FLOW ASSURANCE

CASE STUDY USING STEADY STATE & TRANSIENT TOOLS

Introduction

As operators start to explore more remote hydrocarbon plays, our production systems are exposed to more challenging environments and fluid behaviour. In this contexts, any **operational decision** can have far reaching implications upon recovery. As such, our decision making process must be rooted in understanding of the environment with respect to the physics. This is where (in recent years) the flow assurance discipline has taken a central role in guiding operations.

In the field, turndown of production rate is often required so that routine maintenance operations can be performed on parts of the production system, such as ESP maintenance, wellhead maintenance, and pigging operations. As the production system is subjected to a lower throughput, the concept of turndown stability becomes important. Lower throughput, or even shut-in can lead to operationally difficult scenarios such as wax blockages, hydrate formation, asphaltene deposition, riser slugging etc. all of which are undesirable. Traditionally, this has been the domain of the flow assurance discipline, where modelling has been performed exclusively by transient simulators which account for pressure/temperature changes in seconds/hours.

In the production context, production is usually considered in much larger time frequencies (recovery is considered over decades). As such, using transient simulators for production forecasting is not practical due to the long run times, which limits their applicability to forecasting. Thus in terms of field planning/forecasting, steady state tools are used, where the entire production system is modelled over decades with reasonable run times, capturing the full reservoir, well and surface network response.

In reality, the long term is made up of the aggregated short term periods, and as such the two (**steady state** and **transient**) responses must be considered together. However, this has seldom been the case – as the traditional approach of functional silos mean these disciplines rarely interact, and use completely separate software. As such, consistency in assumptions and learning was rarely captured, whilst the practice of multiple engineers working on the same thing in isolation in different time periods was prevalent.

To address this shortfall, Petroleum Experts has been advocating for many years the combination of steady state and transient simulation, and RESOLVE (vendor neutral platform) is used to make this work. This article show how the **LEDAflow** data object can be used to fulfil the above objectives of integration between two traditionally different approaches.

Context

The production system below has 3 producing gas wells that deliver fluid to the production manifold, before entering the subsea riser which delivers fluid to the offshore production platform.

There is an opportunity to drill another well (Well 4) once the gas production comes off production plateau (and this is captured in GAP as a separator constraint).

Overall Engineering Objective

The production platform is sensitive to production surges, and as such any slugging that develops in the riser results in consequences that vary from being undesirable to damaging of production facilities downstream.
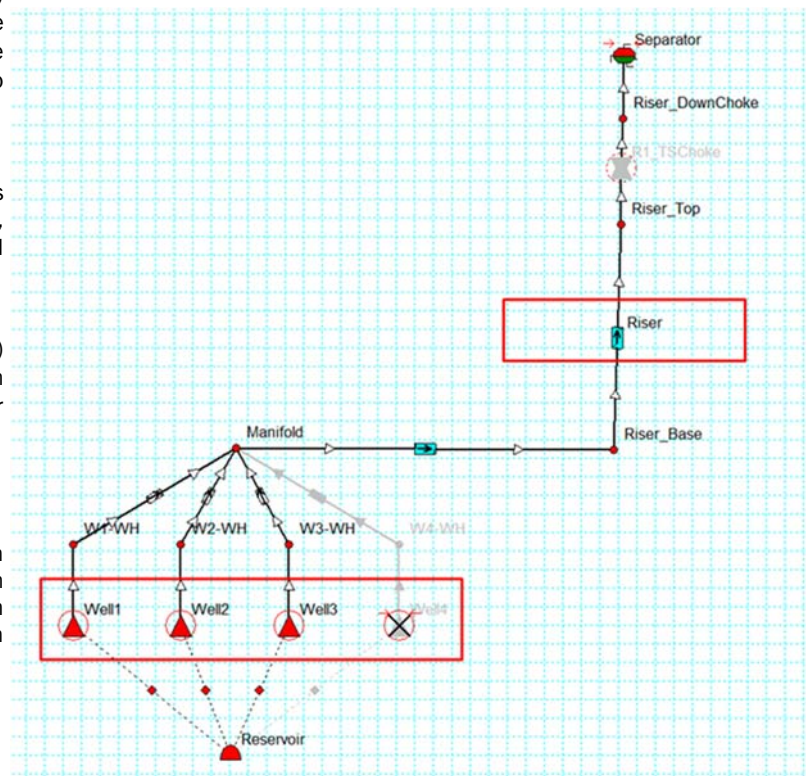
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Traditionally, flow assurance limits were *implicitly modelled* in steady state simulations by use of constraints. In the new approach (shown below) the limits are *explicitly modelled* in a transient simulator, and controlling logic applied in the steady state model. The traditional approach is outlined below:

- The flow assurance discipline would perform isolated studies on the turndown stability of the production system, and the propensity to result in riser slugging.
- The study would have to assume a PVT description, and approximations of pressures/rates. These would then be used as boundary conditions within the transient simulator to calculate the slug volumes and velocities that may damage process equipment. (Additionally, the transient simulator may not handle the PVT in the same way as the steady state tool).
- The next task would be to take this understanding and apply it to the steady state simulation, and this is usually captured as a "proxy" constraint in GAP (i.e. a constraint that is not due to the physical limitation of the equipment, but rather an operational limit).

With the introduction of the *LEDAflow data object*, the transient simulation is:

- Dynamically triggered depending on the conditions that manifest in the simulation
- The intake pressures, rates and PVT are not approximated, rather they come directly from the steady state simulation, and the discharge pressures are calculated by the transient simulation.

Modelling Objective
- Detect slugging in the riser
- If slugging occurs, assess the severity based on slug volumes and velocities
- If required, mitigate the slug occurrence by changing the control strategy in the steady state model.

Model Setup
The below model setup was used to capture the response of the Riser over a prediction forecast. The modules solve in the following order:

1. *GAP* was used to perform the forecast (Steady state multiphase network Optimiser)
2. *PROSPER data Objects* in *RESOLVE* were used to evaluate the occurrence of slugs (Steady state nodal analysis)
3. The results of the data object are used by the **Workflow**, to evaluate whether a slug exists or not. If a slug does not exist, the next timestep is taken.
4. If a slug exists, then data from **GAP** is passed to **LEDAFlow** (Transient simulator) and the simulation run
5. The final piece of the analysis, is to find the **average slug properties** for volume and velocity (the transient simulator solves the riser in time, and so different volumes exist at different times within a specific section).
6. *Feedback Loop:* If the response of the system is not acceptable, an additional control feedback loop can also be introduced in step 1 and the analysis re-run for this timestep.
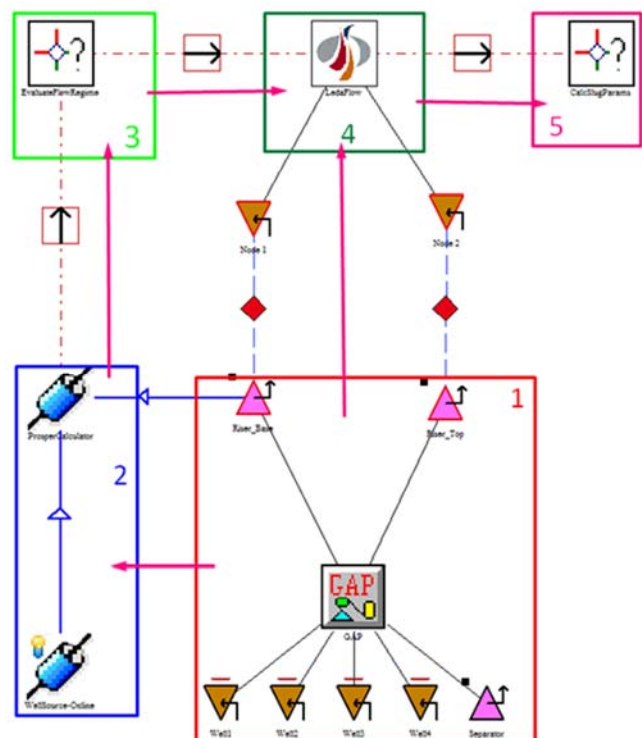
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Steady state Analysis

The results of the workflow (step 5) show "SlugVelocity" and "SlugVolume" variables, which are user defined and are reported in the RESOLVE results. As soon as WGR of these wells increase, the slugs start to form.
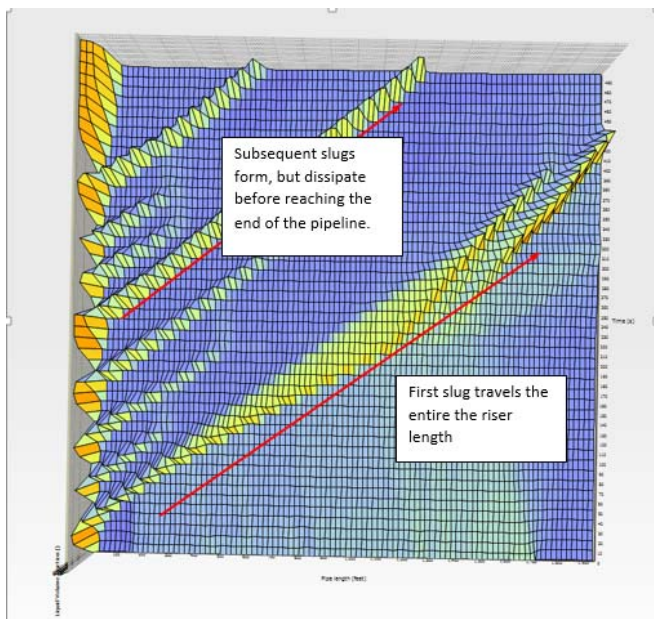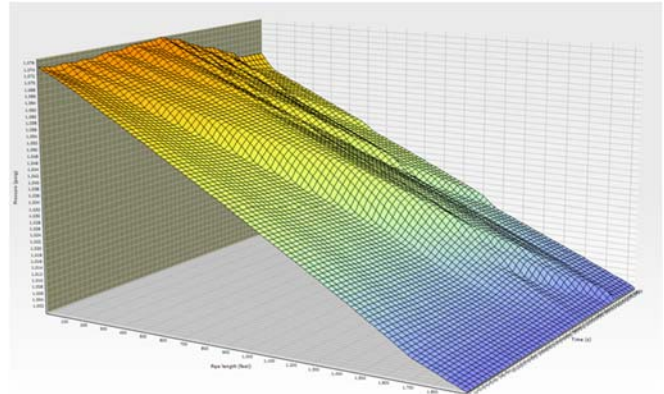
In the below screen shot it can be seen that after a particular WGR threshold is reached (blue curve), the slugs immediately form (green curve).
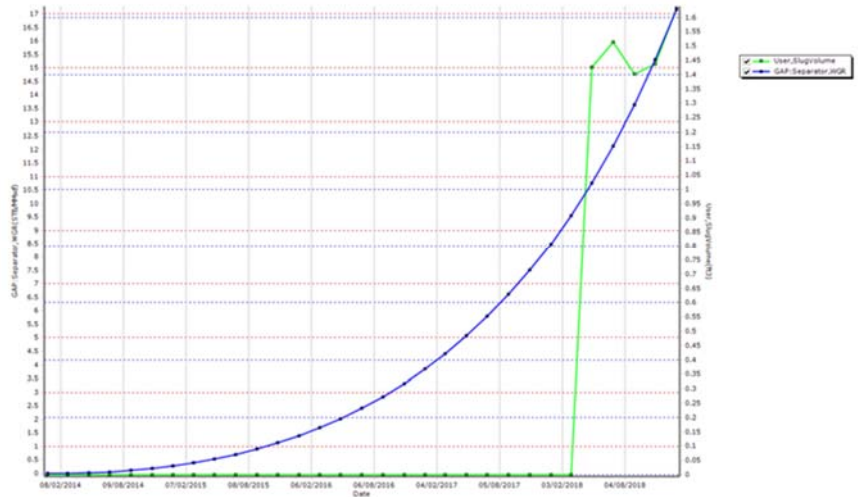
Transient Analysis (Results imported into RESOLVE)

The below graphic is from LEDAFlow, and shows a 3D Plot (time, pipe length and pressure): it can be seen that slugs develop and travel up the riser.

Rotating the above graphic makes it easier to interpret:

It can be seen that a slug forms and travels the entire length of the Riser, and is immediately followed by smaller slugs that dissipate as the travel the length of the riser.

Subsequent slugs form, but dissipate before reaching the end of the pipeline.

First slug travels the entire the riser length

In this case the slugging starts but appears to dissipate (rather than grow in strength).

The model was modified to initiate stable slugs, and the transient response can be seen in the liquid volume fraction overleaf.

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The below plot shows that a large portion of the riser is being exposed to slugging, and that the slugs travel the entire length of the pipeline.

Looking at the pipeline at one moment in time (250seconds) shows that there are more than one section that have slug regime manifesting.

Summary

Traditionally, flow assurance limits were *implicitly modelled* in steady state simulations by use of constraints. In the above approach the limits are *explicitly modelled* in a transient simulator, and controlling logic applied in the steady state model.
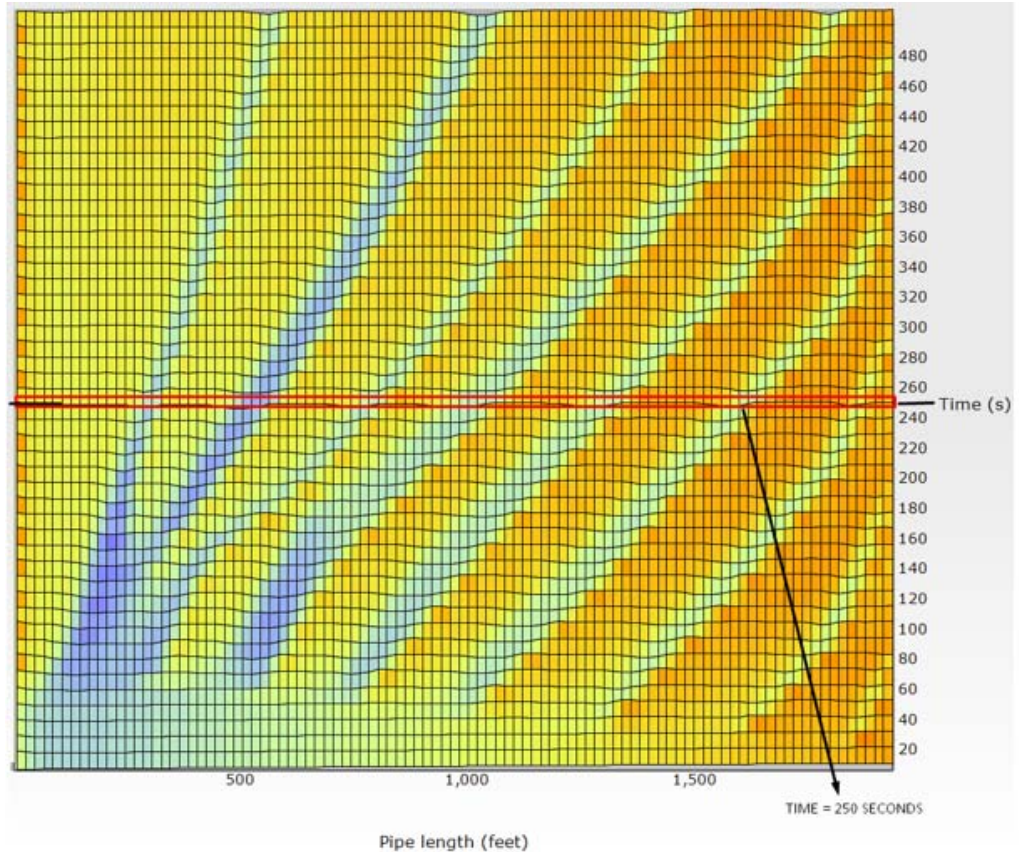
The above example of riser slugging shows how the steady state and transient modelling approaches should be used together to understand the response of the system.

In this case the transient simulation is fed with pressures, rates and PVT that are pertinent to the time in question (this may not always be the case when modelling efforts are isolated), and automatically triggered based upon events in the steady state model.

It is only after evaluating slug volumes and velocities that decisions can be made to impose control logic, or indeed modify the system (e.g. Wellhead chokes) to mitigate the above response.

A similar approach could be readily applied to a whole host of flow assurance issues (Waxing, Asphaltene dropout, hydrate formation, slugging, etc.) that have historically had the modelling engineer hopping from one programme to the next, in an isolated way.