

Virtual Reality Training Program

A Comprehensive Plant Crew Training Solution Improving Process Reliability and Safety

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Abstract

One of the key challenges that capital-intensive industries will face over the next five years is replacing the gray-haired workforce with the computer-savvy/gaming generation. High-fidelity operator trainer simulators that represent the production process, control system and the control room interface have proved to be very effective for control room operations training. However, for the remaining 50% of the plant start-up procedures that are executed in the field, no fully interactive training environment has been available – until now.

Industries like oil and gas, refining and power companies need to institutionalize their workforce knowledge in more efficient and effective ways. Leveraging Virtual Reality (VR) models to improve time-to competency in critical areas like safety, environment protection systems, knowledge, performance training, and reliability provides a vehicle to rapidly train the new workforce in ways that align with their interests and skills.

With continuing advances in hardware and software techniques Virtual Reality (VR) is accessible today as the best aid to multimedia training, process design, maintenance, safety, etc. which are currently based around conventional 2-Dimensional (2-D) equipment views.

The real time rendering of equipment views puts demands on processor time and so the use of high fidelity simulators is becoming more and more of a standard in process understanding and training. Within many VR commercial projects in the past, the results have either been unrealistically slow or oversimplified to the detriment of the solution effectiveness. As the technology continues to develop, these issues have been eliminated,

giving way to a new process simulation era that is based on commercially standard IT hardware.

IVRP (Immersive Virtual Reality Plant) now provides a large range of effective multimedia aids that are easily and economically accessible to support design, training, maintenance or safety in the process industry by linking the power of dynamic simulation – DYNASYM – to VR applications and tools.

Invensys has filed patents for the solution outlined in this paper.

A revolutionary new training medium

Virtual reality is a rapidly growing technology that utilizes the increasing power of computers to simulate real or imaginary environments and situations with a high degree of realism and interactivity. It is an emerging technology with potential applications in areas such as product design and modeling, process simulation, planning, testing and verification, real-time shop floor controls, training and maintenance. Virtual reality technology is being used for training applications in a wide variety of process industries and fields such military, medicine, aircraft, art and business.

Virtual reality offers the potential to expose personnel to simulated hazardous situations in a safe, highly visual and interactive way. Customized simulations of chemical plant layouts, dynamic process operations and comprehensive virtual environments can be set up allowing users to move around the virtual plants, taking operational decisions and investigating processes at a glance. The consequences of both correct and incorrect decisions can be immediately fed back to trainees giving them the opportunity to make mistakes and directly learn from them. Users can interact with the virtual worlds using a variety of hardware devices such as joysticks and data gloves, and the impression of actually being in the virtual world can be enhanced by special optical and audio devices such as head mounted displays and three-dimensional, surround sound.

The overall aim of IVRP is the development of novel training techniques to improve the operational efficiency and skills of plant personnel. This includes the development of a wide range of training scenarios that can be applied in the chemical process industry. The use of IVRP will increase process understanding, readiness, safety awareness and knowledge of safety procedures and therefore lead to production improvements while reducing the plant accident rate.

The large spectrum of objectives for the IVRP solution can be classified as follows:

- General suitability and potential of virtual reality technology for training application in the field of the process industry

- Development of a wide variety of virtual chemical plant environments to train operators on a range of different scenarios
- Identification of key components and characteristics of the chemical processes and exploration of new, visually-intuitive learning techniques to be implemented in a virtual world for adequate realism and training acceptance
- Adherence to the new Human Factor Engineering (HFE) trend by broadening the individualized focus on training to cover communication and teamwork

IVRP Platform & Architecture

The IVRP interactive system is a server-centric distributed application that centralises the scene update and enables scene rendering on many concurrent stations. It has a central component, the server, which synchronises directly with the Invensys SIM4ME simulation engine so that the properties of each plant element in the VR scene are always updated with the process simulation. The VR system also has other stations that are used for different roles in the simulation. All of these elements communicate via network, relying on standard TCP/IP protocol.

The server application is in charge of handling the communication among the various modules and of keeping an updated version of all scene parameters. It holds a copy of the scene graph (a hierarchical representation of the 3D scene) that is synchronous with the one present in each satellite application. It constantly updates the scene graph data and provides notification of the changes through a network protocol to the satellite applications.

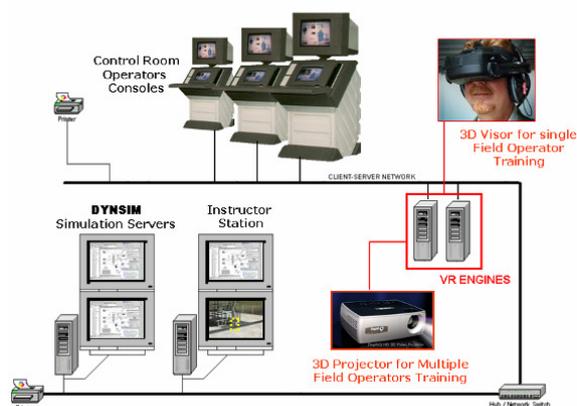


FIG. 1: IVRP Architecture

The satellite applications are in charge of rendering the visualised data and providing additional functionality to the users. The main client station allows for playing the role of the Field-Operator by reproducing the plant environment and enabling a user to perform actions on plant elements (e.g. opening a valve). All the actions that the virtual Field Operator performs are tracked and synchronised with the other platform elements, including the process simulator. The output can be displayed on different systems, ranging from standard desktop monitors to head-mounted displays to immersive projection systems; it can use both mono- and stereoscopic vision.

The main simulation modules that interface to IVRP include Invensys' powerful high fidelity process simulator, **DYNSIM™**, as well as **FSIM™**, the control system emulation software for the I/A Series distributed control system. IVRP is also compatible with a variety of process simulators and control systems emulations.

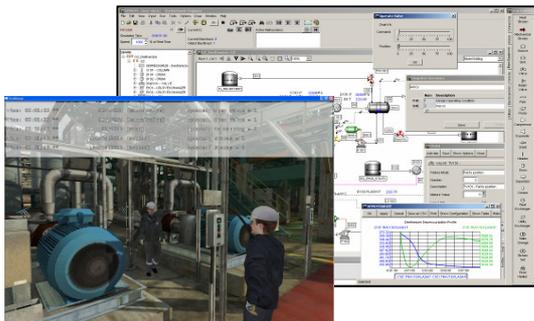


FIG. 2: Instructor can track all trainees in the field by a free view camera available as a window on the Instructor Station

Augmented Reality

Augmented Reality is a combination of virtual and graphic three dimensional images that are transmitted to a user. Augmented reality differs from virtual reality in overlaying these graphic images onto the real (virtual) life, engaging the user in an immersive, interactive and three dimensional “augmented” environment.



FIG. 3: Augmented reality: example of a trend popup in the virtual field

By superimposing virtual images, videos, or text onto real (virtual) life, an experience can be heightened or even modified.

Fig. 3 shows the example of a dynamic trend diagram calculated by DYNSIM which can be activated / deactivated by the user with a simple touch on the hand device anytime during the plant walk-through or a task procedure. Variables and trends can be selected /customized by type (temperature, pressure, flows, etc.) and by equipment exactly as they are available in the control rooms. Source of data will be the same: simulation engine or real time data base.

Alternatively, Fig. 4 reports a different type of augmented reality, where equipment units become transparent and the information relayed is given as a video animation of the process behavior.



FIG. 4: Augmented reality: example of transparent units for a visual direct feedback on process behavior

There have been a number of recent and well-publicised accidents in which human error has played a prominent part. For example, in Texas City in 1969 the operators opened an escape valve in the overhead product line of a butadiene plant which was placed on total reflux while other parts were being serviced.

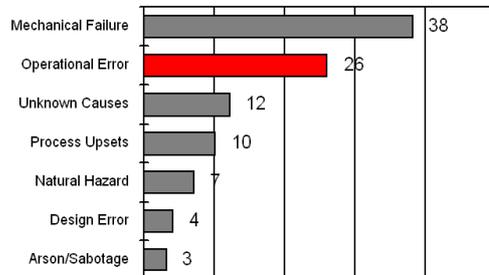


FIG. 5: Accident causes

As a result an unstable compound, vinyl acetylene, concentrated in the bottom of the column. Eventually two tonnes of vinyl acetylene in the liquid phase detonated, scattering large pieces of the column up to 900 metres and the fire burned for 60 hours. In order to understand the contribution of human behaviour to the risk of accidents it is essential to examine the errors people make and what leads to such errors. The reduction of human error probability can lead to a reduction in the probability of accidents in process industries.

A useful classification framework identifies the human errors as slips-lapses, mistakes or violations. Slips or lapses typically occur through lack of attention or from stressful situations with the result that individuals fail to achieve what they intend to do. Slip or lapse human errors include forgetting to turn off power, becoming inattentive to important safety checks or forgetting important steps in safety procedures, which may cause equipment damage and loss of lives.



FIG. 6: A virtual fire

To reduce these errors in operating procedures, effective training methods must be developed. In the past the objective of operator training was only to prevent direct damage and to reduce the loss of lives and property from accidents but at present it includes the broader meaning of developing human resources and increasing productivity, safety and efficiency. The importance of operator education is emphasized now more than ever.

Training has always been considered an important factor in staying competitive in a global economy. Operators need to remain up to date with the latest methods and technology. Training should involve an introduction to basic hazards and plant safety procedures, incorporating fire alarm systems and detailed work safety processes. Therefore, there is a need to create hazardous simulated conditions to provide a real (virtual) world situation for such training without causing any harm to the trainee or to the environment.

IVRP allows users to navigate in any direction within a computer-generated environment, creating crisis conditions and deciding what actions to take and immediately see the impact of those actions.

1) Reference: Causes of losses in the largest hydrocarbon-chemical plant accidents. Source: Large Property Damage Losses in the Hydrocarbon-Chemical Industries: A Thirty-Year Review. (New York: J& H Marsh & McLennan Inc., 1998), p. 2.

IVRP allows trainees to walk around the plant, see all the equipment that constitutes the process, have the possibility of starting, running and shutting down equipment and responding to error conditions without causing any damage to the equipment or harm to themselves.

In practice, all of those abnormal situations that an operator may dream of but was never able to test in reality can now be tested by IVRP as well as the different atypical plant behaviours understood. Expected and predictable malfunctions can be tested entirely and even forced until the accidental sequence results in a disaster.

IVRP provides a powerful environment to test human behavior in normal and abnormal process conditions by enabling the operator to move around and virtually “touch the reality”.

Maintenance & Reliability

Plant maintenance best practices require a team-based approach where operators perform certain equipment maintenance activities and maintenance crafts work closely in the daily operation of equipment.

In process operations, for example, the nature of the organisation of the maintenance task is heavily dependent upon the maintenance establishment’s industry sector, range of equipment maintained and specific culture. However, regardless of the subject matter, the maintenance tasks can be generally broken down into the following subtasks:

- Replication – being able to reproduce the reported fault;
- Identification – being able to accurately diagnose the source of the fault;
- Rectification – correcting the fault by taking action appropriate to the policies of the maintenance establishment;
- Confirmation – checking to see that the identified fault has been cleared.

Each of the four stages described above requires a mixture of generic and specific physical and mental skills.

Using VR, facilities maintenance operators can be trained to have a deeper understanding not only of the maintenance task itself but also of the science behind the equipment that they are dealing with. This means that the structure of a typical training course will include objectives that can be taken from a broaden number of training categories:

1. Initial Theoretical Training
2. Instructor Led Training
3. Systems Appreciation
4. Fault Diagnostics Training
5. Rectification Training
6. Equipment Familiarisation
7. Scenarios Simulation
8. Visual Appreciation
9. Hand/Eye Coordination
10. Spatial Appreciation

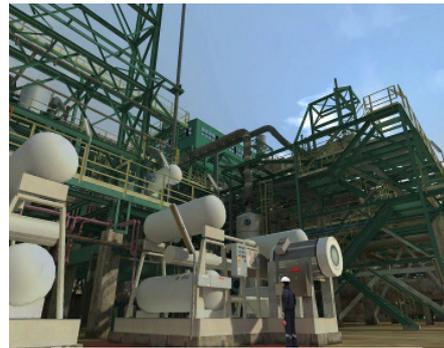


FIG. 8: VR spatial analysis

This is primarily a spatial system analysis (3, 8, and 10) where working spaces, escape routes, risky areas and transportation routes in the plant could be investigated from a logistic point of view. The result of such analysis could allow maintenance procedures to be optimized or serve as a request to maintenance management for improvement or modification.

A second example (see fig. 9) could refer again to a spatial appreciation (10) but with a purpose of equipment familiarization (6) and hand/eye coordination (9). As a matter of fact, the operation of a highly automated industrial process is to a large extent dependent upon the maintainability of the process equipment.

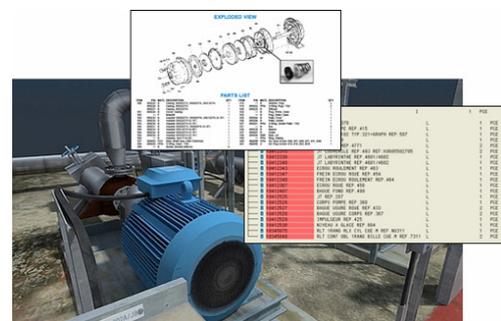


FIG. 9: Multimedia maintenance equipment analysis

Maintenance issues on diagnostics, timing and procedures are highlighted and consequently optimized by interactive links to the virtual equipment as well as to a computer integrated maintenance and documentation management system. Therefore, fault diagnostic training (4) and rectification training (5) can be based on a comprehensive multimedia tool that is able to transfer not only knowledge but also skills (9):

- Capturing instrument calibration and lubrication activities within a VR model provides a means to integrate and align operations and maintenance activities.

- Integrating operations, maintenance activities and checklists using VR models can provide a means to establish joint ownership and improve team work.

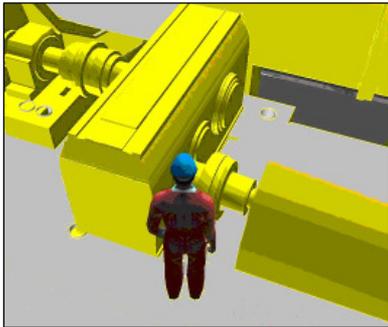


FIG. 10: Highlighting a plant section

Moreover, model areas can be color coated to represent areas of the plant that require inspection as well as establish safety and integrity risk boundaries.

Benefits and Value Proposition

IVRP has proved to improve design procedures while saving staff time and money with respect to maintenance. It provides a superior means of training operation staff relative to more traditional approaches by offering:

- More realistic training environments for trainees
- Greater opportunities for practice in training sessions
- Ability to react quickly and correctly in medium/high- stress situations
- Improved skills for rarely-performed, but safety-critical tasks (e.g. emergency shutdown)
- Optimised transfer of skills from a training environment to the work environment
- Reliable and valid evaluation of operational procedures and performance
- Team training: control room, field, shift, operational & Safety managers (Communications)

An investment on IVRP typically results in a ROI (Return Of Investment) of more than 50%.

The technology’s main economic benefits fall in the following categories:

- 30-40% saving on time/costs for “on-job-training” for new large personnel needs, familiarization in case of mobility from plant to plant and scheduled replacement of grey-hair workforce
- 15-25% saving time to be “back-on-run” and to optimal production for planned or unplanned shutdown by having the all plant crew frequently refreshed on all critical procedures
- 1-3% saving on maintenance budget by improving maintenance operators training and by using IVRP equipment pre-analysis for predictive maintenance

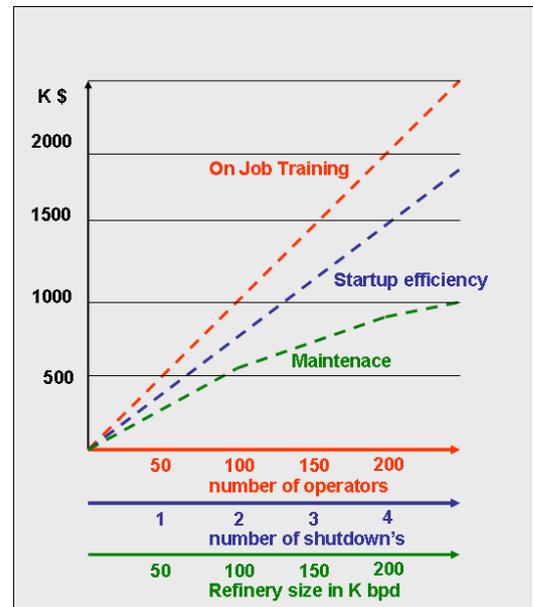


FIG. 11: A conservative scaled view on benefits

Trainers and trainees can be anywhere in the world. Using web facilities, remote workers can work together in the same virtual area, on a chemical plant or a building site for example, even though they may be physically a great distance apart. As a result, travel costs can be reduced and interactive programs with multiple sites networked for group learning and communication can be properly developed.