Planta de Regasificacion de Sagunto, S.A (Saggas) is constructing a new LNG receiving facility in Sagunto, 50 km north of Valencia (Spain), with a capacity of 3 million tpy of LNG, to be supplied from Egypt through a project initially promoted by Union Fenosa.

Saggas is owned by three major electric companies in Spain: Union Fenosa (50%), Iberdrola (30%) and Endesa (20%). Saggas will be in charge of the management of the plant from construction through to the final operational stage, including responsibility for the operation and maintenance of the facility once it is fully operational.

In February 2003, Saggas awarded the EPC contract to a consortium of five European and Japanese companies: ACS, a general construction firm in Spain, and leader of the consortium; SENER, a Spanish engineering firm; DYWIDAG, a German civil engineering firm; TKK, a Japanese LNG tank construction firm; and Osaka Gas Engineering (OGE).

SENER’s scope of responsibility in this project includes:
- Basic engineering update, from the initial Kellogg design.
- Detailed engineering.
- Purchase management of all equipment.

The Sagunto regasification plant is of prime strategic importance for the Spanish gas market, as it will allow the injection of LNG into the Spanish system, resulting in increased competition. The new terminal is scheduled to commence operations in March 2006.

**Process description**

The process of an LNG import terminal is relatively simple; a simplified diagram of the process shown in Figure 2.

When a ship arrives at the docking bay, the gas is in its liquid state (LNG) at a temperature of -163 °C. The liquid is unloaded from the containers on the vessel through arms located on the dock. Then the LNG is transported through a 600 m pipe and is held inside cryogenic storage tanks.

The addition of heat to the LNG (from the pumping process or from solar radiation) causes a fraction of the liquid to become vaporised. This boil off gas is used for refilling the empty space in the ship as the liquid is unloaded, and for reinjection into the process via the recondenser unit. When there is an excess of boil off gas, it is flared.

The primary pumping system is located inside the tanks. It pumps the LNG towards the recondenser, where the liquid is collected prior to the secondary pumping stage, and any boil off gas is added back to the liquid gas flow. The LNG is then pumped to the vaporisers at high pressure by the secondary pumps, where it is transformed into vapour above 0 °C.

There are two kinds of vaporiser: the ‘open rack’ vaporisers (ORVs), which use seawater to heat the LNG, and the ‘submerged combustion’ vaporisers (SCVs), which burn a portion of regasified gas to heat a water tank, which in turn heats the LNG.

The gas from the vaporisers is directed through a common collector to the regulation, measurement and odourisation systems. The gas is then injected into the general network.

In the first phase of the project, the plant has two LNG storage tanks, providing a capacity of 600 000 Nm³/h with a peak flow of 750 000 Nm³/h. In the second phase, a third LNG tank will be added, increasing the capacity to 1 million Nm³/h with a peak flow of 1.3 million Nm³/h.

**Dynamic modelling**

An LNG terminal has two modes of operation: unloading from a ship or no ship present. Neither of these modes reaches a true steady state, as the ship or LNG storage tanks are continually being filled or emptied. As a result, the material balance of the ship or the tanks is never zero.

The design simulation tools typically used by engineering companies only work in steady state mode, so the material balance is always set at zero (no accumulation). When these simulation tools are used to model LNG terminals, some special treatments and custom calculations are required to calculate the right material balance within the ship and tanks, and the right amount of gas to be evacuated from the loading tank or suctioned from the ship.

In contrast, however, the intrinsic nature of dynamic simulation tools means that all these effects are taken into account by default, thus avoiding the need for any special custom calculations or analysis.

Jorge Contreras, SENER Ingeniería y Sistemas, Spain, and José María Ferrer, AspenTech, Spain, describe how dynamic simulation is being used to verify safety system performance and study transient behaviour for the new Sagunto LNG terminal.
To maximise the efficiency and quality of its engineering design work for the Sagunto project, SENER therefore decided to utilise both steady state and dynamic modelling tools as a core part of its approach. The company chose the Aspen HYSYS® software from AspenTech as the main simulation platform, using it to develop all the steady state models for the process engineering design, and then using these models as the starting point for developing the dynamic models used in the subsequent transient studies.

Aspen HYSYS is an integrated package for both steady state and dynamic simulation, and it is a key application within the aspenONE™ Simulation and Optimization for Oil & Gas module. Within Aspen HYSYS, steady state simulations can be transformed easily into dynamic simulations by specifying additional engineering details, such as vessel and pipe sizes; valve characteristics; pumps curves; control structures; elevations; and boundary specifications. The Dynamics Assistant in Aspen HYSYS makes this a simple task, initialising all items from the steady state models. Aspen HYSYS Dynamics is also flexible enough to allow a dynamic model to be built directly without a steady state simulation if this is the preferred approach.

**Analysis of safety systems and transient behaviour**

For the Sagunto project, the main applications of dynamic simulation were to analyse and verify the performance of the emergency shutdown (ESD) system and to study other transient conditions, such as pump or compressor startup/shutdown, cutting supply gas to the network, or startup/shutdown of vaporisers. This analysis was then used to check the correct sizing of control and pressure relief valves, flaring system dimensions, closing time of ESD valves and minimum cooling flows to prevent gasification.

As the basic steady state models had been created by SENER during the process design phase, it was possible to generate the dynamic model by initialising the process items directly from the steady state solution. To support this process, Aspen HYSYS provides a number of powerful and easy to use dynamic modelling tools: stripcharts; controllers (on-off, PID, ratio, split-range, Feedforward, anti-surge, DMCplus); signal selectors; transfer functions; Boolean gates; and Cause and Effect Matrix (Figure 4).

All emergency shutdown valves (ESDVs), with their corresponding closing time, were represented in the model and, in order to provide an accurate representation of the transients, a number of fidelity aspects were taken into account:

- Elevation and nozzle location for static head contribution.
- Holdup and heat loss of significant pipe segments.
- Seawater modelling.
- Burner with Gibbs reactor for SCV vaporisers.
- Non-flash equilibrium for tanks.
- Pressure relief valves (PRVs) and venting system.
- Detailed heat loss model for tanks.
- Primary pumps produced heat to tank.
- Recondenser.

**Emergency shutdown system: conceptual design and validation**

Safety is an area that has always been an important factor for process plants. Stricter regulations regarding hazardous spills and waste generation, and the ever increasing fines that result from infractions, have placed an even greater emphasis on fault tree and plant safety design.

One of the most critical systems of a plant is the ESD system, and the most common way to define the logic of the ESD system is through a cause and effect matrix (CEM). This matrix looks at values throughout the process and, based upon safety thresholds, determines whether certain equipment and/or valves should be shut down. The rows are the inputs (or causes), which are based on critical instrumentation signals of the plant. The columns are the outputs (or effects), which close or open certain valves (ESDVs) or shut down equipment to leave the plant in a safe condition. Figure 6 shows a hypothetical example of a small CEM.

The safety analysis consists of the design of the relief and shutdown systems and a review of the behaviour of these systems during emergencies. These systems are inherently dynamic. Specialised expertise is necessary to design

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**Figure 1. Virtual picture of the LNG terminal.**

**Figure 2. Main equipment in LNG regasification terminals.**

**Figure 3. Main flowsheet of the LNG terminal model.**
these systems with confidence, and dynamic simulation is a valuable tool in the effort.

With the CEM and the event scheduler integrated in Aspen HYSYS, realistic chains-of-events can be modelled, tested and evaluated against industry standards and guidelines. In this way, problem areas in the plant can be identified in the design phase, and can either be redesigned or fitted with ancillary safety equipment. Additionally, by being able to model the sequence and duration of events leading to a fault or safety incident, plant personnel are able to define more effective safety action plans and shutdown/evacuation strategies. Again, using this information early in the design stage helps to ensure that the process design is intrinsically safe, and that personnel, property and equipment are protected.

As well as its use in safety system design, the dynamic model is particularly useful in the hazard identification techniques: Hazard and Operability (HAZOP) studies, or Failure Modes and Effects Analysis (FMEA). These methodologies analyse failure modes and safety system robustness. The dynamic model offers the review committee the luxury of asking and answering many more questions than are practical given the normal time limitations.

SENER used dynamic simulation to study a range of scenarios, including:

- **Pump startup/shutdown (primary/secondary).** This involved provoking the tripping conditions to shut down primary and secondary pumps, and studying the restart transients. The analysis confirmed the correct sizing of valves, closing time and minimum flow assurance to keep lines cooled with a certain liquid flow.

- **Supply gas cutoff and vaporiser shutdown.** In a supply shutdown, the supply gas valve is closed and the plant is isolated from the gas network. The secondary pumps and the SCV vaporisers are stopped, but ORV vaporisers continue using the seawater and vaporise all the remaining liquid. The study showed how the vapourised gas can be accommodated by the supply collector, a 250 m, 30 in. pipeline, without opening the PRV valves of the venting and flare system. The ORV vaporisers and supply collector work at 85 bar and the PSVs are set to 130 bar, so there is a 45 bar margin with the volume of the supply collector line to avoid opening the PRV valves. This study demonstrated that the process operated safely without the need to double the size of the venting system to evacuate this extra amount of gas, resulting in significant cost savings.

- **General or partial shutdown.** The total gas flow to flare was calculated during general or partial shutdown, recreating the tripping conditions of each specific unit or area. This analysis verified the calculated sizing of the venting system.

- **Failure in the boil off gas (BOG) compressor.** During the LNG unload from the ship, one BOG compressor is stopped, analysing the pressure transients, time to PRV opening, and different procedures to reach normal conditions.

The dynamic model can also be used in a number of other ways to support the safe and efficient operation of the new facility. These include:

- **Startup support tool.** The dynamic model allows process engineers to anticipate problems that could arise during startup conditions or in normal operation of the plant. This makes it possible to identify solutions during the design phase, avoiding any production disruptions, increases in capital investment or delays to the project schedule.

- **Control loop tuning.** As the dynamic model incorporates the key control and logic elements from the process, and the fidelity of the model is very close to the real plant, this enables control engineers to use the simulation results to pre-tune the control loops of the plant, thus saving time during the operational startup of the facility.

- **Procedure development and timing.** In addition to verifying equipment sizing, dynamic simulations can also be used to help develop operational procedures for the facility. For example, analysis of ship unloading allows engineers to size the BOG system correctly, but it also helps in understanding the time available to take corrective action in the event of situations such as compressor shutdown, or other operational disturbances.
Conclusion

The Sagunto project demonstrates that dynamic simulation can be a valuable tool for supporting the efficient and safe design of LNG facilities. Dynamic models developed using the Aspen HYSYS platform provide engineers with a straightforward way to analyse process performance during the design and implementation phases of a new plant. The development of the models requires a deep knowledge of the plant equipment and processes, but the tool is capable of being used by any engineer with limited experience of Aspen HYSYS.

The new cause and effect matrix object introduced in Aspen HYSYS (Figure 7) extends the use of dynamic simulation to emergency system design. It allows engineers to represent the Cause and Effect logic configuration in a generic way, independently of any vendor specific ESD system.

The project also illustrated that dynamic simulation can be an excellent tool for the support and verification of HAZOP studies. Using this approach, it was possible to identify that the proposed sizing of the venting system was enough to handle all potential scenarios safely. Due to the limitations of steady state analysis, rigorous dynamic simulation of this kind is the only way to explore system behaviour under these conditions.

References