A Human Focus

***Hector Perez* explains how paying attention to alarm management and HMI design can yield higher plant safety, productivity and profitability.**

In most process industries, manufacturing is directly controlled by the real-time actions of a console operator. If that operator makes a critical mistake, the entire company and its shareholders may be adversely affected.

The disciplines of Human Factors and Ergonomics explore the way humans interact within their work environment. Every individual's job performance directly impacts safety, production, and profitability within any given industry and across all levels of an organisation.

Hence by focusing on improving the operator's "human reliability" by creating an optimal work environment, manufacturers can achieve the ultimate goal of optimal safety and profitability. Alarm systems and human-machine interfaces (HMIs) are main contributors to improving the operator's human reliability.

Alarming problems

Prior to the arrival of the modern distributed control system (DCS), the creation of a new alarm required the addition of physical alarm panels and their associated wiring. Since each alarm had a discrete cost associated with it, only the most essential alarms were installed. In a modern DCS, however, alarms require only minimal parameter configuration, and therefore have no discrete cost associated with them. As a result, the number of alarms configured in a typical plant has grown tremendously over the last few decades.

It is not uncommon for DCS operator consoles to have over 3500 configured alarms, which often results in thousands of alarms being announced each day. Many of these alarms are a result of a relatively few common alarm system problems.

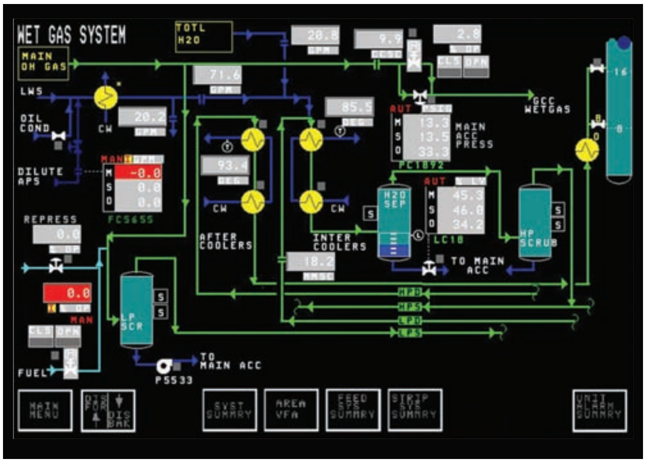
These problems include: alarm floods (large numbers of alarms triggered within a short period of time); chattering and nuisance alarms (caused by measurements that oscillate in and out of their alarm state frequently); stale alarms (measurements that have remained in an alarm state for a prolonged period of time); and predictive maintenance information that is wrongly expressed on the screen as an alarm.

Each of these factors contributes to operator overload and reduced human reliability, often causing critical alarms to be missed. In fact, poorly performing alarm systems have repeatedly been cited as significant contributing factors to abnormal situations and major accidents.

Making improvements

Fortunately, creating and maintaining an effective alarm system is very achievable. A good alarm management methodology includes a robust set of techniques for optimising an alarm system, as listed below:

- **Creation of an alarm philosophy:** a comprehensive document that sets the requirements for effective design, implementation, and management of alarm systems.
- **Conducting benchmark assessments:** analyse the performance of the current alarm system relative to industry best practices.
- **Bad actor alarm resolution:** a work process providing immediate relief from the most problematic alarms.
- **Alarm documentation and rationalisation:** a reengineering of the alarm system using methodologies established in the philosophy document, and ensures that only actionable alarms are brought to the operator's attention.
- **Real-time alarm management:** sophisticated techniques required for dynamic plant operating environments. These include:
  - *Alarm shelving:* the temporary and controlled suppression of alarms for the purpose of eliminating currently unused alarms from the operator's view.
  - *State-based alarming:* the modification of alarm settings to match the current operating state of the plant.
  - *Alarm flood suppression:* the dynamic management of pre-defined groups of alarms based on triggering events.



A traditional HMI: schematic graphic displays do not provide a level of situation awareness necessary to safely and proactively manage the process.

In addition to the above, continual auditing of the alarm system and enforcement of the settings established in the documentation and rationalization process is necessary. By implementing the recommended techniques, the alarm system can become an enabler for improved process safety and human reliability.

The human interface

The importance of effective alarm management to operator performance is well known and documented. However, creating an effective alarm system alone is not sufficient, and the human-machine interface must also be optimized if true human reliability is to be achieved. Indeed, poorly performing human-machine interfaces (HMIs) have been cited in almost every plant incident report, whilst remaining relatively under-explored.

In the late 1970s when graphics-based operating displays were first introduced, there were no guidelines for their effective design. Rather, they were implemented based upon the plant piping and instrumentation diagrams (P&IDs), which are simply schematic representations of the plant. These schematics were then "sprinkled" with live numbers and a variety of other attributes to convey operational data, such as colours, animation, and shape changes. The result was typically far from optimal.

There has been little improvement since, and these schematic depictions are still in common use. Schematic graphic displays do not provide the operator with the level of situation awareness necessary to safely and proactively manage the process.

There is generally too much raw data on the screen, which requires too much interpretation to infer operational context. Furthermore, excessive data on the screen obscures the operator's ability to quickly identify problems and subsequently slows their response.

Since their human interface does not provide the context necessary for situation awareness, operators are often forced to react to alarms instead of proactively managing problems before alarms occur.

High performance HMI

To increase the situational awareness of operators and produce more reliable operations requires a higher performance HMI that is able to:

- Provide optimal awareness of the state of the process
- Make operators aware of key performance indicators and process trends
- Enable immediate detection of abnormal conditions
- Increase the success rate for handling abnormal situations
- Reduce the time to complete mitigation tasks
- Discourage reactive operation

A significant difference of high performance graphics is the underlying principle that, wherever possible, operational values should be shown in an informational context rather than as raw data. Most traditional HMIs have large amounts of raw process data, yet unless the operator is highly trained and experienced with the equipment, it is not apparent whether the process is running at peak efficiency or is about to fail.

Informational context is achieved through consistent and effective use of colour, proper alarm depiction, and pattern recognition. The guidelines listed below are drawn from well-documented principles in the science of human factors and ergonomics.

Consistent & effective use of color

Traditional HMIs typically use colour in a sub-optimal way. For example, a colour scheme commonly used in traditional HMIs employs bright green to depict running equipment and bright red to signify non-running (vice-versa in the power industry).

A high performance HMI would depict these in grey-scale, with a very light shade of grey for the background, a brighter shade of gray to depict equipment that is running, and a darker shade of grey for equipment that is off. In designing high performance HMIs, monochromatic or grey-scale tones are best suited to depict normally operating systems because they merit a lower level of operator attention.

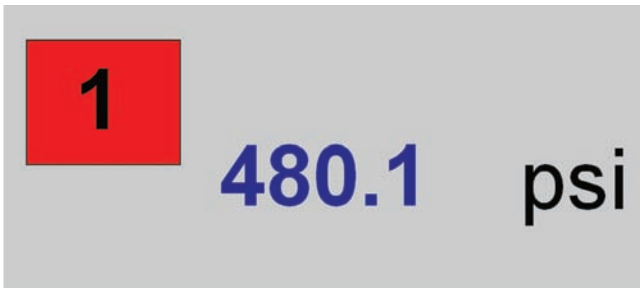
Since the human eye is naturally attracted to bright colours, they should be reserved for the depiction of abnormalities, such as alarms.

High performance HMIs employ a consistent color palette using only a limited number of universally distinguishable colours. Each colour should have a unique meaning and should only be employed to convey that particular meaning.

For example, alarm colours should be used to only display alarms and nothing else. If yellow is an alarm colour, then yellow is never used as a text label, line colour, border, or any other non-alarm-related element. This consistent use of colour allows operators to quickly draw meaning from a display even if it is one they seldom use.

Proper alarm depiction

Alarms are used to signify an abnormal situation arising in an otherwise normally operating system. Proper alarm depicting uses



Shape and text should be used consistently to depict the priority of an alarm.

colour, shape, and text to denote the importance or priority of the abnormal situation. Alarms are typically depicted using bright red or yellow.

Be mindful however, that not all humans distinguish colour equally. There are several types of common colour-detection deficiencies, also known as colour-blindness, which may cause an operator to miss an alarm that is depicted with colour only. Therefore, colour should never be the only indicator of an important condition or status.

In addition, shape and text must also be used consistently to depict the priority of the alarm. An example would be using a red square with "1" written in it to depict a first priority alarm.

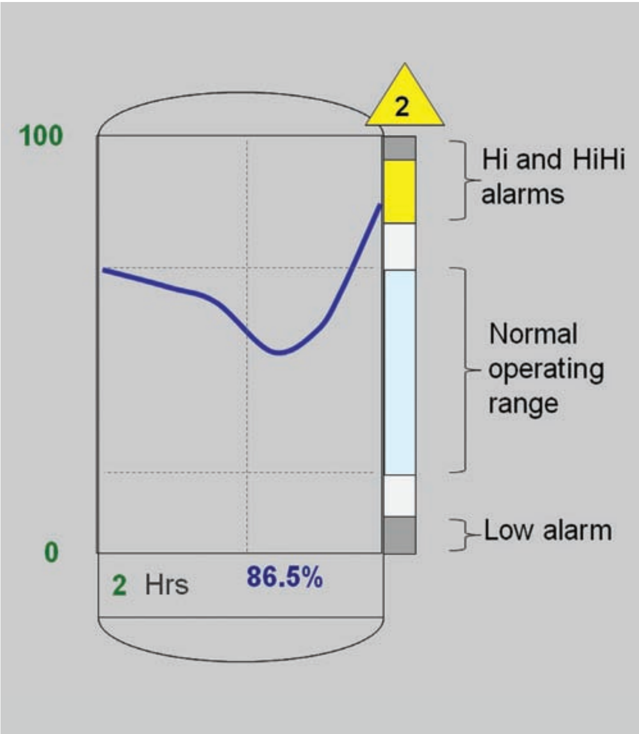
Most people do not detect colour change well in their peripheral vision, but movement, such as flashing, is readily detected. This animation should be used only when the abnormal situation has occurred but has not yet been acknowledged by the operator. Use of flashing, without the ability to turn it off, should be avoided. Using these principles provides recognition of abnormal situations, at a glance, even by an inexperienced operator.

Capitalise on pattern recognition

As humans, we have a natural ability to recognise patterns. High performance HMI design capitalises on this by creating easy-to-interpret graphics that often employ trend display elements. Trends should depict both the normal and abnormal ranges of a measured value, and should be scalable over a wide range of history.

Other powerful pattern recognition tools are analog indicators. These are favoured in high performance HMI design over digital displays, which typically just add more distracting numbers to the screen. With a single glance at a properly designed analog indicator, operators can tell if any values are outside of the normal range; if so, by how much; and the proximity of the reading to both alarm trip points and the values at which interlock actions occur. In seconds, the operator knows which readings, if any, need further attention. It is often desirable to combine the two concepts of trends and analog indicators into a single graphic element. This provides an easy mechanism to quickly recognize an emerging abnormal situation and to determine how much time is left to remediate it.

By optimizing the alarm system and implementing high performance HMIs, operators can detect disturbances as they emerge and intervene before an upset occurs.



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Display hierarchy

Displays should be designed in a hierarchy, which provides progressive exposure of details. A four-level hierarchy is considered optimal:

- **Level 1:** Process Area Overview – displaying the entire span of control for an operator
- **Level 2:** Process Unit Control – depicting a sub-unit
- **Level 3:** Process Unit Detail – showing specific equipment or controllers
- **Level 4:** Process Unit Support & Diagnostic Displays – showing such items as interlocks, emergency shutdowns, and diagnostic screens

Display hierarchies provide a comprehensive view of the process and the ability to easily drill down for specific information.

Transforming performance

By optimizing the alarm system and implementing high performance HMIs, human reliability can be significantly increased and operators can work proactively rather than reactively. They can detect disturbances as they emerge and intervene before an upset occurs. Transformation of the operator's performance using these principles is possible, regardless of the type of process, because human factors remain the same across all industries.

By implementing these systematic ergonomic changes to alarm systems and the human interfaces, we can minimise human error and create a more reliable operator who ultimately enhances a company's overall safety, productivity, and profitability. **CEA**

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