CIRED Working Group No 4 on Dispersed Generation

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1) Introduction

At the CIRED Conference in Birmingham in 1997 the issue of dispersed generation was identified as becoming of increasing importance for distribution engineers and a working group was set up to gather information on how the various countries represented within CIRED were responding to this new development. The main focus of the working group was the interaction of dispersed generation with electric utility distribution systems. Thus the interest of the CIRED working group was largely complementary to that of the CIGRE working group on "Impact of increasing contribution of dispersed generation on the power system" (WG 37-23) whose draft Final Report was issued in September 1998.

The membership of the working group met on 3 occasions in 1998. The main activity was to create and issue a questionnaire of 22 questions which sought to identify the current state of dispersed generation in the various CIRED countries and to establish how dispersed generation was managed with reference to the distribution system. Some 16 countries provided replies which could be collated sensibly to try to form a general view of the state of dispersed generation. A summary of the replies is given in the Tables of Appendix A and this report provides some interpretation of this information.

The questions have been grouped into various topics and, where appropriate, the answers have been compared to similar information given in the report of CIGRE WG 37-23. Early in the investigation it became apparent that different countries had quite different approaches to various aspects of dispersed generation and that the information gathered showed very considerable diversity.

2) General Information

Three questions were asked to provide some basic information on dispersed generation.

Q1) What is your definition of dispersed or embedded generation?

Q2) What is the peak electrical output of dispersed generation in your country? How much of the electrical output is despatched, how much of the electrical output is determined by heat demand (or process demand), how much of the electrical output is determined by new renewable energy sources?

Q3) What are the main policy drivers in your country which are leading to dispersed generation?

Even on the question of definition there was no clear consensus as to what constituted dispersed generation. Some countries used a definition based on voltage level while others considered that dispersed generation was that connected to circuits from which consumer loads were supplied directly. Certain definitions relied on the type of prime mover, e.g. renewable or co-generation (CHP), while other definitions were based on the generation not being despatched. Finally some definitions were based on a maximum power rating. It was common for a number of these descriptors to be applied. This diversity is reflected in the CIGRE WG 37-23 definition which is that dispersed generation is:
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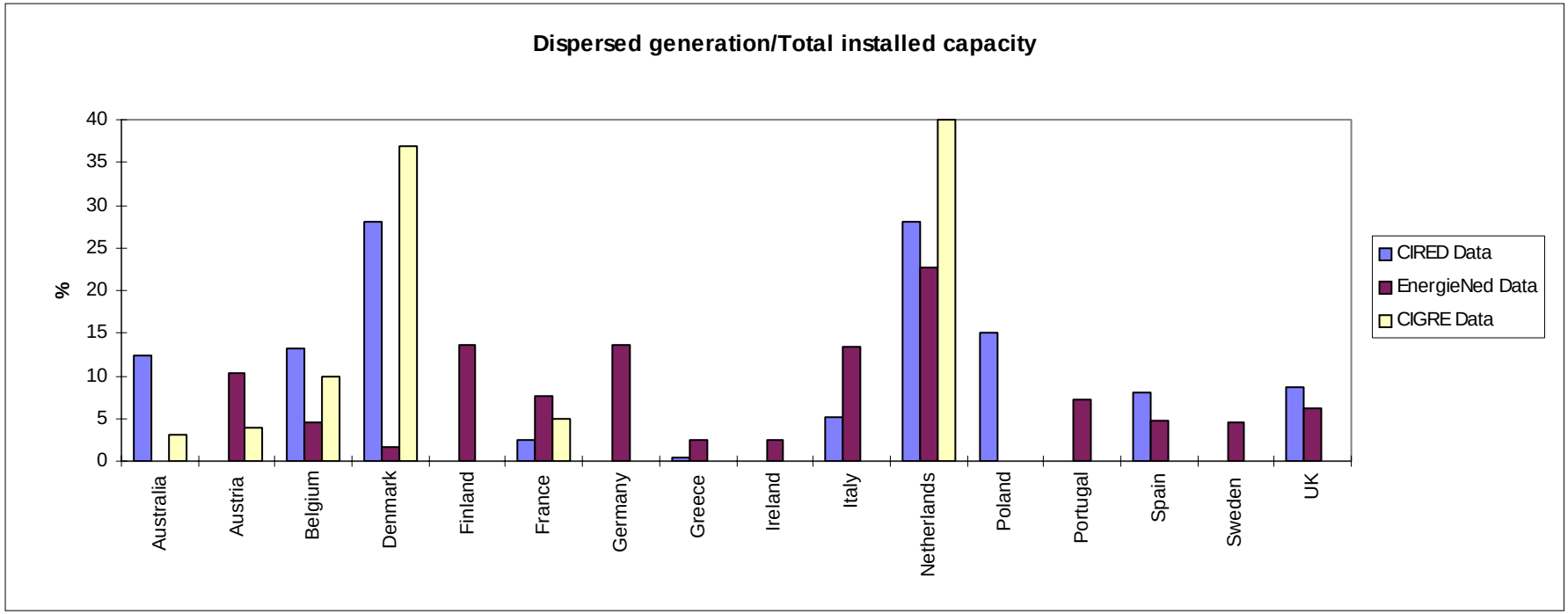
- not centrally planned
- today not centrally despatched
- usually connected to the distribution network
- smaller than 50-100 MW

Not centrally planned or dispatched means that major influences such as unit commitment or reactive power generation are out of control of the system operator."

Question 2 attempted to establish the level of dispersed generation and the replies are summarised in the Table. The data gathered using the CIRED questionnaire is compared with that presented in the report of CIGRE WG 37-23 and information from the 1997 EnergieNed report. It may be seen that agreement is not good, no doubt, partly due to the use of different definitions of dispersed generation.


Dispersed generation/Total installed capacity
%
40
35
30
25
20
15
10
5
0
Australia
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Italy
Netherlands
Poland
Portugal
Spain
Sweden
UK
CIRED Data
EnergieNed Data
CIGRE Data

There is also large divergence in why the penetration of dispersed generation is growing. Reasons given ranged from commercial factors and competition policy to government initiatives which encourage the use of new renewable energy sources. Although environmental issues were clearly important these were not the only policy driver. The CIGRE WG 37-23 report quotes a similar large number of reasons, twelve in total, to explain why dispersed generation is increasing.
It is of interest that in no case was the development of dispersed generation considered to be associated with the requirements of the distribution network. It may be concluded that dispersed generation is increasing due to a number of factors external to the electrical distribution network and it is likely that the distribution companies can have little influence on the rate at which dispersed generation schemes come forward for connection.

3) Technical aspects of connection of dispersed generation to the distribution system

Four questions were asked to try to determine the way distribution companies decide how dispersed generation might be connected. The questions were influenced by a discussion at the CIRED 1997 Conference during which some delegates expressed a strong preference for simple rules to govern the connection of dispersed generation.

Q4) What are the national technical rules or regulations for connecting dispersed generation? Are there simple rules for the maximum power which may be connected by a generator at a particular voltage level?

Q5) What do you see as the main technical connection issues at each power/voltage level?

Q6) When connecting dispersed generation do you use general guidelines or carry out system studies?.

Q11) What rules are used for studying the effect of the generator on the system voltage?

Considering Question 5, there was a reasonable consensus concerning the important technical issues of the impact of dispersed generation on distribution networks. The main issues identified were:

- Voltage rise
- Islanded operation (and cost-effective anti-islanding protection)
- Increase in short circuit level
- Impact on power quality

In addition some concern was expressed over operational issues including voltage control and central dispatching.

The replies to Questions 4 and 6 were more varied. In some countries (e.g. France and Italy) simple rules are applied which define the voltage level to which dispersed generation may be connected depending on its rated output. It was generally recognised that, although this approach saves engineering effort, it may be possible to relax these simple rules in some cases after suitable studies have been done. The alternative approach is to evaluate the impact of the dispersed generation on other users of the network by undertaking engineering studies of various complexity.

There was considerable divergence in the answers to Question 11. Some countries considered only the effect of dispersed generation on other customers while others had intermediate regulations to try to limit voltage variations at particular voltage levels. In addition to steady state voltage effects this question also elicited answers concerning power quality. It was noticeable that EN 50160 was not applied in a number of countries.

The information obtained from the answers to these questions is in broad agreement with the report of CIGRE WG 37-23. The report of WG 37-23 draws a clear useful distinction between studies which consider only the effect of dispersed generation on the voltage received by other customers and the use of special connection rules to avoid the engineering work required for this evaluation. This divergence of approach was reflected in the answers to the CIRED questionnaire.

4) Effect of dispersed generation on system security

Three questions were asked concerning the impact of dispersed generation on system security.

Q7) At present do the utilities in your country consider that dispersed generation makes any contribution to system security?

Q8) Do you foresee any mechanism or arrangements for dispersed generation to be able to contribute to system security in the future?

Q9) Do electrical power utilities in your country consider installing dispersed generation when planning to supply new loads or reinforce the network?

Questions 7 and 8 were deliberately wide ranging and not prescriptive in terms of generation, transmission or distribution systems. However, the answers were generally clear that dispersed generation does not make any contribution to system security at present and even has a negative effect. Some countries recognised that this situation was not sustainable in the longer term as the penetration of dispersed generation increased. Question 9 concerned the use of dispersed generation to reinforce the distribution network and this was not seen as an attractive option by the respondents.

5) <u>Reactive power output and voltage control</u>

Q10) What are the requirements for controlling the reactive power output or busbar voltage of dispersed generation? Is there a particular power level at which a voltage regulator scheme is required?

The answer to this question revealed considerable diversity. Many utilities placed some sort of requirement on the reactive power capability of (large) dispersed synchronous generators and some specified an operating requirement in terms of power factor or VAr flow. There was little evidence of the integration of dispersed generation in voltage control of distribution networks. The detail of the answers provided in response to this question showed that it is an area of some concern but the approaches adopted appear to be quite disparate,

6) <u>Commercial issues</u>

Two questions were asked on commercial issues.

Q12) What arrangements are made for the change in distribution network losses caused by dispersed generation?
Q20) How is the output of dispersed generation sold?

The issue of changes in network losses caused by dispersed generation was clearly not of great importance in most countries. This may change if distribution companies are separated into energy suppliers and network operators. The various ways in which the electrical energy output of dispersed generation is sold also reflected the different commercial arrangements and structure of the electricity supply industry in the various countries. Most renewable energy schemes receive government support and their energy is purchased at a premium price at the point of connection with the local distribution utility.

7) <u>Power Quality</u>

Q13) Are generators treated in the same way as loads in terms of power quality issues e.g. harmonics, unbalance, sags etc.?

There was clear agreement that dispersed generation was treated in the same way as customer loads with respect to power quality.

8) <u>Protection</u>

Four questions were asked with respect to electrical protection of dispersed generators. This reflects the continuing importance of this area.

Q14) Do the distribution utilities in your country specify or provide guidelines for any particular form of generator protection? Is the generator protection too sensitive and subject to nuisance tripping?

Q15) What interface protection is required in order to protect the distribution network and other customers from the generator?

Q16) Is specific loss-of-mains protection required? Is auto-reclose of circuit breakers used on the distribution networks to which dispersed generation is connected?

Q17) Do you consider that the presently available loss-of-mains relays are satisfactory*?*

There was a clear consensus that the generator protection was the responsibility of the generator operator. As most dispersed generators do not contribute to system security this approach would appear to be entirely reasonable.

There was a degree of consensus in the main types of interface protection required but considerable differences in practice, particularly for the detection of loss-of-mains. The Danish experience

of positive sequence undervoltage relays appeared to be very good while other countries (e.g. Spain and Australia) used transfer trip schemes. Some countries have special rules for small PV inverters.

Most countries used auto-reclose on distribution circuits and so sensitive and fast-acting loss-of-mains protection was required. The main exception was the Netherlands where most distribution circuits are underground and auto-reclose is not used. There was considerable experience of nuisance tripping with df/dt and vector shift loss-of-mains relays and present designs were not considered to be satisfactory.

9) Isolation

Q18) What procedures and equipment is required to isolate a dispersed generator for work on the network?

There was general agreement that a disconnect switch accessible to distribution utility staff was required although it was recognised that this presented problems for small (< 5 kVA) generators.

10) Dispatch and central control of dispersed generation

Q19) What level of generation is despatched? What information is exchanged between the generator operator and network operator?

The answers to this question indicted considerable diversity. Practice varied from central or regional despatch, to notifying the utility of a power production plan some days or a week ahead, to completely independent operation. Generally larger dispersed generators were obliged to inform the system operator of their production plans in advance.

11) Short circuit calculations

Two questions were asked

Q21) What calculation techniques/standards do you apply to calculate plant short circuit ratings for circuits containing dispersed generation? Is there any special attention paid to the out-of-phase switching capability of existing circuit breakers?

Q22) Is special attention paid to unusual switching conditions caused by dispersed generation?

There was a fairly clear consensus that fault level calculations were based on IEC 909 although other simulation type approaches were also used. In general, no particular precautions were considered necessary for unusual switching conditions on the distribution network caused by dispersed generation.

12) Conclusions and suggestions for further work

The survey showed very considerable diversity in the reasons for, and extent of, dispersed generation in different countries. The data which has been obtained describing the proportion of dispersed generation in power systems is unlikely to be entirely reliable as agreement with other sources of data is not good. Given that the pressure for the connection of increasing amounts of dispersed generation is likely to continue, it would seem useful to try to establish with greater confidence the levels of dispersed generation presently operating in various countries.

There was generally good agreement concerning the important technical issues of connecting and operating dispersed generation on distribution systems. However, practice varies with the extent of engineering studies which are undertaken before the point of connection is agreed. There would appear to be a requirement for improved computer based tools so that comprehensive studies may be undertaken at reasonable cost to determine the connection point of dispersed generators.

At present dispersed generators make no contribution to system security and may even degrade it. Doubts were expressed as to whether this situation was sustainable with increased penetrations of dispersed generation. Dispersed generators are not considered by the distribution utilities as an alternative to network reinforcement. In general dispersed generation was not despatched although larger units informed the system operator of their production plans in advance.

Reactive power and voltage control has clearly been considered carefully by most distribution system operators but the requirements placed on the dispersed generators vary quite widely. There would appear to be a useful further investigation to find out more details of the practices adopted and to document the best practice.

The commercial impact of dispersed generation on distribution network losses is not yet a significant issue in most counties. Similarly the electrical output of most dispersed generation is purchased by the local distribution utility. There may be increased interest in this topic if distribution companies are split into network operators and energy suppliers.

The effect of dispersed generation on power quality is considered in the same way as a large load.
The main issue of electrical protection remains effective and reliable loss-of-mains protection. This problem is clearly not resolved and more work is needed either to decide that sensitive loss-of-mains protection is not desirable or to develop suitable equipment.

Short-circuit calculations were generally carried out to IEC 909 and no particular attention was paid to unusual switching condition caused by dispersed generation.

A final conclusions might be that, generally, dispersed generation is not, at present, well integrated with the distribution system. This would seem a desirable long term objective as, if present trends continue, more and more dispersed generation will apply to be connected and only by effective integration will a minimum cost electricity distribution network be achieved.