Emergency Stopping

(Note that this text is the original version of the article and differs slightly from the version that was published in the July / August 2003 edition of the Engineers Journal (the Journal of the Institution of Engineers of Ireland).

1.0 INTRODUCTION:

1.1 General

Everybody is familiar with the sight of an emergency stop button. Whether we note them in passing at the bottom of escalators, eye them nervously as we watch a precocious child playing on the luggage conveyor in a busy airport arrivals hall, or fix our gaze on them as we pound the treadmill to try and work off the effects of Christmas – or even if we don't notice them at all - the humble mushroom-head red button is to be found in ever-increasing numbers throughout our modern world.

One would think that the decision of where these stopping devices should be installed and how they should be wired would be very simple and straightforward but it is an area of increasing complexity – due mainly to two parallel developments, which have come about in recent years.

- The first of these is the introduction of European machineries legislation incorporating formalised structures for risk assessment etc.

- The second is the development of safety related legislation which specifically places onus on designers to consider safety during the entire life cycle of equipment.

On the practical front, machines and industrial processes are becoming, if anything, more complex rather than less.

The purpose of this article is to touch on some of the main issues, which the designer should consider when assigning emergency stop locations and designing safety circuits in general. This is normally a design function, which is led by electrical engineers and design staff. The article is written very much from the point of view of the designer of a process plant or industrial facility who is procuring or installing a new machine or process step. For simplicity I will deal with fairly basic machine circuits in which a single motor is controlled automatically by a remote controller (a programmable logic controller for example).

Even an outline treatment of the subject such as this will touch on a number of issues which are quite complex in themselves – CE Marking, Risk Assessment, Safety Circuit categories. Unfortunately, it is not possible to deal with these subjects in the detail which they merit and most of them would require their own articles (if not text books) to be adequately covered. Some inaccuracy of terms and description is almost inevitable given the brevity of these notes and for that, I can only apologise in advance.

I have used the term ‘safety circuit’ throughout these notes instead of ‘emergency stop circuit’. This is because many of the concepts discussed relate equally to the wiring of devices such as safety interlocked switches and doors as well as to emergency stop buttons.

1.2 Basic Terms and Concepts:

ET 101 2000, National Rules for Electrical Installations, by the ETCI 3rd Edition.

Generally, power distribution and motor control designs at low voltage (less than 1000V) in this country are designed in accordance with the National Rules for Electrical Installations, by the Electrotechnical Council of Ireland.

This is the Irish Version of IEC 364 and HD 384.

There is a common misconception that ET 101 is based in some way on the IEE Regulations BS 7671. Having used both sets of rules (though I WILL show my age by admitting that the IEE were only on the 15th edition in my day) I reckon that this does an injustice to the Irish rules which I have generally found to be better written, clearer and more complete.

The Machinery Directive

The Machinery Directive 98/37/EC (formerly 89/392/EEC) is one of a series introduced under article 100a of the Treaty of Rome, applying to machinery and to safety components.

Some classes of machines and components are excluded from the Machinery Directive – notably equipment which is covered by other directives (lifts, for example).

The Directive is a 'New Approach' Directive – instead of dictating prescriptive measures to be adopted, it lays down guidelines in the form of essential health and safety requirements (the infamous EHSRs) which are then further interpreted in a suite of technical standards which are developed under the directive.

Category of Stop

As defined by EN 60204 there are three categories:

- Category 0 – remove power (crash-stop)
- Category 1 – stop under power and then remove power.
- Category 2 - stop under power and don't remove power.

The reason for the various categories is that some equipment can not be safely crash-stopped. Emergency stopping shall always be achieved through a Category 0 or a Category 1 Stop.

IS (Irish Standard) EN 60 204 Safety of Machinery - Electrical Equipment of Machines.

Seeing as I mentioned EN 60204 above, I guess it deserves an entry in its own right. EN 60204 is probably the most important standard for the design of control panels and electrical equipment associated with machines.

Equipment covered by EN 60204, and conforming to its requirements, is exempt from the National Wiring Rules.

Machine

Believe it or not, those considerate folk in Brussels have given us a definition of a machine – and it is a definition, which is frequently called on in deciding whether the Directive and associated standards apply to a particular piece of equipment.

In essence, an apparatus qualifies as a machine under the directive if it is an assembly of linked parts or components, at least one of which moves.

This enables you to bypass a lot of tiresome discussion.

Category of Safety Circuit

As defined by EN 954 there are five categories defined according to the degree of fault tolerance of the safety circuit:

- **Category B**
- **Category 1**
- **Category 2**
- **Category 3**
- **Category 4**

In essence (and I am probably simplifying somewhat here), Category B relates to a circuit in which the safety function can be lost through a single fault. Category 1 is very similar but includes the use of well tried components and safety principles. These circuits will normally be met by the 'traditional' emergency stop or safety circuit in which a single circuit interrupts the coil supply of a contactor and causes supply to a motor to be interrupted.

- Category 2 further includes a requirement for a safety function check.

- Category 3 further includes circuits in which the safety function cannot be compromised by a single fault.

- Category 4 further requires that any single fault must be detected before the next demand on the safety function OR that an accumulation of faults cannot cause loss of the safety function.

Alternatively the categories can be defined according to the level of hassle and expense incurred in their implementation ranging from Category B (no worries) to Category 4 (painful).

Safety Health and Welfare at Work Act 1989 and subsequent statutory instruments:

Well – the title is kind of self-explanatory really. The most significant piece of associated legislation from the electricity user's point of view is SI 44 of 1993 (Safety, Health and Welfare at Work (General Application) Regulations 1993 which states in relation to work equipment,

> ***Where appropriate, and depending on the hazards the equipment presents and its normal stopping time, work equipment shall be fitted with an emergency stop device.***

2.0 DESIGN OF SAFETY CIRCUITS AND LOCATION OF EMERGENCY STOPS:

Let us assume that you are buying a machine to install in part of an industrial plant. Let's further assume that this machine has a single on-board motor that is going to be started and controlled by a remote controller (a programmable logic controller or building management system outstation, for example) and that the motor starter is mounted on the machine.

You are wrestling with the knotty problem of whether and where to install emergency stop buttons.

The first question that you must answer is the following:

Is the motor in question a machine as defined by EN 60 204 (see the definition of machine given above).

The answer will only be NO in the case of very simple (mostly standalone) units such as single pumps or fans.

In this case the National Wiring Rules (ETCI) apply and they state:

- ***Means of emergency stopping shall be provided where electrically produced movements may give rise to danger (Regulation 464.4).***

AND

- ***In the case of equipment that is remotely controlled, devices for stopping motors shall be provided at all points where danger is likely to occur (Regulation 552.4).***

What this means is that it is not necessary to install emergency stops where dangerous situations are not anticipated to arise.

For example: ***A fan which is totally enclosed in a duct with a lockable local isolator – this motor will not normally require an emergency stop – particularly as an isolator which fulfils certain requirements can be taken as meeting the requirements for emergency switching and emergency stopping.***

Common sense and Engineering judgement will be required.

Note 1**: Emergency stops and associated circuitry cost money and shouldn't be installed where they obviously are not required – don't just stick them in for the sake of it.**

Note 2: **Emergency stops are not maintenance isolators and should never ever (ever) be used as such. If they are installed inappropriately, then the danger may arise that maintenance personnel will treat the emergency stop as an isolator.**

An isolator which fulfils certain requirements can, however, be taken as meeting the requirements for emergency switching and emergency stopping.

Note 4: ***It is unwise for an electrical systems designer to ever make assumptions about what are the risks and where they may arise in the installation, commissioning, maintenance or operation of any machine or motor. Unless it is an extremely cut and dried case, it is always wise to check with mechanical designers or experienced maintenance people.***

On the other hand, what if the answer to the question '*Is the motor in question a machine as defined by EN 60 204 and the Machinery Directive*' is YES ?

Then the fun begins.

If the machine in question is of any complexity at all, it is essential that the design of the E-Stopping / Safety Circuit System is carried out with the involvement and knowledge of people who understand the installation, commissioning, operation, start-up, shut-down and maintenance procedures which will be followed.

Moreover, all electronic or electrical equipment sold, or brought into service in the European Union, must carry a CE Mark which affirms that it conforms to the essential health and safety requirements of the applicable EU Directives. In the case of electrical equipment, this can mean conformance to the LV (Low Voltage Products), EMC (electromagnetic compatibility), machinery or (ATEX) hazardous area directives (and that's just a few of them). Sometimes several directives apply. Sometimes equipment which is covered by one directive is exempt from the requirements of others.

The Machinery Directive itself requires that all machines be fitted with an emergency stop at the Operator Station. Furthermore, any machine which falls under the ambit of the Machinery Directive must be the subject of a Risk Assessment to be carried out as part of the CE Marking Process (by the party which affixes the CE Mark).

This risk assessment will define the following:

- **Are emergency stops required and where**
- **What Category of emergency stops (0,1 or 2)**
- **What Category of safety circuit (B,1,2,3 or 4).**

Note 1: ***Safety circuits for machines covered by the Machinery Directive may include emergency stops, hardwired interlocks or a mixture.***

Note 2: ***It is unnecessary – and may be reckless – for the electrical designer of a plant or facility (who is not the party responsible for the CE Marking) to allocate emergency stops to a machine which is being installed in that facility.***

Why ? – because with most machines of any complexity, knowledge of the machine design and operation is required to adequately design in the safety systems.

If too many E-Stops and interlocks are put in then money will have been wasted and confusion – even danger - may be created (a classic example is where emergency stops are not clearly related to the equipment which they control).

If too few – or the right amount in the wrong place – then the electrical designer may be seen to have assumed design responsibility for somebody else's job and for something that he was not competent or qualified to do and then to have made a mess of that job.

There is a legal obligation to properly design the safety systems for a machine and it rests with the party responsible for that machine.

That said, it is very often the case that additional Emergency Stops are required (beyond those identified in the risk assessment) due to site standards, the Electrical Designer's knowledge and experience or even just by virtue of the fact that looking at the design, it is clear that a dangerous situation can arise. This brings me back to that common sense and engineering judgement stuff that I mentioned above.

Note 3: It is a requirement of IS EN 60204 1998 that a Category 0 stop not be effected by electronic components or software, or that it be implemented over a data link. Various suppliers will argue that this requirement is superseded by other more recent standards and indeed there are safety bus systems and safety PLCs on the market. Indeed, a suite of standards has been produced to cover the design of Safety Instrumented Systems and electronic/programmable safety systems, notably IEC 61 511 and EN 61 508. The whole topic of programmable safety systems is deserving of an article in its own right and I don't propose to deal with it here.

Note 4: Note that your control circuit and/or control system must be designed so that reset of the circuit does not initiate automatic restart of the driven equipment. This is a requirement of both ET 101 and IS EN 60204. Both standards leave it pretty much at the designer's discretion as to how this is achieved and there are several options open to the designer. Again – the topic of how operator intervention must be designed into the system after reset of a safety circuit is one that is deserving of a lot more attention than I can give it in this article.