INTRODUCTION

CHP, Combined Heat and Power, or Cogeneration of Heat and Power, is the simultaneous production of heat and electricity. This proven technology gives a very high utilisation of the fuel, and in the 2001 10% of Europe’s electricity and heat requirements were produced through CHP. In Denmark, 21% of the electricity production that year was through CHP.

The CHP technology has now reached a stage where production of very small units begins to be feasible and "micro-cogeneration" i.e. systems with a capacity below 11 kVA electrical have been developed. This has brought domestic cogeneration forward as a realistic development in the (near) future i.e. dispersed generation of heat and electricity intended for use in the domestic sector. The perspective of an electricity supply system with domestic cogeneration being responsible for a significant part of the electricity production attracts interest, both because of its challenge to the control of such a system and due to its environmental benefits.

Other sectors than the domestic, industries, institutions etc. will certainly have an interest in micro-cogeneration also. Due to the high number of possible installations, however, the domestic sector is an extremely important market. It may act as a driver for the production of standardised micro-cogeneration units and bring the production volume up to an economical size. Although the technological solutions for micro-cogeneration are available, it is still an emerging technology and needs the economy of scale to bring down the prices to a realistic level.

The rules for the connection of the system to the grid are essential factors in this process. If micro-cogeneration systems are not safe and simple to connect to the electrical network, they will never penetrate the domestic market. A first step towards a large-scale introduction of domestic cogeneration is thus to establish common and generally acceptable technical rules for the electrical interface, for the protection of the system and for the influence on the local power quality parameters from the cogeneration unit.

Even in a limited geographic region as Europe, the establishment of rules for the connection of the units, which can be generally accepted, may not be a simple task, considering the differences in rules and practice for domestic installations throughout Europe.

The European standardisation organisation CEN has however a device for such a situation, the CWA, the CEN Workshop Agreement. At the time when this work was initiated, only CEN possessed this possibility, and it was decided to use the CWA even though CENELEC would have been the relevant standardisation organisation, as the work deals with the electrical interface of the cogeneration unit. It can be added, that also CENELEC now possesses the possibility of a Workshop Agreement.

THE ESTABLISHMENT OF A CWA ON DOMESTIC COGENERATION

The CWA, the CEN Workshop Agreement

A CWA is an agreement between a number of individuals and organisations on for example a sensible set of technical rules for a new product family. It is a formal process and the work is endorsed by the National Members of CEN, but neither the National Members nor the CEN Management Centre can be held accountable for the technical content of the CWA or possible conflicts with standards or legislation.

In this actual case, the intention of the CWA is to recommend future good practice, and it represents a sensible starting point for the ordinary standardisation process.

The CWA on Domestic cogeneration

The work was initiated by CEN with a public call for participation in February 2001 to individuals and organisations representing sectors like manufacturer, testing- and certification-institutes, distribution network operators (DNOs) etc.

The process was initiated with a kick-off meeting in April 2001.

The participants in the CWA comprise 28 different organisations from 10 European countries plus two European organisations, of which CIRED is one.

The final document contains the complete list of members. [1]

A drafting group was established which CIRED also attended. Drafts prepared by the drafting group were discussed in a number of plenary meetings, and the CWA was produced to its official final version, announced to be issued by CEN in the very start of 2003.

CIRED participated in the work as a European organisation representing research and development in the area of electrical distribution, and which through its WG04, Dispersed Generation, has an efficient contact network to a group of experts in the relevant fields. The responsibility was given to the chairman of Session 4.

From the very start of the work it became evident, that the
establishment of common European standards for the connection of domestic cogeneration would have to face and address considerable differences in installation practice in Europe. Further, that the operation of the distribution network follows different traditions, and that differences in fundamental parameters like for example tolerances on the nominal voltage are in existence.

It was however acknowledged that the CWA will be issued in a situation where the number of domestic cogeneration units in operation is very low. It is thus justified to establish a set of rules for their electrical interface, which is acceptable as long as they only represent a minor part of the production capacity. As long as their number is low they will only have a limited and very local influence on for example the voltage quality. In a (future) network, where domestic cogeneration represents a dominating part of the supply, other set of rules will have to apply.

With this condition it should be possible to establish a set of commonly acceptable rules.

THE CIRED QUESTINAIRE

It was felt important at the start of the work to have a clear picture of the current rules and practice in Europe on the area.

CIRED could contribute with the report on dispersed generation from the conference in NICE in 1999 including the update from June 2001.

CIRED offered to establish a survey more specific directed towards micro-cogeneration and domestic cogeneration. It was again left to CIRED WG04 through its secretary, and conducted at the end of 2001/start of 2002.

Replies were received from:
Belgium
Switzerland
Denmark
Norway
Portugal
Italy
Spain
United Kingdom
Germany
The Netherlands

The complete survey is included in the CWA [1]

A summary of the answers is given below:

**Question 1:**
What are the current national regulations that apply for the electrical connection of micro-cogeneration to the electrical network?

*No country reported any regulation specifically for micro-generation, although there were standards in place for small PV installations (Belgium and Spain) and general small generation (Portugal < 100 kW, Italy < 50 kW)*

**Question 2:**
Are there simple rules for the maximum power that may be connected by a generator at a particular voltage?

In particular can a generator connect to the electrical network at low voltage? If so what rules are applied? If not please explain why.

*Simple rules were reported from Portugal (generator rating to be less than 4% of short circuit level), Italy (< 20 kW 3-phase may be connected to LV network; < 3 kW 1-phase may be connected to LV network) and Spain (for asynchronous generators up to 60 kVA for a 220 Volt connection and up to half the transmission capability of the feeder).*

**Question 3:**
What do you see as the main technical connection issues for micro-cogeneration?

*The main issues identified:
Safety (particularly of workers on the network)
Power Quality including steady-state voltage rise.*

**Question 4:**
What are the requirements for controlling the reactive power output or busbar voltage of micro-cogeneration?

*No clear consensus:
Belgium and Italy ask for a high power factor. Portugal ask for injection of VARs during periods of heavy network load.
Spain, Italy and Norway identified a requirement to maintain voltages within permissible limits.*

**Question 5:**
What rules are used for studying the effect of the generator on system voltage?

*Only Italy identified a clear simple rule that the voltage at the DG busbar must be maintained within 4% of rated voltage. In other cases it appeared to be a matter for engineering judgement.*

**Question 6:**
Are generators treated in the same way as loads in terms of power quality issues, e.g. harmonics, unbalance, sags etc.? There was general agreement that micro-generators should be treated in the same way as loads

**Question 7:**
Do the DNOs specify or provide guidelines for any particular form of generator protection? Is the generator protection too sensitive and subject to nuisance tripping?

*In general the DNOs did specify guidelines for generator protection and there was concern expressed over nuisance tripping.*

**Question 8:**
Interface protection required to protect the distribution network and other customers, like Over and Under Frequency, Over and Under Voltage, Over current and earth fault, Pole slip, Circuit Breaker Failure, Loss of Mains etc.

*Detailed replies!*

**Question 9:**
Is specific loss-of-mains protection required?

Is auto-reclose of circuit breakers used on the distribution networks to which the micro-cogeneration will be connected?

*Auto-reclose is not used on LV networks but is widely applied on MV and HV networks and so impacts directly on micro-generation.
There was general agreement that some form of loss-of-mains protection was required to ensure that islanded operation and out-of-phase reclosure did not occur.*

**Question 10:**
Do you consider that the presently available loss-of-mains relays are satisfactory?
Opinion differed on this point with concern expressed from Belgium but other replies stating that the position was unclear.

**Question 11:**
What procedures and equipment are required to isolate a micro-cogeneration generator for work on the network?

A lockable switch is required in a number of countries but discussions were also reported to consider if suitable automatic alternatives could be adopted.

**Question 12:**
What are the disconnect and reconnect times in the event of a fault occurring?

Listed in the individual replies

It is important to realise that absence of local rules for grid connection of micro-cogeneration do not imply, that unrestricted connection can be expected, but merely that no specific rules for this type of appliance exists.

It must also be noted, that the answers reflects the situation in the very start of 2002, and that the situation may be different now. In UK for example, the Engineering Recommendation G38 for small scale embedded CHP generation has been issued by the Electricity association recently. It covers the connection of small-scale embedded generators (up to 16 A per phase) in parallel with public low-voltage distribution networks.

**CONTENTS OF THE CWA ON ELECTRICAL INTERFACE FOR DOMESTIC COGENERATION**

The CWA covers the electrical interface between the appliance and the low-voltage electrical network. Specific elements like metering are not included. It restricts itself to micro-cogeneration systems for domestic use.

The CWA acknowledges that both the CWA and the local existing standards and practices may require modification in the future due to larger market penetrations of domestic cogeneration and/or due to experiences gained with the operation of the equipment.

The scope of the CWA includes

- all technologies for micro-cogeneration
- all generator types
- size up to a maximum of 16 A per phase in a single low-voltage installation
- both 3-phase and single phase connections
- connection is limited to low voltage networks
- the electrical interface is the principal focus. This includes the method of connection, the settings and protection requirements for connection, the operation of the electrical interface under normal conditions, emergency shutdown, distribution network independent operation, start-up and distribution network synchronisation

Larger units as well as for example generators never to be connected to the supply network are explicit excluded from the scope.

The intention of the CWA is to insure that micro-cogeneration satisfies appropriate provisions for:

- safety of persons
- information to electricians working inside the house
- voltage quality and reliability of supply
- protection of the cogeneration unit

The CWA does not cover the safety for DNO personnel working upstream of the unit; this must be secured by other means.

A typical micro-cogeneration system will be an assembly consisting of:

- An engine, like a gas engine or a Stirling engine, which convert fuel to mechanical power
- A mechanical driven generator or alternator and/or inverter
- The electrical interface.

Alternatively:

- Fuel cell(s)
- Inverter
- The electrical interface.

In addition to this, there will be a fuel system, a flue system and a heat system, but their treatment is not a part of the CWA.

The CWA contains provision for:

- Safety requirements
- Power quality
- Operation and safety of the appliance
- Commissioning
- Type-testing and type certification

**Safety requirements**

The most important part of this paragraph in the CWA is the protection functions of the electrical interface. The protection shall serve the purpose of:

Safety of persons

Voltage quality

Security of supply

Protection of the micro-cogeneration appliance itself.

The same protective measure may serve several purposes.

The protection settings need to be agreed nationally. The CWA indicates the type and range of settings that may be required. If no national settings are available, the settings proposed in the CWA may be used.

As with all dispersed generation, special consideration is given to the situation of islanding, i.e. a situation where the generator and its local domestic installation is cut off from the rest of the distribution network. Dependent on the specific type of generator, synchronous, asynchronous or inverter, this situation may lead to the generation of considerable over voltages, and represents a danger to the generator due to out-of-phase conditions when the connection is (suddenly) restored.

The loss-of-mains protection system must thus react rapidly and selectively. A fast disconnection from the network of the unit is necessary but the protection must be insensitive to the normal voltage and frequency variation in the distribution net. Ideally, the appliance shall stay connected in situations with under- and over-voltages and under-
over-frequencies, to avoid a cascade loss of generation, which may cause (local) instability in the electricity supply. The CWA suggests protective functions, which balance these demands. It appeared important not to specify very complex protective systems, in view of the domestic cogeneration unit’s character as a simple and uncomplicated piece of domestic appliance.

An other situation that the protection system must prevent, is the feeding of faults from the cogeneration unit. The ordinary electrical installation is designed to protect faults from being feed from the higher levels i.e. downstream. The protection system of the cogeneration unit must prevent the unit from feeding into a fault. Although closely related to the loss-of-mains situation, the protection for this situation may be different.

The specific types of protections mentioned in the CWA are:

- Over-/Under-frequency protection
- Over-/Under-voltage protection
- Over-current protection
- Special protection for islanding, for example a ROCOF protection.

The safety provisions include rules for earthing, residual current protection, procedure for re-connection of the appliance, synchronisation etc.

### Power quality

A major issue when discussing a large-scale introduction of domestic cogeneration is the influence on the power quality especially on the voltage quality. A combination of many small generators will exert a dominant influence on the voltage-quality in the local section of the distribution network, and any possible interference between the voltage regulations and protective devices of the individual units must be considered carefully.

The scenario for the CWA is however a situation with relatively few domestic cogeneration units connected to the (local) grid. In this situation, it is sufficient to specify parameters for the individual cogeneration units. Their influence on voltage quality parameters like voltage variations and flicker depends on the local short-circuit impedance of the network. The CWA restrict itself to a reference to EN 61000-3-3 for basic emission standards.

### Operation and safety of the appliance

A subject that attracted some discussion during the preparation of the CWA, was the safety aspect of a dual supply, i.e. a supply of electricity from the upper level of the network as well as from the individual domestic installations.

The CWA specifies a warning label stating “WARNING-DUAL SUPPLY”. Whether this is satisfactory or not will depend on national rules, and is closely related to national installation practices.

### Commissioning

The CWA contains provision for commissioning a domestic cogeneration system. The DNO must be informed, but the installation will not have to wait for a formal acceptance. The DNO will need to be informed not later than 30 day from the installation.

### Type testing and type certification

The CWA contains some general considerations and remarks concerning type testing and certification. The functional requirements in the CWA can be verified through a type test in a testing house. For use in the EU the appliance will have to comply with a number of EU directives in addition to the CWA.

### ACTIVITIES FOLLOWING ACCEPTANCE OF THE CWA

The CWA serves as mentioned as a starting point for the ordinary standardisation process. The relevant Standardisation organisation is CENELEC, which in 2002 has set up a working group CLC/BTG 112-2 “Domestic cogeneration”. The kick-off meeting of this work has been announced to take place the 6th of February 2003. The members of the CWA on Domestic Cogeneration are invited to participate in the work together with the CENELEC National Standardisation Bodies and relevant CENELEC Technical Committees.

### CONCLUSION

CIRED has contributed to the removal of obstacles for the introduction of domestic cogeneration as a new appliance type in the distribution net, through work with the establishment of common standards for its grid connection.

The technological solutions for a large-scale introduction of units for the cogeneration of heat and electricity in the domestic sector are now available, but unit prices need to be lower. This can be obtained through the economy of scale and one of the conditions for this is a common and widely acceptable set of rules for the electrical interface and the connection to the grid.

The Standardisation organisation CEN possesses an instrument for that kind of pre-standard work, the CEN Workshop Agreement. Work was initiated on rules for the grid connection of domestic cogeneration. CIRED contributed to this work, both with a survey on the existing rules and directly in the drafting group.

Work commenced in 2001 and a final document is being issued in the very start of 2003. This CWA contains a set of
rules that in general, if not in every detail, can be accepted by the distribution net operators in Europe.

The manufacturer of the units will through this have a good indication of the specification for the electrical interface, and will accordingly be able to design for types with an expected general acceptance. The DNOs on their side will have an indication of the characteristics of the cogeneration unit as a network component, and can act accordingly.
And finally, the work with the “proper” standards for the electrical interface of domestic cogeneration units has a firm starting point, which serves both to facilitate and shorten the process.

References

[1] CEN Workshop Agreement (CWA)-Electrical interface for domestic cogeneration. Requirements for distribution network connection for micro cogeneration systems for domestic use up to 16 A per phase in low-voltage distribution networks (230/400V) Published by CEN. (In December 2002 only available in an unofficial final version)