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The Science of Operator Decision Making

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Author: David Walker, Chief Engineer, Yokogawa Australia and New Zealand

Operators on process plants are required to make decisions throughout the shift based on the information presented to them. The quality and timeliness of these decisions is dependent on many factors, including how process information is presented to them. In fact, I would argue, that this is the single most important factor in operator decision making. If the information that is presented to the operator is confusing, incomplete, scattered over multiple pages or overwhelming in quantity, the operator will have great difficulty in understanding the plant situation and determining the best course of action.

"There is a science around HMI design that takes into account human psychology, ergonomics and information processing, and understanding this science is key to the design of a well functioning operator interface. Understanding how the human brain processes information is key to understanding how information should be presented to an operator."

The key elements of cognitive processing are:

- **Memory** - how many different bits of information can the brain hold at any one time
- **Cognitive Capability** - the ability of the brain to use this information to make decisions
- **Stress** - the ability of the brain to make decisions while stressed

On average, the brain has the ability to hold seven pieces of information at any one time. You can test this for yourself. Use a random number generator to generate a five digit number. Hide the number and write it down. Repeat this exercise with a six digit number and so on. Most people will be able to remember and write down numbers of up to seven digits in length, plus or minus two digits. This is the general guideline when considering how much information to provide to an operator for effective decision making.

Try repeating this exercise with loud music you don't particularly like. For most people this will significantly affect their ability to memorize the numbers they could remember in a quiet, relaxed environment. Generally speaking, a person who performs a routine task will get it right 99.7% of the time under normal conditions, but only half the time when they are stressed.

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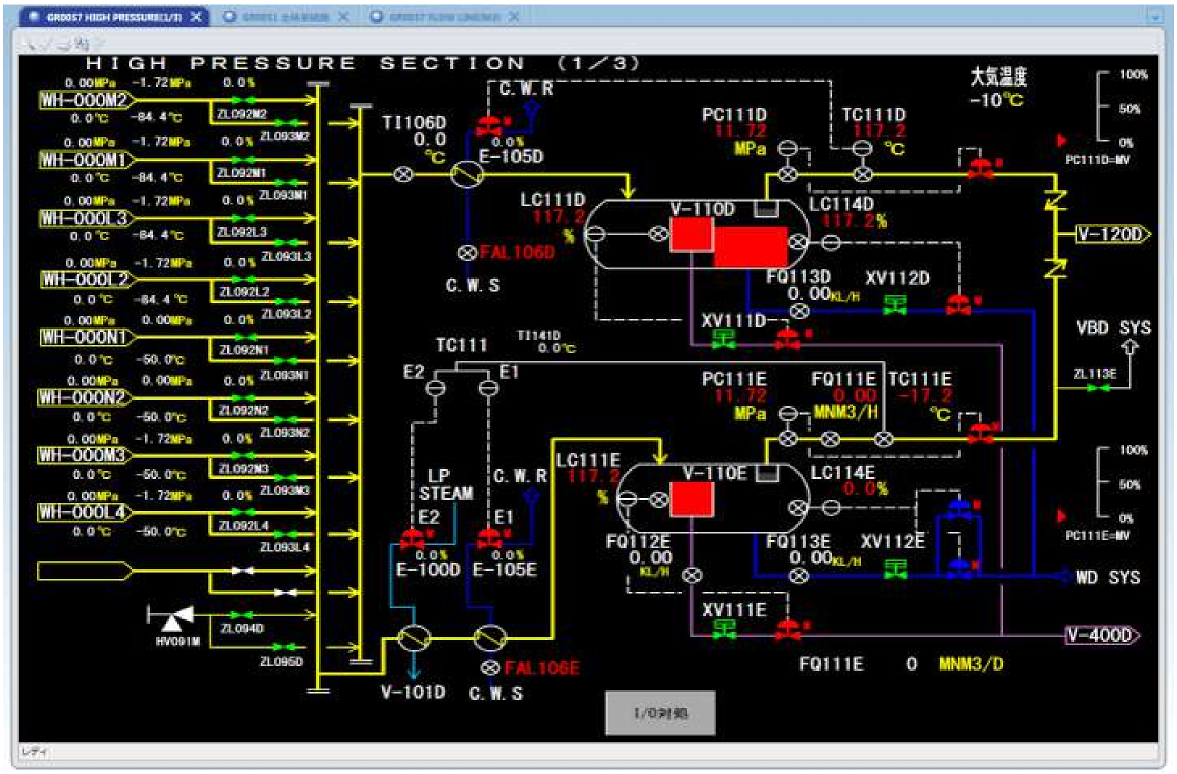
Now, imagine you are an operator whose responsibility it is to keep an oil refinery running. The graphical interface you are working through is high contrast (black background) and highly colored. It has one hundred pieces of information on it, including pumps and valves, vessel pressures, pipeline flowrates, separation column temperatures. In addition, they have an alarm interface that has hundreds of alarms scrolling through it continuously.



On the process graphics, pumps are red because they are not running, and green because they are running. On the electrical distribution graphic, motors are red because they are live (running) and green because they are not live (stopped). The separation column temperature half way up the column is red because it is in high alarm.

The previous shift prepared for the start-up of the separation column, and you have been left with the job of running it. You start the feed and the heating and let it run up.

And then something goes wrong.

You know something has gone wrong because the alarms scrolling through the alarm page seem to be scrolling through faster than normal, and there seem to be more flashing lights on the graphics in a range of colors than normal. You look again at the graphic. A lot of red flashing lights indicating a mixture of problems in addition to the normal operation of actuators, pumps and motors.

Because the red colored running motor is next to the column temperature, you miss the fact that the temperature is in alarm.

You look at the pressure on the outlet of the column. There are two pressures, one right on the outlet, but is shown as part of the condenser circuit, and one further downstream which is more obvious and is the first one you notice. It indicates a low pressure, which you think indicates there is no problem, but in fact means that the leak is upstream of it.

Then you think that maybe you should check the pump on the inlet to the column, and if it is running, stop it. You open the electrical graphic which shows the pump as a red color (meaning there is power to it and so it is running) and you think it is stopped because you are used to interpreting red as “stopped”. So you think there is no more feed going into the separator, and there is no indication of high pressure in the column.

This means, to you, that the problem is elsewhere, that the leak is unrelated to the column, and so you start looking through different graphics, trying to see problems in other areas of the process. It is slow going, because every graphic has 100 pieces of information on it, and the red colored objects could mean the normal operation of an actuator, or could mean an alarm.

And then there is a very loud explosion and the CCR shakes, and everyone looks at you. The shift supervisor comes rushing out of his office and comes straight to you, wanting to know what you have done. No pressure!

Now I am going to rewind, back to the beginning of the shift. What went wrong, and how could things have been done differently such that the leak and resultant explosion could have been avoided?

Firstly, the graphics present too much information, and it is confusing and ambiguous. The coloru red has three different meanings:

- A pump is stopped or valve is closed on a process graphic
- A pump is running or a valve is open on an electrical graphic
- An alarm

Secondly, everything is foreground, whether it is normal operation information, or abnormal situations, making it hard for the operator is distinguish between a problem and normal operations.

Thirdly, there is no context to the information. Values are displayed on the graphic without any indication of whether a variable is close to an operation envelope, or moving at a rate that might indicate a problem. In this case, the operator could see the temperature in the column but could not see that the temperature was rising too rapidly.

Also, for the operator to understand the complete picture of the process, required paging through multiple graphics to read all the required information. This is because the graphics were built up from the P&IDs instead of being laid out according to the process flow.

The alarm page was not useful because it was completely cluttered with alarms that were not important to the operators requirements at the time.

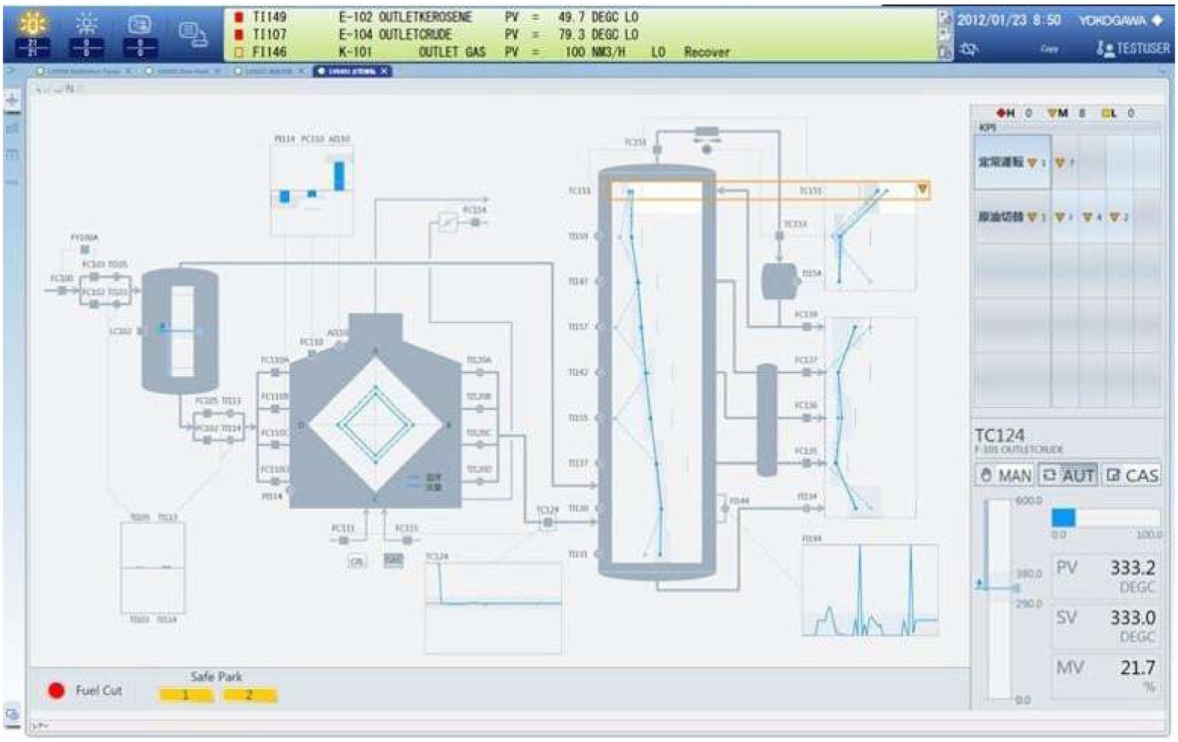
The ISA101 standard defines design of all aspects of the user interface for a process automation system, including the colors used, navigation, layout and the foregrounding of important information. In the context of the above example, it addresses:

• **Colour** - gray-scale is used for all background information, such as process equipment, normal statuses and process data. Anomalies are yellow and alarms are red. Most importantly, red and green are not used for normal status indication.

• **Information Density** - Information Density - all non-essential information is removed from the graphic so that only that information that is important for the operator to carry out their task is shown. A design criteria is to keep the maximum amount of important information presented to an operator at any one time at around 7 pieces of information.

• **Layout** - the graphic should show all the necessary process equipment relevant to the tasks related to that part of the process. In this case, the separation column and associated heat-exchangers, condensers and pumps should be shown to minimize the need to page through different graphics to carry out the required task.

• **Context** - instead of showing process values as numbers, they should be shown in the context of an operating envelope so that the operator can easily see if a process value is moving outside its normal operating range. Similarly, showing trends of process values over the top of a normal trend will tell the operator if the process value, such as the column temperature is moving too fast.



So, in this new scenario, you, the operator, start your shift with the intention of starting the separation process. You still miss the high level alarm because in this article we haven’t addressed alarm management at all, and so you start the feed pump and heater as you previously did.

Except this time, you notice that the temperature in the column is rising too fast. And because the pressure indications are laid out in a clear and unambiguous manner, you immediately see that the pressure is going high. When the temperature goes into high alarm, it is the only thing on the graphic that is red, and so you see it immediately.

The pump feeding the column is clearly running and you know that it needs to be stopped. You have the time to check and carry out this operation, because the process information is being displayed to you in a way that gives you the time and clarity needed to make the right decisions.

You stop the pump and the steam flowing to the heater and log into the shift log that the temperature and pressure went high in the column. An angry shift supervisor comes storming out of the office, wanting to know why production has been stopped, and you point to the graphic. The issue is identified, the problem fixed, and the start-up resumed.

Humans are not robots. They are easily distracted, and make poor decisions under pressure. By understanding how the human brain works, we can design interfaces that assist the operator in understanding the process they are operating, and help them make the right decisions under abnormal conditions.

Yokogawa Australia & New Zealand has decades of experience in working with operations to facilitate good decision making in the operations environment. This includes advanced graphics design, procedural automation to assist operators with the execution of procedures, alarm management and control room design.

We understand the value this can bring to a process plant in terms of more efficient operations and reduction in downtime and abnormal incidents.

About the Author

David Walker is a chemical engineer with over 30 years of experience in control systems across a wide range of technologies and industries, including oil and gas, mining, power, water and waste and chemicals. David has worked in many aspects of the business, including engineering management, systems engineering, project management, training and research and development (R&D), including a secondment to Yokogawa in Japan to work in the development team of their edge devices. David continues to advise R&D on a range of industry issues and solutions.

Currently David is Chief Engineer for Yokogawa Australia, and provides technology support, project execution management, engineering improvements and standardisation. In the past, David worked in the UK on Join European Taurus (JET) to implement the automation of the cryogenic separation of the experimental fusion reactor and developed the controls for the Birmingham Water Treatment plant. Most recently, David was lead engineer for the Wheatstone Upstream project and was involved in the implementation of the topsides and subsea controls.

Contact Us (Australia)

Email: enquiries@au.yokogawa.com

Website: www.yokogawa.com/au

Telephone: +1300 558 965

Contact Us (New Zealand)

Email: enquiries@nz.yokogawa.com

Website: www.yokogawa.com/nz

Telephone: +0800 706 050

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