The Role of the "Full-Scope" Pipeline Simulator: Risk Management for the New Millennium

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Abstract

The increase in mergers and acquisitions and the formation of consortiums and partnerships to support new construction in the pipeline business places operating personnel in positions they may not be familiar with. The increased profit focus resulting in fewer people available for these operating positions only aggravates the situation. In order to be successful in this high-pressure environment, a new approach is needed.

This paper describes a new approach that has been developed and proven to meet the challenge. The tool that is central in the support of this approach, the "Full-Scope" Pipeline Simulator, is described along with what differentiates it from a typical trainer. Furthermore, the enabling technologies that have made it available at a reasonable cost are presented. Details are given which show how both risk and cost are effectively managed by validating the design and commissioning of a pipeline and its' associated SCADA and Control Systems. Also covered is a listing of the management commitments required to realize the rewards of this approach. The paper will then show how the majority of these benefits can be achieved by existing pipelines, particularly in the area of training of operating personnel and procedure validation. In conclusion, by using the "Full-Scope" Pipeline Simulator and the processes it enables, a committed pipeline operating company will have a firm foundation on which to build an Operator Qualification Program that will meet the new proposed D.O.T. regulations.

The New Approach

The current situation of the Pipeline Industry is being shaped by a number of conflicting forces. Profit pressure is forcing companies to consolidate and downsize while safety concerns are mandating Operator Qualification programs. Personnel resources are reduced by one force and required by the other. A new approach is needed to balance these competing forces. This approach was developed and applied in the aviation and nuclear power industries, two industries where public safety is of paramount importance, but profitability is still a major concern. The hallmark of the approach is to use simulation technology during the design, commissioning, and operating phases of all major projects to confirm designs, expedite startup, optimize operations and train personnel. The idea is to view this technology not as something that is stuck on or near the end of a project

to drive applications or provide training, but to view it as an integral part of the process of doing business from start to finish.

The cry has always been yes, but it's too expensive, it's a money pit, it doesn't pay for itself. Some of these charges have had merit in the past. The technology was not mature, the resident hardware and software too expensive, and the project goals not well defined. The aviation and the nuclear power industries could have made these same claims in the 80's but persistence and eventual success prove out the value of this approach. Each year technology gets better and cheaper and the past reasons for not using it become less valid. The assertion of this paper is that for new pipeline projects, the time for using simulation technology from start to finish has come. Recent projects have shown that the savings in startup time alone, is enough to pay for the entire effort. This doesn't take into account the reduced risk of having procedures already verified and controllers already trained **before** pipeline startup.

To fully realize the benefits of a pipeline simulator build it before (or while) you are building your pipeline project. Use the simulator to verify all decisions and validate all data every step along the way. When the pipeline goes into operation, have the simulator also go into operation as the basis for both a training system and a decision support tool. As control logic or physical changes are proposed for the actual pipeline validate them on the simulator first. Keeping the simulators design in step with the pipeline can be of immeasurable value for those unexpected challenges when you're faced with situations you have never seen before; remember Apollo 13. Finally, allow time for Controllers to gain experience responding to startups, shutdowns, transients, and abnormal situations on the Simulator. They will get a feel for how the pipeline responds to their actions and gain the equivalent of years of operating experience in a matter of days.

Enabling Technologies

This type of approach would have been unreasonably expensive and technologically challenging just a few years ago. There have been a number of significant technological developments recently that have mitigated this situation.

First, hydraulic models from all the vendors are improving. Models are available that accurately simulate the physical characteristics of the fluid through both the pipeline and the stations. Computers are continuing their trend towards being significantly faster and cheaper. Pipeline models are notoriously CPU intensive, therefore increasing computer power allows for higher fidelity models to be used for training. Operating System Software is standardizing and third party software providers are rallying around that standard. This makes a lot of the non-modeling software, such as drawing, database, and reporting packages available at a reasonable cost from others who are experts in their fields. The last critical enabler has been that control systems are more often built with computer based tools that have export abilities using standards such as IEC 1131. This facilitates the development of an exact simulation of the PLC's in the field that we call the Virtual Control System. This is the defining differentiater between a trainer and a pipeline simulator.

All of these trends have made possible the development of what we call the "Full Scope" Pipeline Simulator which is the asset that supports this new approach.

The "Full Scope" Pipeline Simulator

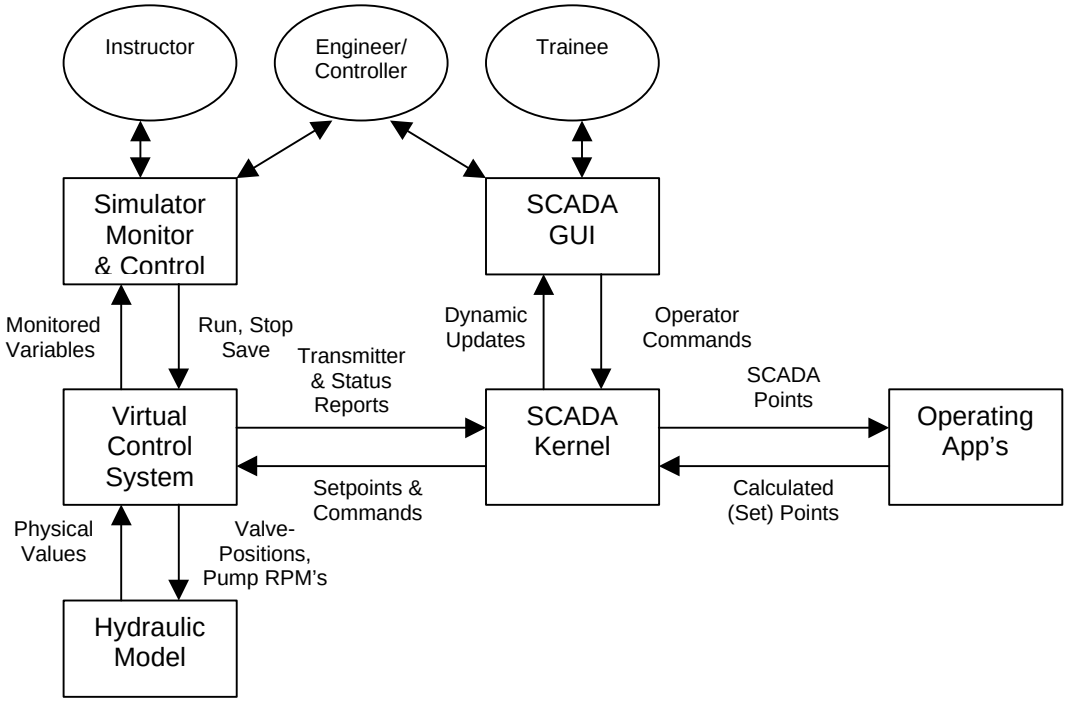
The underlying characteristic of this simulator is that it is a near copy of the actual control room. The following is a list of specific traits that the pipeline simulator should have:

- Same physical layout as the control room
- Identical operator screens, keyboard layouts and peripherals
- Included operational applications
- Hydraulic model that produces responses indistinguishable from the pipeline
- Virtual Control System that mimics the actual controls in the field

The simulator should also have a minimum number of Basic Functions that it can perform to satisfy its intended purpose.

- Run in Real Time and preferably Fast Time
- Stop at any point and then continue from that point
- Save its configuration at any point and recall it at a later time to be run

"Full Scope" Pipeline Simulator Architecture



There are a few things that are in the control room but usually omitted from the simulator architecture. Typically the SCADA system is not redundant. This saves on hardware, license and maintenance costs and does not cause any appreciable loss of functionality. Secondly, business and historian applications are not included, only applications related directly to the immediate operation of the pipeline are simulated.

The basic function list may seem short, but we have found that extending it adds undue complexity to the simulator without adding an equal amount of benefit. For example, Fast/Slow Time is often added to the list of desired functions. In order to provide this

function both the SCADA system and the Operational Applications have to be independent of the "Hardware Clock". In most cases, the effort to accomplish this is beyond the value it provides. Often, it is challenging enough to be able to just stop an application and then run it again from where it left off without any disruptions. Also, by simply saving the condition of the simulator at a point in time and then being able to return to that point at a later time and run is usually sufficient for satisfying the requirement for replaying simulator sessions. Elaborate replaying of all operator window operations is usually not required and difficult to obtain from most SCADA systems and applications.

Validation of System Design

Simulation models have been successfully used to validate the physical design of Pipelines for a number of years. What is new, is that they can now be used to validate the entire system design. This includes the physical pipeline, the pipeline equipment, the field controls, and the SCADA system with its' displays and applications. All of these system components have been validated individually in the past. What's new is that the interactions between them can now be checked out thoroughly. For example, a control popup window in a SCADA screen can be activated causing a command to go to the field PLC. The PLC moves a control element, that in turn changes the flow in the pipeline that causes a transmitter to change value. This change in value is reported back to the dynamic fields in the original SCADA screen. Seeing this happen in real time prior to the pipeline startup is a true validation that the system works the way its needs to; not just that the individual components, sometimes supplied by different vendors, each work.

Facilitation of Commissioning

Using a pipeline simulator in the commissioning of a new pipeline has benefits beyond those mentioned above in validating the system design. Once the simulator is built, the tedious job of point to point checkout can begin. Insuring that SCADA screens are tied to SCADA values, which in turn are correctly mapped to PLC registers, which are then read by PLC control programs and activate field control elements can be accomplished on the simulator prior to going to the field. When the system gets to the field, the remaining work related to point to point checkout is reduced to the task of insuring that the field transmitters are working and wired properly to the PLC's.

The PLC logic is received from the Control vendor prior to being installed in the field. It is converted to simulation code and dropped onto the pipeline simulator for testing with the hydraulics and the SCADA system. Timing idiosyncrasies caused by the SCADA polling and communications as well as responses by the fluid (in the hydraulic model) provide a thorough testing environment for the control system. Setpoint validation along with PID loop tuning is also completed prior to field installation. Aside from any unexpected mechanical problems, stations should come up and run with all continuous and sequential control debugged. This is where the real hard savings are realized in this process. The magnitude of these savings can pay for the entire modeling effort.

Training and Procedure Verification

The pipeline simulator used in the validation and commissioning also becomes the means to rigorously test operating procedures and train pipeline controllers. Controllers gain confidence in their ability to control the pipeline before they are put under the stress

of the real control room. Operating procedures can be checked out and optimized on the simulator. Different techniques for starting up and shutting down can be thoroughly analyzed for interactions between the control system and the surges in the pipeline. This analysis minimizes pump motor trips during the actual startup and increases the margin between operating pressures and MAOP. Procedure verification is particularly important in dealing deal with hazardous conditions, such as leaks. Realistic leaks of varying sizes and locations can be simulated and different operating procedures can be tested to reduce loss of product and time to isolation using the simulator.

The simulator can be used for both instructor based and self-training sessions. With instructor based training, an experienced instructor or senior controller can control the simulation and insert various malfunctions into the system for the trainee to recognize and respond to. With self-training, stored scenarios can be selected and run under the direction of the trainee alone. The results can either be viewed by the trainee for their own interest or reviewed by the instructor at a later date and included as part of their formal training results.

A side benefit for management is that the simulator can be used to show visitors how your operation works without disturbing the control room and show your commitment to doing what it takes to be both safe and fiscally responsible. And by permitting some employees outside of operations, time on the simulator, company morale and employee motivation can be enhanced.

Management Commitment

All of the advantages listed so far come only after time; money and effort have been expended. It is imperative that top-management buy into this approach in the beginning and support it through the entire process. It is also critical that there be one high level manager or executive that champions the process and whole heartedly believes in it's value. This person becomes the single point of focus for the effort insuring that the team stays motivated in working toward their goal. It is tempting to save money in the short run by not updating the simulator with changes that are being implemented on the real pipeline. By committing to keeping the simulator up to date, it is not possible to allow control system changes to be patched in, SCADA screens to be changed, pipeline equipment to be added without first understanding the effects of such changes on the operations, procedures and people involved. It is not possible to have bad or missing configuration data, malfunctioning transmitters or out of date software and not be aware of it when you commit to this process.

Some basic commitments needed of management include:

- Keep the simulator up to date
- Mandate that when time permits, every procedure be run first on the simulator
- Use the simulator to analyze and scrub pipeline facilities configuration data
- Force rigorous standardization and documentation of the pipeline control systems
- Have business processes that are designed to take advantage of using the simulator
- Encourage ad hoc learning time on the simulator

By committing to keep the simulator up to date and to use it in the day to day business of the operations center, management is showing a high level of preparedness and discipline.

Application to Existing Pipelines

While most of the examples listed so far deal primarily with using a simulator in the rollout of a new pipeline, similar benefits can be achieved for existing facilities. As previously mentioned, one of the things that differentiate the "Full Scope" Pipeline Simulator from a trainer is the rigorous manner in which the control system is simulated. In order to achieve this rigor, everything has to be known about the existing controls in the field. The very process of obtaining this information forces the operating company to take a good look at the state of their field controls and its' corresponding documentation (or lack of). If the condition of the field control system were such that an upgrade may be in order, then most of the benefits of design verification and commissioning that apply to new pipeline projects would also apply. In fact, any project that upgrades the pipeline could be added on the simulator first to verify that there would be no disruption to the operations.

The main benefit for existing pipelines is in the area of Training and Procedure Verification. By using the "Full Scope" Pipeline Simulator as a platform on which to first practice any planned major operation on the pipeline, such as a shutdown, risk in performing the procedure is greatly reduced. Documenting the procedure to be used and verifying its successful operation first will save valuable production time if there is as much as a single error. Secondly, controllers can feel free to experiment with new and unique ways in which to operate the pipeline. Any of these might yield a step change improvement in the operation. Controllers might also spend time understanding how their actions affect the transient pressures inside the pipeline by watching the hydraulic profile closely for any sonic effects. This could, in essence, be called using pipeline models for "Leak Prevention" as well as leak detection.

Having the simulator up to date and nearby makes it advantageous for the controllers to try procedures that they will be or might be executing in the near future for last minute practice and confirmation. If the simulator is networked to a compatible on-line model, an "Initial Conditions" file could be transferred to the simulator and the procedure would be performed on the exact operating condition that the pipeline is currently experiencing.

Operator Qualification Program

On August 27, 1999 The Office of Pipeline Safety of the Research and Special Programs Administration in the Department of Transportation issued a new ruling (49 CFR Parts 192 and 195) regarding Pipeline Safety related to the Qualification of Pipeline Personnel.

The rule specifically states that simulation is one of the options for evaluating an employee's qualification:

> *"Evaluation* means a process, established or documented by the operator, to determine an individual's ability to perform a covered task by any of the following
>
> (g) Simulations…"

In addition, the rule states employees be qualified on tasks covered by the ruling and also to be able to effectively deal with abnormal conditions on the pipeline facility:

> "*Qualified* means an individual has been evaluated and can
> (a) perform assigned covered tasks
> and
> (b) recognize and react to abnormal operating conditions."

While a pipeline simulator is not specifically required, and in some cases may be overkill, it does provide what we believe to be the best way to learn to recognize and deal with abnormal conditions. In addition, a simulator is the best way to evaluate an individual's ability to perform operations related tasks that are infrequently done with no impact on the business.

Conclusion

But a pipeline simulator is more than a tool to meet a training requirement. It is a business asset that forces rigor in your business data and processes. While at the same time, it provides you with a safe method of being informed when something is amiss. A Pipeline Simulator shows that a pipeline operating company has been willing to invest in doing all that is possible today to insure that your people, systems, and procedures are all of the highest quality possible; quality that addresses safety as well as economics.