



ELECTRICAL DOCUMENTATION ACCORDING TO STANDARDS

by Jørgen Sommer

Developed in cooperation between PCISCHEMATIC A/S and EFU – Danish Electricians Educational Secretariat.

1/6-2011 © No part of this publication may be distributed without the written permission of publishers according to valid copyright law.

Published by PCISCHEMATIC A/S

3rd edition 2011

Copyright © 2003-2011, PCISCHEMATIC A/S

No part of this publication may be distributed without the written permission of publishers according to valid copyright law.

Electrical documentation according to standards

1st edition 2003

2nd edition 2006, reprinted and corrected 2008.

3rd edition 2011

Illustrations are made with PCISCHEMATIC Automation

ISBN 978 87 989072 4 4

EAN 9788798907244

Introduction

Reliability comes first!

The present publication is written for machine producers; electrical control panels assemblers and other technical personnel who have to prepare technical documentation. The book does not always prescribe what one should do in a certain situation, but provides examples and instructions that can be used as a basis for compiling technical documentation. The 2nd edition contains more useful samples and directions. The standard users must decide for themselves which version is the most appropriate on the basis of rules, references, suggestions and requirements. If you still have any doubts, please ask for help from the National Standard Association or any other expert. But the final decision is yours and according to the Machinery Directive (Directive 98/37/EC) you are responsible for the final solution.

Who is the publisher of this book?

The current edition was published by DpS CAD-centre ApS at the request of and in cooperation with EFU – The Danish Electricians Educational Secretariat (today EVU - the Danish Electricians and Plumbers Educational Secretariat) in Denmark. The book is written by Jørgen Sommer, an employee of DpS whose responsibilities include selling and marketing of PCschematic® CAD-programs intended for preparing electrical documentation. According to an agreement with Dansk Standard (Danish Standards (the Danish national standards association)), the publishers have rights to use and distribute the drawings and texts from various standards.

The book is compiled in cooperation with the following experts: Per Holmstrøm, consultant of electro techniques and, among other things, an expert on the Machinery Directive; Karl-Anker Thorn, the project leader in the standardization commission S-503 (documentation standards) from Danish Standards; Flemming Larsen from ELFO-TEKNIQ, and Leif Steffensen from the National Work Environment Authority (Arbejdstilsynet). In addition, the author has consulted several companies and technical schools.

Thanks to everyone who has contributed to compiling this piece of writing.

Introduction to 3rd edition

You are holding the 3rd edition of the book, which has been updated with the latest editions of the standards. Jørgen Sommer is once again active as author, even though he has retired. Once again, we invite you to send in any suggestions, ideas and corrections that could be taken into considerations in the next editions. You can use this email: book@pcschematic.com.

Jyllinge, June 2011

Contents

Introduction	4
Briefly about the book	11
Directives	15
Machinery Directive	15
National regulations	16
Low Voltage Directive	17
EMC Directive	18
Responsibility	21
Is the electrician “the manufacturer” when changing the machine	21
European requirements	23
General information about standards	27
What does the present publication cover	27
Electrical documentation and documentation in general	27
Electrical documentation with or without a CAD-program	28
How you can work with standards	28
Use the references to other standards	28
Your guarantee when choosing a CAD-program	29
Technical documentation	33
General requirements to electrical documentation	33
Three standards of essential importance	33
What should technical documentation include?	34
Common requirements for the complete documentation	37
Technical dossier	38
Information sheet	43
Some examples of explanations	43
Types of diagrams	47
Equivalent circuit diagram	48
Connection diagram	49
Circuit diagrams	50
Examples of documentation	51
Combined circuit and connection diagrams	59
Inner connection diagrams and tables	60
Outer connection diagrams and tables	61
Terminal connection diagrams and tables	61
Cable diagrams, tables, and lists	62
Location and installation documents	63
Installation drawings and diagrams	63
General information about diagrams and plans	63
Parts, components and spare parts lists	69
Technical drawing	73
Drawing formats	73
Drawing header and title block	73
Reference grid	74
Conductors	74
Lines and line thicknesses	74
Connecting lines	75
Symbols	83
Graphical representation and overview of symbols	83
Non-standardized symbols	86
Symbol size and shape	86

Symbols and operating state	90
Design of symbols	95
Composite symbols	95
Correct use of symbols	98
Marking and identification	103
Function marking	103
Marking of control equipment	103
Reference designation	104
Identification of conductor	104
Information about conductors	106
Conductor identification by supplier	106
Numbering of wires and conductors	106
Labelling of cables and conductors according to IEC/EN 62491	107
Terminals for predetermined conductors	109
Identification of terminals within a system	113
Terminal blocks in combined circuits and connection diagrams	115
Marking of terminals on contactors, switches etc.	115
Structuring principles and reference designations	121
What is a reference system?	121
Classification and letter codes	122
Single level reference designation	123
Multilevel reference designation	124
Name and sub-name	127
Type or item number can be the top in a structure	128
Functional structure	129
Product structure	129
Location structure	130
Reference designation of documents	131
Reference designation of signals	134
Letter codes	139
Purpose of letter codes	139
Double codes	146
How to use the letter codes	148
Rooms, locations and areas	149
Choosing the lettercode	151
Letter codes	153
Installations	157
General information about electrical installations	157
General information about the power supply of machines	161
Electrical installations in buildings	162
Building installations	165
Intelligent Building Installation	168
Automatic fire alarm systems	169
Overview of standards	173
Documentation and guidelines	173
EMC and telecommunication	174
Installations	174
Marking and identification	174
Products	175
Reference designations	175
Symbols	176
Technical drawing	176
More references	178
Index	180



Introduction and reading guidance

How is the structure of the book? How are the different sections highlighted?

Briefly about the book

This is not a classical book that needs to be read in the right order. You can read it in any order you think best. Nevertheless, we suggest you start from the introducing chapters. The second edition is extended based on questions from users since the first edition. Each chapter begins with brief notes on possible limitations, references, etc. that are relevant to the topic discussed in the chapter. You might need this information for your machine, control panel, or installation. In this case you can follow suggestions given in an instructive paragraph as shown below:

Read in the book:

This paragraph gives an outline of those topics in the book that might be useful to remember and those that are connected with this chapter you have started reading.

Get and read:

Quite often you might need to find more information on some topics. This paragraph provides a list of standards and publications where you can find additional information that assists you to prepare the electrical documentation accurately.

Note: Particular remarks to standards about changes, new editions or revisions will be given in notes like this one.

The list of standards

At the end of the book you can find an overview of standards by groups. The lists include mainly these harmonized European standards the IEC counterpart of which can be found on the IEC home site www.iec.ch. Only those standards are listed that are necessary when preparing electrical documentation or are in some way related to it. However, you should be careful, especially if you work in a very specific or rare technical area because some standards could be missing from the list.

There are different markings/highlights in the text:

The most important highlights

Important highlights, examples, tables

Index and terms

Index is built in such a way as to allow searching both on the basis of those terms that are used by professionals every day as well as on the basis of terms used in standards. In headings, however, terms of standards are used. For instance, the standard IEC/EN 61082 uses the term control circuit diagram, although it is often called circuit diagram. There could even be several different terms describing the same object.



Directives

Briefly about the Machine Directive, National regulations, Low Voltage Directive and the EMC Directive.

Directives

As a minimum requirement for producing machines and control panels of machines/equipment, you need to comply with directives valid in your country.

This book deals with this type of electrical documentation that is necessary for electrical equipment of machines. That is why it gives a brief account of the Machinery Directive and the corresponding standard IEC/EN 60204-1. If your company produces or uses machines, there are many other relevant directives to comply with besides the Machinery Directive.

Read in the book:

All the chapters of the book are based on the corresponding standard of the Machinery Directive – IEC/EN 60204-1.

Get and read:

Machinery Directive 2006/42/EC and national laws and regulations, among them: IEC/EN 60204-1 Safety of machinery – Electrical equipment of machines.

Low Voltage Directive 2006/95/EC and national laws and regulations, among them: IEC/EN 60439-1 Low-voltage switchgear and controlgear assemblies, part 1: Type-tested and partially type-tested assemblies.

EMC Directive 2004/108/EC and national laws and regulations, among them: IEC/EN 61000-6-1:2007 Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity for residential, commercial and light-industrial environments.

If necessary, respective national publications on this subject matter.

Note: The standard IEC/EN 60204-1 was revised in 2005.

Machinery Directive

The standard IEC/EN 60204-1 – harmonized by the Machinery Directive – is called “Safety of machinery - Electrical equipment of machines”. This standard covers any kind of electrical equipment, components, and devices that operate in the voltage range of:

0 to 1000 V AC and 0 to 1500 V DC, with supply frequencies up to 200 Hz

If you are a manufacturer of machines, you must comply with the Machinery Directive. This directive covers both technical and administrative requirements. If you meet these requirements, you can be sure that the equipment/machines you manufacture comply with valid legislation on this field.

The Machinery Directive does not only concern industrial machines, but it is also used for maintenance, assembly, and testing of electrical equipment of machines. The directive describes briefly and clearly what the requirements for technical documentation and for documentation in general are. Documentation within the meaning of the Machinery Directive is a broad concept and electrical documentation comprises only a minor part of it.

As mentioned above, the IEC/EN 60204-1 standard or national legislation and regulations on electrical equipment of machines can be found under the heading of the Machinery Directive.

The main purpose of the standard is to provide requirements and recommendations of machines so as to promote:

- safety of persons and property
- consistency of control response
- ease of maintenance.

The material and components covered by IEC/EN 60204-1 standard begins where the power supply is connected to the electrical equipment of the machine. In other words, the standard is applicable to the electrical equipment or parts of the electrical equipment that operate with nominal supply voltages not exceeding 1000 V AC with nominal frequencies not exceeding 200 Hz or not exceeding 1500 V DC.

IEC/EN 60204-1 covers the application from electrical and electronic equipment and systems to a group of machines working together in a co-coordinated manner. This book, however, does not describe the equipment itself but only points out some requirements to meet and gives some suggestions to consider when preparing electrical circuit diagrams etc. – Hopefully there are some national publications on electrical equipment of machines that provide, among other things, information about the equipment itself.

Please note that there are some machines or products that are covered by both the Low Voltage and Machinery Directive, whereas in case of some machines and products only the Machinery Directive must be complied with. Each device that incorporates at least one moving part, e.g. a spherical valve, is considered to be a machine and therefore covered by the Machinery Directive.

What else is covered by the Machinery Directive? The directive applies to all the machines that are delivered to and used within the EU. To be more precise, it applies to all the machines manufactured after the 1st of January 1995 with some exceptions.

National regulations

The Machinery Directive also covers aspects concerning health and safety of persons working with or close to the machines. It is the duty of national authorities to guarantee that the requirements of persons' health and safety are met and to inform the public of the subject matter. National authorities should also provide information on valid technical standards and specifications that deal with people working with electrical equipment of machines.

As far as electrical equipment of machines is concerned, Annex I of the Machinery Directive should be of particular interest; its title being "Essential health and safety requirements relating to the design and construction of machinery".

As a mechanic or a person of any technical function, you should also pay attention to national regulations. Those regulations might provide the right solution in your situation. For example, if you manufacture control panels for lifts or contractor machines, the requirements applying to them could differ from the requirements applying to “ordinary” machines.

In addition, there are harmonized standards (providing details on acoustic noise, emergency breaks, system faults etc.) that exceed the limits of the current publication. Therefore these topics are not included here.

Low Voltage Directive

Legislation concerning power installations and (household) electrical equipment is within the competence of respective national authorities. The national authority is also responsible for providing information on valid requirements and for ensuring that they are complied with. If you need information on any regulations you can turn to the corresponding authority for help. Related harmonized standards and harmonizing documents for designing equipment usually comprise a part of national legislation. In these matters you should consult the authorities of the country you are staying in.

In 2006, a new Low Voltage Directive was issued (2006/95/EC). This directive is a merger of the old Low Voltage Directive (73/23/EC) and the following amendments.

There are no technical changes or new requirements in the new Directive. Thus there are no required implementations with a fixed time frame in the member countries. At this moment, we are in Denmark referring in our national regulations to the old Directive (73/23/EC), and at the same time the website of the European Union states that it has been replaced by a new Low Voltage Directive (2006/95/EC). This is a completely legal and acceptable situation. Especially exporting manufacturers are asked to refer to the new Low Voltage Directive, (2006/95/EC).

Be aware that the Low Voltage Directive and the Machinery Directive covers a long series of different risks. In the Machinery Directive 2006/42/EC, there is a clear difference between what equipment belongs to the Low Voltage Directive, and that is: appliances for private use, audio and video equipment, computer equipment, general office machines, connectors (control panels) and control equipment, electric motors; and high voltage equipment: connectors and control equipment in addition to transformers.

Control panels used with machines must be manufactured in accordance with appropriate requirements and recommendations outlined in standard IEC/EN 60439-1. According to IEC/EN 60439-1, when an assembler of control panels and a machinery manufacturer make a trade deal, control panels must comply with the Low Voltage Directive in the same way as other electrical equipment. Therefore the equipment must bear the CE-marking. For the assembler of control panels, the machine producer must carry through a risk analysis himself, in addition to an EMC test of the panel.

IEC/EN 60439-1 is valid for control panels: Type tested control panels (TTA) and partly tested control panels (PTTA), of which the marked voltage does not exceed 1.000 VAC at frequencies not exceeding 1.000 Hz, or 1.500 VDC. This is

valid for control gears, low voltage equipment, encapsulated power distribution systems, type tested control panels and partly tested control panels. These control panels are called control gear and besides having to comply with regulations for control panels they must also meet the appropriate requirements set in standard IEC/EN 60204-1 for control panels.

The manufacturer must provide technical documentation to be used to evaluate the agreement of electrical equipments with the requirements according to the Low Voltage Directive. The documentation must cover the construction of the electrical equipment, its production and function in the extent it is necessary to evaluate the equipment.

The documentation must be kept at least 10 years calculated from the last time of production. The national authorities must be able to use it for the purpose of inspection.

The manufacturer must also provide a Declaration of Conformity before marketing. Only the manufacturer and his representative in the Community are allowed to do this.

EMC Directive

The EMC Directive includes the standard IEC/EN 61000-6-1:2007 EMC European Norm – a generic standard for EMC. Part 6-1 deals with residential, commercial and light industrial installations.

Harmonized standards related to this directive provide, among other things, details on maximum permitted noise level for a specific device or machine. In addition, they provide information on the capacity of the machine depending on where it is located and whether it is used in a factory or workshop.

There are several ways to limit the emission of electromagnetic noise. You can short-circuit or remove the interference signals by using RC-filter, suppressing the sparks caused by switching, etc. However, the purpose of this book does not include a lengthy discussion on this topic, although such circuits have to be documented as well.



Responsibility

When is the installer responsible and why?
Facts about CE-marking.

Responsibility

Machines with their documentation are often complex and the possibilities of error are considerable. Typically, manufacturers, electricians and the owner are involved. And still, mistakes are made, even though most of them could be avoided. Who is responsible? Always contact the authorities in case of doubt. The content in this chapter is based on the Machinery Directive with articles and information from the Danish national authority.

Is the electrician “the manufacturer” when changing the machine

The information to the electrician – possibly from an insufficient documentation – is perhaps merely, that the machine has some free terminals, and only a cable should be mounted.

Normally there are no problems for the electricians who connect the machine, but when the machine consists of more units or single parts, the electrician must think it carefully over.

By doing the connection and the coupling of units and single parts, the electrician risks being “the manufacturer of the machine” because he/she has changed it. The electrician is unintentionally on the way into some problems with long-range consequences. The electrician should consider the following:

What should I do? Which role do I have? Am I the manufacturer of the machine or an electrician?

This is a question about responsibility!

The rule is: nothing at all must be connected before the electrician has investigated the technical data, and only if a Declaration of Conformity exists for the particular machine and accompanying documentation.

In other words, the point is to find out if others already have taken the responsibility that the machine meets the present requirements. And not least of all, how the responsibility covers the particular machine. Because there can be big differences.

Is there already a Declaration of Conformity or is it only a Declaration of Incorporation?

Some manufacturers work out a Declaration of Conformity and documentation which is valid where the machine is going to be used. In such cases the electrician can connect the machine without problems by following the instructions from the manufacturer, because the manufacturer of the machine has undertaken the responsibility. But often only a Declaration of Incorporation exists, where it says:

This machine must only be put into service until the final machinery into which it is to be incorporated has been declared in conformity with the Machinery Directive. The manufacturer of the completely assembled machinery will undertake the CE-marking of the machine.

Here many fall into the trap. They just connect the machine. But the paperwork is not valid and such a machine is against the law. In many cases a power supply breaker is missing. It must be connected in the installation before the machine. This should be clearly shown in the installation instruction and diagrams, which accompany the machine.

The manufacturer has only written a Declaration of Incorporation and noted in the assembly instruction that the main switch is not delivered with the machine. Therefore, the electrician shall deliver it. If the electrician connects the machine without reading the documentation, he/she is on the way to be a manufacturer with responsibility for the Declaration of Conformity.

The point of separation is the admission terminals of the power supply breaker.

From and within the power supply breaker the machine installation begins. From there it is the responsibility of the manufacturer that the machine complies with the legal requirements (Machinery Directive). That is why the electrician always should remember to ask him/herself: am I on the way to become the manufacturer?

The main circuit breaker shall secure that the machine can be disconnected (by using padlock), in this way maintenance of the machine can be provided, while the machine is out of operation.

These as well as other relations should exist in an agreement between the manufacturer and user. This agreement can be made by using the form in Annex B of the standard IEC/EN 60204-1.

When an accident occurs where a machine is connected without main circuit breaker, there will – besides human injury – be an investigation about who has the responsibility for the machine, the documentation and the accident.

Identification of conductors

Some electricians choose to be manufacturers or perhaps only sub-manufacturers and both roles are possible to take. One must only ensure that the right technical solutions are made and bring the documentation up to date. In many cases the problems concern (missing) conductor identification.

The standards of the machinery safety point out that every conductor on a machine must be identifiable. In some cases you can easily see and follow a conductor over its whole length, and then it is legal not to mark the conductors in other ways. But there can be several hundred conductors in a machine. Then marking of all conductors is the only solution.

Finally, the responsible person shall sign the Declaration of Conformity and hereby he or she guarantees that the documentation exists with diagrams, operation manuals, maintenance manuals and others documents according to valid requirements.

The customer must also make sure, that the machine is made according to valid rules and regulations, even though the machine is CE-marked.

European requirements

There are examples showing that some manufacturers claim that conductor identification is not a requirement in their country. This is not true.

The same rules and requirements apply throughout the whole of Europe.

It is clearly visible that it creates problems to get such a manufacturer to understand that he must deliver with conductor identification on the machine, which is going to be installed in another country or anywhere in Europe. That is to emphasize that all parts – the electricians, the manufacturers of machines and the owners – are meticulous and take responsibility for their parts of the machine and the corresponding installations.

Facts about CE-marking

Is not allowed to market a machine or use a machine before it has been declared to be in conformity with the particular health and safety requirements, relevant requirements in the Machinery Directive and relevant CE-marking directives, like the Low Voltage Directive and the EMC-directive. The CE-marking is the declaration from the manufacturer to the authorities, that the requirements in the CE-marking have been observed.

Machines must only be CE-marked after the Declaration of Conformity is signed. The Declaration of Conformity must only be signed when the machine is produced according to the directives, including complete documentation.

Partly assembled machines should not be CE marked, but they must comply with current requirements. A Declaration of Incorporation must be submitted with the required documentation.

Declaration of conformity and enclosures

You should be aware that it is rarely sufficient to list the directives and standards that your product complies with to observe the relevant directives. Many rules listed in the standards require that you make one or more choices. For instance, conductor identification: You must make a choice between markings with numbering, letter code or by colours of the conductors.

Therefore, in the Declaration of Conformity you must refer to a document, where subjects like this are specified. The document might be the form Annex B in standard IEC/EN 60204-1 or, where it is relevant, it could be an information sheet included in the electrical documentation. Normally there are other reasons to refer to a certain enclosure in the Declaration of Agreement.

CE marked machines must be delivered with a Declaration of Conformity.

Partly assembled machines are delivered with a Declaration of Incorporation.



General information about standards

General information about documentation. What is covered in the book? Working with the standards. Your guarantee when choosing a CAD program.

General information about standards

You have to meet the minimum requirements of the Machinery Directive. This is the law. The standards exist in order to help to comply with directives. When starting to deal with standards, everything might seem to be slightly confusing. Luckily, this book is here to help you. If you need specific information, the best place to ask for help is the local authorities where you are most likely to receive high-quality guidelines and to get an overview of matters relevant for you. This book is focused on electrical documentation and standards which one needs to comply with in order to prepare the documentation as required.

Read in the book:

Overview of standards, page 173.

Get and read:

Overview of standards by national authorities.

Standards can be found on the IEC home site: www.iec.ch

ISO-standards can be found on the home site: www.iso.ch

What does the present publication cover

The European standards (IEC/EN) and respective international standards (IEC) can be roughly divided into three groups as shown below. Please note that the present publication covers only one group of standards:

This book does not cover the following two groups of standards

- Standards that deal with risks and security with or in the vicinity of machines.
- Standards on usage and assembly of electrical equipment of machines.

The current publication deals with the following group of standards

- Standards on form and content of electrical documentation that one has to comply with in order to meet the minimum requirements of the Machinery Directive.

Electrical documentation and documentation in general

The designation “Documentation” is a broad concept and electrical documentation comprises only a small part of the whole. According to the Machinery Directive, the technical documentation of a machine should comprise: technical dossier, user manuals, declarations, test reports and descriptions.

The part of documentation which in this book is called electrical documentation includes, among other things, electrical circuits, terms, names, markings, numeration, components lists, spare parts lists, graphical plans, and drawings of control panels. Among the most significant standards on electrical documentation is the set of standards IEC/EN 61082 entitled: “Preparation of

documents used in electro technology". The standards of this set can be roughly divided into four categories (see the overview p. 173):

- Standards that set requirements for technical drawings, including lines and line types, texts, symbols, paper sizes, etc.
- Standards providing an overview of symbols and pictograms used in diagrams and on machines, components, and electrical equipment.
- Standards that set requirements for marking and separating the circuits or wires, terminals, links, and colour codes, etc.
- Standards that set requirements for using and preparing different diagram types, connections and other lists and plans.

Electrical documentation with or without a CAD-program

If you prepare and draw electrical documentation, e.g. for machine control or construction installation without a CAD-program, you must be familiar with all four standard types, i.e. you have to know considerably more about standards than in the case of using some version of a CAD-program, e.g. PCISCHEMATIC Automation. If you use a program that already contains the standard symbols, you don't have to think about the rules for symbols.

If you use a CAD-program that comprises user support and functions for meeting the requirements, you basically have to know only the requirements of the third and fourth category of standards listed on previous page.

That is why this book focuses on those standards. One program that "knows" the rules of the first and second category is PCISCHEMATIC Automation.

How you can work with standards

In order to prepare electrical documentation for machines, devices, or installations as required, it is important to work with standards or with other publications that deal with respective standards or situations. We suggest you do as follows:

- Read and learn the requirements set by the actual standard.
- Ask critical questions and analyze the specific "task". What is its purpose? What do I want to achieve? Can it be misunderstood?
- Rely on those requirements to which the answers are pointing and complete the task.

Use the references to other standards

Gain more knowledge on a certain matter using references to other standards provided in the instructive paragraphs of this book. You should not limit yourself to this book only – even though the book is revised to this third edition it does not contain everything.

There might be special situations when this publication is not enough. In this case, you have to study the standard itself (IEC/EN or ISO) and/or (other) appropriate publications. Sometimes it might be a good idea to contact the authorities before starting to study the matter.

Your guarantee when choosing a CAD-program

Paragraph 12 in the new edition of the standard IEC/EN 61082-1:2005 contains a list of standards, which should be followed to prepare electrical documentation correctly.

Paragraph 12 is primarily formulated for producers of the CAD-programs. When a producer claims that the program can be used according to international standard IEC/EN 61082-1, the producer should, when developing the CAD-program, make sure that this can be used to fulfill rules, recommendations, and different choices in the standards mentioned below:

IEC/EN 60617	Graphical symbols for diagrams
IEC/EN 60848	GRAFCET specification language for sequential function charts
IEC/EN 61175	Designation of signals
IEC/EN 61346	Structuring principles and reference designations
IEC/EN 61355	Classification and designation of documents
IEC/EN 61666	Identification of terminals within a system
IEC/EN 62023	Structuring of technical information and documentation
IEC/EN 62027	Preparation of parts lists
IEC/EN 62079	Preparation of instructions - Structuring, content and presentation
IEC/EN 81717	Design of graphical symbols
IEC/EN 82045	Document management

