IEC 62881

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Cause and effect matrix

Matrice des causes et effets

IEC 62881:2018-10(en-fr)

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FOREWORD

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The text of this standard is based on the following documents:

FDIS	Report on voting
65/701/FDIS	65/711/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The contents of the corrigendum of April 2019 have been included in this copy.

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INTRODUCTION

Efficient engineering and reliable operation of automated plants strongly depend on clear and unambiguous description of regulatory controls and logic interlocks. For regulatory controls this description can typically be done for example via process flow diagrams and P&IDs (ISO 10628), which are accepted by process and I&C staff in engineering and operation of manufacturing and process plants. Regarding logic interlocks the widely distributed logic or functional diagrams are very often regarded by process engineers and plant operators as too complex (especially when using the fail-safe principle) and overloaded with detailed information.

This document describes a simple and widely accepted method to document logic interlocks in process and manufacturing industries – the "cause and effect matrix" (C&E matrix). C&E matrices can be applied with minimal previous knowledge and easy handling to describe the functions required for controlling a process independently from the automation platform used. They enable a sound understanding of the required relation from a process point of view without the need of detailed knowledge of the platform specific corresponding PLC/DCS program logic.

During the entire life cycle of a plant (e.g. engineering, commissioning, start-up and operation) C&E matrices are very useful to illustrate the functionalities of package units and their interfaces to related sections of the plant. In particular they support the fulfilment of legal or insurance requirements (e.g. governmental regulations, fire and gas regulations, machinery directives such as IEC 62061). It is possible to find C&E matrices included in other types of documents, for example fire protection datasheets but still the principle of identification of the cause and the effects and their logical relations defined in an intersection applies.

In addition, they can be used to illustrate the consequences of embedded diagnostic functions (e.g. activation of a trip function in case of detection of a broken wire), the functionality of installed back-up systems (e.g. fail to start a pump and switch over to a second one) or the required operator actions to reset plant sections or safety related functions after partial shut downs.

The information presented by C&E matrices might be structured according to the individual needs, for example information necessary for process interlocks in electrical switch gears.

C&E matrices describe the relationship between causing conditions – the causes – and the required outcome or actions – the effects. The causes are herein represented by signals created by sensors or other means of information; effects are actions automatically done by actuators (mainly valves and motors) or manually by shift operators, or alarms and messages provided to operators. Both are linked via a matrix containing the relations. These basic relations are hence documented in an appropriate and structured form enabling a reliable information exchange at the interface between process design, electrical engineering, I&C engineering, etc. In the further course of detail engineering C&E matrices are used as a starting point for the development of more detailed and platform specific (e.g. fail-safe PLC) logic enhancements.

During plant operation the C&E matrices can serve as functional descriptions, for example for the training of plant operation staff.

However, C&E matrices typically are not designed to specify functional sequences (e.g. batch mode of operation) or functional details as might be provided by other methods, for example logic descriptions complying with IEC 61131-3.

CAUSE AND EFFECT MATRIX

1 Scope

This document addresses the setting and implementation of C&E matrices for a consistent use in engineering activities. It aims to describe a simple format used to support a consistent exchange of information between different engineering disciplines involved in project or maintenance activities. The document defines the minimum requirements of the C&E matrix content, which is derived from existing design documents, for example P&ID or verbal descriptions.

The transfer of the relations defined in C&E matrices into a functional or source code for the application programming of PLC/DCS is out of the scope of this document. In addition, this document does not cover the implementation of complex and/or sequential logics at a dedicated automation platform, which will require additional stipulations to be done/ followed.

It is understood, that C&E matrices in fact can be used to document the fault reactions of the plant equipment and therefore can be used as reference point for the necessary safety verifications to be applied.

C&E matrices as defined in this document do not have the same scope as Fishbone or Ishikawa diagrams, which are often named in the literature as cause and effect diagrams.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62708, *Document kinds for electrical and instrumentation projects in the process industry*

IEC 81346-1, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules*

ISO 7200, *Technical product documentation – Data fields in title blocks and document headers*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
cause and effect matrix
matrix which associates causes (3.1.2) and their effects (3.1.3) with the respective relations (3.1.4)

Note 1 to entry: A similar definition is found in ISO 10418:2003, Clauses 5 and C.1 for off-shore production platforms in oil and gas industry.

3.1.2
cause
occurrence in a production process which initiates a reaction of a technical system

Note 1 to entry: A typical cause is a physical change of a process variable which might lead to not wanted and/or not tolerable conditions. This could be a pressure increase beyond an allowed set point or quality leaving manufacturing tolerances.

Note 2 to entry: Causes can also be changes in the position of mechanical devices (e.g. position indicators of valves or movement of robotic arms or the failure of a pump).

Note 3 to entry: A cause is unambiguously defined, registered and reported by its source identifier (e.g. sensor with tag name and trip point). If such a cause occurs, the system responds as defined in the C&E matrix.

3.1.3
effect
reaction of a technical system to a cause, as defined in the C&E matrix

Note 1 to entry: The effect represents the consequence (e.g. stopping and starting of motors, closing of valves, start of a back-up system etc.) of the logic action according to the relation defined in the C&E matrix. The effect is identified by a target with a defined tag name and the triggered action of the target.

3.1.4
relation
functional description which links a cause to an effect

Note 1 to entry: The relation links the triggered action of the target to a certain occurrence.

3.1.5
intersection
area in the C&E matrix where the relations between causes (3.1.2) and effects (3.1.3) are defined

SEE: Figure 1.

3.1.6
non-linear logic
logic which includes deep nesting, temporal functions and/or sequences

Note 1 to entry: Non-linear logic might be logic including feedback information of logical states, memory functions, start-up process of a plant section (e.g. a distillation tower), sequential operation modes (e.g. for start of furnaces), ramps or temporal delay.

3.1.7
linear logic
logic with simple and direct relations of causes and effects

3.2 Abbreviated terms

C&E	Cause and effect
DCS	Distributed control system
FAT	Factory acceptance test
I&C	Instrumentation and control
P&ID	Piping and instrumentation diagram
PLC	Programmable logic controller
SIL	Safety integrity level (IEC 61508-1)
SIS	Safety instrumented system (IEC 61511 (all parts))

4 Conformity

To comply with this document, each of the requirements specified in Clauses 5 and 6 have to be satisfied to the defined criteria.

5 Design of C&E matrices

5.1 Layout principles

For the design of C&E matrices the following layout principles shall be applied:

– causes shall be listed in the lines;

– effects shall be listed in the columns;

– intersections shall contain the required relation;

– a document header shall be attached according to IEC 62708 or ISO 7200.

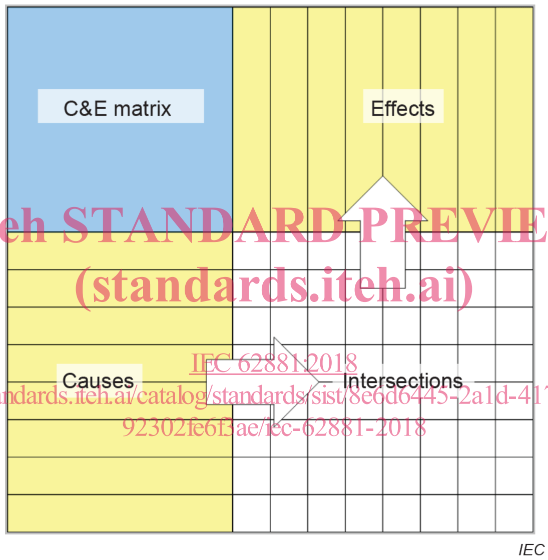

Figure 1 – C&E matrix

5.2 Attributes of causes

Mandatory attributes are (see Figure 3):

– identifier as per the designated reference scheme for example IEC 81346-1 including an activation condition;

EXAMPLE Temperature sensor which triggers an action at a certain temperature, for example: TICSLL1234, T1234/TICS++ etc..

– at least one referenced document (e.g. P&ID);

– safety integrity level of corresponding safety instrumented function if defined (e.g. SIL3, SIL2, SIL1 – see IEC 61508);

– marking of changes/modifications (see 5.5).

Optional attributes may be, for example (see Figure 5):

- description (e.g. service text, remarks, notes);
- timing functions (e.g. on-delay, off-delay);
- exact activation condition/trip point (e.g. > 200°C);
- voting (e.g. 2 out of 3);

- AND, OR functions with respect to Boolean logic.

Detailed stipulations may be subject to individual conventions (e.g. company standard) to be agreed upon and documented in the C&E matrix legend.

5.3 Attributes of effects

Mandatory attributes are:

– effect identifier: tag name according to IEC 81346-1 (e.g. valve – tag name Y1234);
– at least one referenced document (e.g. P&ID);
– safety integrity level of corresponding safety instrumented function if defined (e.g. SIL3, SIL2, SIL1 – see IEC 61508);
– marking of changes / modifications (see 5.5);
– detailed function (e.g. open valve, switch motor off) if alternative 1 (see 5.4) is used.

Optional attributes may be, for example (see Figure 5):

- description (e.g. service text, remarks, notes);
- fail safe position;
- timing functions (e.g. on-delay, off-delay).

Detailed stipulations may be subject to individual conventions (e.g. company standard) to be agreed upon and documented in the C&E matrix legend.

5.4 Attributes of relations

There are two different alternatives for the relations.

Alternative 1 (see Figure 3):

– " " (empty): no relation;
– "X": existing relation.

In this case a verbal description of the triggered action is required on the effect side, for example “close valve”, “switch pump motor off”.

Alternative 2 (see Figure 4):

The use of “X” can be replaced by a simple description of the triggered action.

Those descriptions may be, for example:

- "CL": Close;
- "OP": Open;
- “On”/”Off”.

Other additional simple relations can be used when defined in a legend.

5.5 Marking of changes and modifications

Changes and modifications in C&E matrices shall be marked.

Examples for such markings are shown in Figure 3, Figure 4 and Figure 5.

6 Use of C&E matrices

6.1 Uniform, interdisciplinary access to functional description

In general, C&E matrices are a proven basis for interdisciplinary definition of a plant's functionality during the entire engineering process, the commissioning, the start-up as well as the operation and maintenance phase.

In addition to functional information beyond the P&IDs, C&E matrices serve as a description with multiple purposes:

– between process engineers, electrical engineers, operations and I&C staff during the general design /engineering phase;
– as requirements documentation and input for manual or automated tests of safety programs;
– as reliable and sustainable documentation basis in safety reviews and for discussion with authorities;
– as training information and documentation for plant operators;
– as basis for the DCS/PLC vendors regarding the automation systems' implementation and testing (factory acceptance test (FAT), see IEC 62381:2012, Clauses 5 and A.9);
– as basis for the modelling of access control of distributed control systems.

The extent of C&E matrices used for an individual project can vary according to the type of process (more continuous or more batch mode, or manufacturing oriented) and its complexity (e.g. multi-product, complicated start-up, coupled production lines). Experience has shown that for linear logics the necessary functional description can be done by C&E matrices. In order to ensure their usability, C&E matrices shall be structured according to the structure of the process or manufacturing plant/plant sections. The proven ease of applicability of C&E matrices is also based on their simple graphical structure.

For necessary discussion and agreement between different disciplines involved, C&E matrices can also be used for safety instrumented systems (SIS) (IEC 61511 (all parts)) but it is important to realize that C&E matrices alone are by far not sufficient to fulfil the high demand of detail information required for SIS by IEC 61511-1:2016 and IEC 61511-1:2016/AMD1:2017, 10.3 and IEC 61511-2.

For the implementation in such case it is mandatory to create additional platform specific functions reflecting the platform oriented safety requirements. Otherwise an unambiguous and reliable realization of this functionality in safety instrumented systems cannot be guaranteed.

6.2 Application for linear logic

For linear logic, the C&E matrices can be used as the design and test document. The implementation in any programmable or hardwired logic system can directly be done according to the requirements defined in the C&E matrices. This implementation can be done even more easily, if standardised implementation rules (typicals, macros, etc.) are also used. The C&E matrix shall be the basis for the verification of the implementation during the FAT (see Figure 2).

6.3 Application for non-linear logic

C&E matrices in general can also be used for non-linear logic. Experience has shown that C&E matrices may not be the most efficient way of documenting such applications, as either C&E matrices describing such logic will be hard to understand or will need to reference a lot of additional documents, so that the readability of such diagrams drops off.