, a wave, etc. Flexible risers are mostly fabricated by multiple layers of steel textile and an inner layer of elastomer or polymer material.

Wellhead and Christmas Tree

Wellhead is a hardware complex that incorporates spools, valves and adapters installed either on the casing surface string or on the conductor pipe. The wellhead provides pressure control in the borehole and regulates the well production. Devices for hanging the upper casing and the production tubing are provided for the wellhead. Surface flow control or X-mas tree can be installed in the upper termination of the wellbore (wellhead). The boundary definition is shown in Figure 3.8, which includes the subsea wellhead and X-mas tree on single satellite wells and multiple wells. All the valves and connectors are considered as a part of the wellhead and X-mas tree.

Conclusion

Availability model can reduce significantly the equipment uncertainties in a proposed system, predicting the probability of system failure through its lifetime. As well as, the type of failure, the time to repair and time of occurrence associated with each failure. Thus, this efficient approach will have beneficial use in making financial risk decisions.

The current analysis only takes into account the subsea equipment availability. However, there are other sources of uncertainty, such as, geological and financial uncertainties, which have to be included in order to perform an integral analysis. According with previous works, the geological uncertainties vary from 6% to 20 %, depending on the field case study. For instance, for new developments fields the uncertainty is higher than for the existing producing fields. The case study on the planning of the oil/gas production systems proves that the proposed procedures have a significant effect in the production forecast.

The integration of the availability concepts into the current process simulation technology of hydrocarbons field production is an effective solution to perform accurate production predictions. Therefore, applying this approach in the real-life cases is highly recommended to avoid very worrisome, but common problems stemming from lack of tools to measure the uncertainties in associated equipment. Using this simple but very useful availability approach, we can avoid huge financial losses due to wrong production hydrocarbon predictions.

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