General technical conditions for operator trainings simulators

Fundamentals of the simulation

atlan-tec Systems GmbH (hereinafter called ats) builds operator trainigs simulators (OTS) as a hybrid system of neural and classic rigorous models.

The rigorous models based on equations, differential equations, pump- and valve characteristics, material data tables with solubilities, evaporation, educational, crystallization and solubility enthalpy`s and other known physical and chemical interactions.

The equations are displayed graphically with APC Professional and solved numerically there.

Relationships, that are not known sufficient accuracy or who cannot be mapped precisely for reasons of cost, are represented in the training simulators of ats with using statistical equations, polynomials or neural networks. Examples for it are systems of heterogeneous catalysis with phase boundaries, which can be modeled with sufficient accuracy not rigorously until today. These data will be used in a real process, which adapt the empirical equations.

Illustration of the process control system

Only in rare cases a process control system is available, which is suitable for a simulator. The process control system is simulated in these cases with APC Professional and a visualization interface. This simulation can only be as accurate, as algorithms and relationships of a process control system are documented. For example, is a peculiarity in the PID algorithm of the control system, which is not known to the customer, ats cannot simulate this feature.

Ats ensures implemation of the process control system exactly as it appears from the documents, which were handed over at the time of order award to ats. These documents are part of the offer and the order.

Freezing of the system prior to the date of award of the contract

The simulator is exactly implemented by ats, as it appears from the last known planning documents that have been passed to ats before awarding the order by the client. These documents are part of the offer and the order.

Typically a system and a process control system is often changed after start of a process. These changes are not part of the order and therefore not part of any purchase, unless no after-assignment or revision of the order is involved.

Limitations of simulation accuracy

Each model and thus each simulator has limited accuracy in the mapping of the real process. This limitation has essentially four fundamental reasons:

I) Limited knowledge or illustration of the relationship

Many technical and scientific contexts can be described by equations, which are based on simplifying assumptions and simplify connections.

Even simple relationships, such as the behavior of gases, cannot describe infinitely exactly how their high number of gas equations shows, that describe the ideal and the real specific volume of gases as a function of temperature. Even materials databases are limited precisely, because most material data up to standard conditions (NTP) and tighten dependencies thermal or pressure dependencies are described only in individual cases. Especially processes such as currents and turbulence and interfacial effects of tube- or reactor walls cannot be described with reasonable effort with equations.

Thus it is sometimes technically impossible infinity accurately represent reality or it is so complicated that even a mainframe would be overtaxed.

II) Initial Value Problems / "Butterfly Effect"

Starts a calculation in a simulation with values that are not infinitely precise, develops a small calculation error. The slightly erroneous results of this calculation are included in further calculations, which returning results with slightly larger errors.

Just as there are in reality streams or heat fluxes are fed back, so run in closed circles, there are those in simulators. Thus also simulated heat- and mass flows are driven repeatedly in a circle with minor errors. As a result there is the fact, that the simulator further and further away from reality with its results. The error of the simulation against the reality so increases with its term.

In systems theory, this effect is also popular science called butterfly effect, since small errors after several iterations may lead to large effects. Here the picture is like trying that, theoretically, could affect the weather situation in Europe, the flutter of a butterfly's wings in Asia after several weeks. Under certain circumstances, this statement is demonstrably correct.

Based on the simulator does the "butterfly effect" means, that a change in the initial conditions in the 10th decimal place after a certain time to quite different simulation result can be controlled.

This fact leads for example, that weather forecasts within one week will be quite inaccurate. Even infinite computational resources would not change anything, because the initial state of a system is never infinite precisely known. Measurement error is usually a few percent, so many values, the first digit after the decimal point is not exactly known.

III) Numerical Artefacts

Explicit or implicit differential equations are not solved in symbolic simulators, but numerically, so by iteration. For this there are various methods. The simplest variant are Newton's method, in which the differential equations are solved as difference equations. Somewhat more complicated are, for example Runge-Kutta-method, in which equations are solved by quadratic approximations.

Numerical methods have one thing in common: they produce an error, because the simulation time is divided into finite steps, as it is digitized. This digitization leads to artifacts and errors. The effect is similar to a digitized image, in which you can see at a high pixel resolution and continuous impression from a distance no longer being maintained, when one wants to see fine details.

In addition to refined methods, e.g. embedded methods with time step size control, is it possible, to increase the temporal resolution. However, both approaches lead to an increase in computational complexity. As a simulator should expect at least in real-time operation, thus the required computing power is getting higher. As the computing power provided is naturally limited, the possible accuracy of the solution method is limited, thereby compromising the accuracy of the solutions are required.

IV) Seriality-artifacts

While in reality events occur concurrent or simultaneously, the simulator parses the reality of equations and partial events, that are calculated sequentially and only then share the results with each other. This leads to a fundamental difference between the simulators and reality.

Find some events absolutely occur in reality, that appeals for another event, will these simultaneous events calculated in the simulator succession. Since events are in reality very closely interconnected, it can be avoided that a result is calculated before acting on event is recalculated or not always update.

This can lead for it, that a simulation in certain conditions shows a behavior, which does not match with the reality. So even oscillations can occur, which arise only from such pure serilization errors can appear. This can be prevented completely not merely reduced. It is important to make the order of calculations in a logical manner, but this is always a compromise.

In summary it can be stated, that there can be no perfect picture or simulation of reality. A simulator will inevitably have to deviate from reality due to technical reasons. These variations can be quite substantial.

Therefore, it is imperative, to design a simulator so that it has a specific purpose, which is previously determined precisely. Any subsequent use for any other purpose may fail because of the facts described here.

It follows **that the simulator can certainly serve the purpose just exactly and only can reflect the situations safely, for which it was developed**. All other situations may possibly be displayed, but can fail because of the difficulties described here.

Description of the simulator purpose through lessons

The purpose of the simulator is described in the offer and in the order as accurately as possible, to establish common procedures which can represent the process of simulator exactly should. Exactly these processes are mapped by the simulator guaranteed. All other processes may be possible, but not guaranteed.

This description is made in the form of **lessons**

Lessons are descriptions of specific situations to which a control room operator or user of the simulator must respond correctly. The simulator must as behave with correct service and also with false service, as the simulated arrangement. In this case, the simulator may differ only to the extent of the real system, as two identical plants would differ.

Single acceptance criterion of the simulator is strict adherence to the lessons that are defined in the offer, the tender- or functional specification or the order.

The implementation of the translation of such lessons is bound to defined initial states of the simulator which this loads this before the lesson as a starting states of lesson files (so called DynaScenes). Before testing the simulator so a DynScene is loaded, the simulator is started and an exactly agreed training plan is processed within the scope of which the simulator must behave, as the real arrangement.

Client and ats agree that the simulator must be able to guarantee only a flawless function, when it is used in the execution of the defined lessons. The simulator is therefore always bound to a predefined curriculum.