THE ELECTRICAL DISTRIBUTION OWNER AND DISPERSED GENERATION

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SUMMARY

This study represents a compilation of the knowledge and experience of how distributed power generation (DP) affects the quality of the electricity in the networks. The report also deals with operating matters linked to the fact that the number of small generation sources in the distribution networks is increasing. It also sheds light on matters such as load control, installation of DP plant instead of expanding the network.

1 Quality of electricity distributed power generation

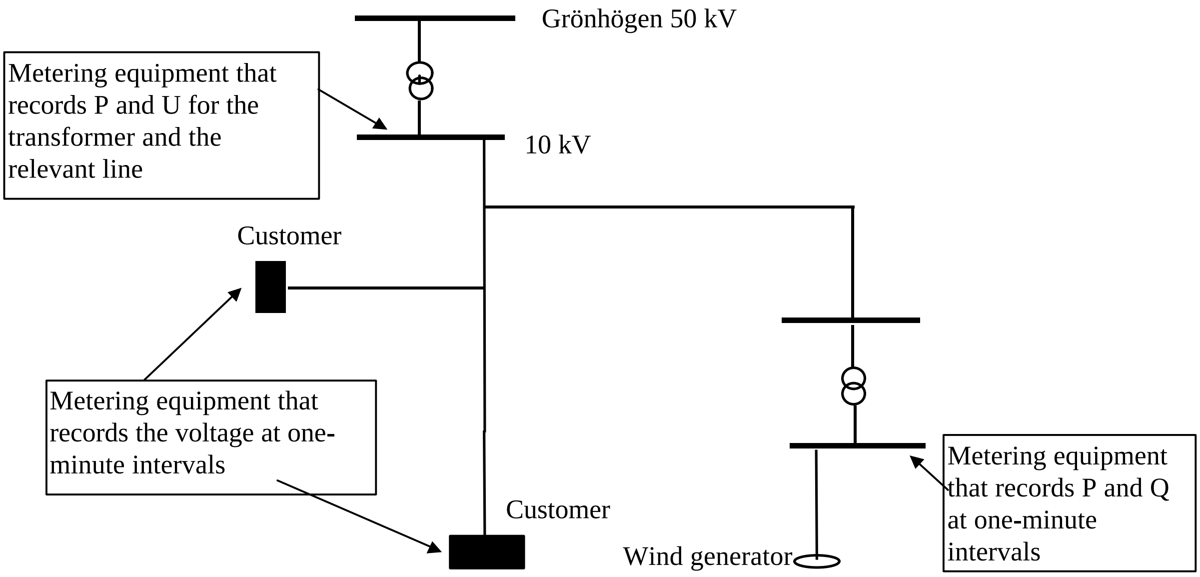
1. 1 Wind power on southern öland

Nine wind generators of Västas type (225 kW) were running in the Grönhögen distribution network on the island of Öland on the occasion when measurements were taken.

The distribution network is of a rural nature, with a short-circuit power of 27 MVA on the 10 kV busbars (normal connection). The load on the network is 2.3 MW at high load and 1.1 MW at low load.

The nine wind generators are arranged in two groups, one of which comprises three wind generators and the other six. Each group is connected to its own transformer station (0.4/10 kV), which means that no consideration need be given to the voltage quality on the 0.4 kV side, although it must be taken into account on the high-voltage side (10 kV). The DAMP report of the Association of Swedish Electric Utilities was basically used for sizing the cables and rating the transformers for connecting the units.

Measurements were taken during two separate weeks, one of which was in April and the other in June, in order to obtain readings at different loads in the network. The measurements show wide voltage variations (207 - 244 V) at customers far out in the network. In all probability, these variations are dependent on the customer's consumption pattern and his location in the network.



In extreme cases, the wind power generated could be up to twice the load on the network. In spite of this, no major voltage variations were recorded. Measurements were therefore taken in order to determine in detail whether any voltage variations occurred under different load conditions.

On the other hand, no relationship could be established between wind power generation in the network and the voltage variations at the customers.

A strong contributory reason for no relationship being discernible between voltage variations and wind power generation is probably because the wind generators are located close to the feed point, i.e. the distribution station. If the same wind generator were connected further out in the network, the effects would presumably have been greater.

The results of the summer and winter measurements vary widely in the voltage at the customers, although the variations in the winter were low. No relationship between wind power generation and voltage variations at the customers is detectable, even though the total load in June was only 65% of the load in April. It was even found that, during certain periods, wind power generation accounts for the whole of the power demand of the network, without any major voltage swings being noted.

We can thus ultimately state that these measurements do not reveal any relationship between wind power generation and voltage fluctuations at the customers. Not even during summer measurements at low load in the network can any such relationship be observed. The fact that the voltage is not significantly affected by the wind generators is probably due to the following:

- The relevant rating and project design rules were followed.
- The wind generators are connected to their own 0.4/10 kV transformer stations.
- The wind generators are located close to the feed point (50/10 kV).

1.2 Wind power experience from Ystad Energi

The Vattenfall electricity utility has a wind generator in the distribution area of Ystad Energi, the energy utility that serves the region around the town of Ystad. The unit has a rating of 500 kW and runs at variable speed, with active pitch control. The generator is a multi-pole synchronous machine with a large circumference (approx. 5 m diameter) and is direct-driven, without gearbox. When the wind speed increases, the generator speed thus also increases. This naturally leads to current and frequency variations of such magnitude that the generator cannot supply the network directly. This problem has been solved by employing a frequency converter which ensures that the network is supplied at correct frequency. This type of wind generator is also in operation on the island of Gotland and is of Enercon brand, manufactured in Germany. The electric power generated is supplied to the network via a frequency converter which controls not only the frequency, but also the voltage and the reactive power. Measurements made on the low-voltage side (400 V) show that the voltage does not vary by more than + 1V, which must be regarded as very good. According to Ystad Energi, the content and magnitude of harmonics are also within reasonable limits. No formal report has been prepared on the measurements taken.

Plans are currently afoot for installing five new wind generators (500 kW each) in the Ystad distribution region. These would then be sited at the extremity of the distribution region. Since the conductors are slender and the electricity consumption in this region is low, the network must be strengthened up to the nearest receiving station (50/10 kV). The cost of this network reinforcement and new switchgear is estimated to be SEK 5.5 million. This example is probably not unusual. Wind generators are often sited out in rural areas, in places where the wind conditions are good. These areas are often characterized by being sparsely populated, with low electricity consumption and thus a weak network.

As a result, it would probably be unusual if wind generating plant could replace reinforcement of the network. On the contrary, the networks would have to be reinforced to enable energy to be transmitted onwards.

Wind power has also faced some resistance. Local organizations that are actively involved in environmental conservation consider that areas of natural beauty are spoiled by the establishment of wind generators. County councils monitor such areas of cultural interest and therefore oppose siting in areas that fall into this definition. The armed forces have also expressed views.

1.3 Experience from Gotland Energi

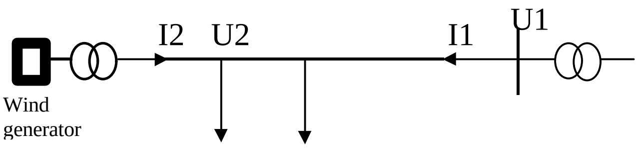
General:
The electricity network and electricity generation on the island of Gotland are special in their nature. Gotland is supplied from the mainland by a DC link capable of transmitting 250 - 320 MW, depending on the outdoor temperature. The generation capacity on the island consists of gas turbo-generators and wind generators.

Slite	2x60 MW	Gas turbines
Hultungs	10 MW	Gas turbines
Roma	10 MW	Gas turbines
Visby	10 MW	Gas turbines
Hemse	10 MW	Gas turbines

The total wind generation capacity amounts to around 40 MW (70 GWh/year) and consists of several different types and sizes of wind generators. Around 30 MW are generated in Näs and surroundings, and the remaining 10 MW are scattered around the island. Three synchronous condensers (2 x 75 + 30 MVAr) are used for power factor correction, together with a 50 MVAr capacitor bank.

Voltage variations, flicker
A great deal of time has been devoted at Gotland Energi (the utility serving the island of Gotland) to the study and investigation of how the quality of electricity is affected by wind generators(Ref. 2,3 and 4). The utility has also developed its own calculation routines for use when new wind generators are connected.

In the formulas derived, consideration is also given to the fact that the voltage U2 constantly varies and changes in angle to I1, which is the reference direction.



The reason for this is that the current changes, since power is tapped from the line to supply different loads. Consideration is thus given to both loads and voltage drops along the line.

The formulas developed (not presented in this report) are used to convert the various voltage drops in the sections to obtain a resistive part and an inductive part. These are then added so that the voltage drop per section can be calculated. Calculations were made, including those for a new plant to be built, in which a number of scenarios were calculated. In one of the calculations, it was found that the voltage at the wind generator plant was around 11.6 kV and then dropped to 10.8 kV at the transformer station (U1). In this calculation, the wind power generated was assumed to be 1.72 MW.

On a comparison with DAMP, which specifies that the voltage must be between 207 and 244 V, Gotlands Energi does not use this interval as a point of departure. The above calculations are used instead for checking that an excessively high voltage will not occur at any point. On the other hand, it is obviously important to ensure that the voltage supplied to all customers is within the specified range.

It was also found that the DAMP recommendation of Sk/Pv = 20 times is not always relevant.

Calculations were done for a 10 kV line with a shortcircuit power of 10 MVA and an installed wind power rating of 1 MW (Sk/Pv = 10). These calculations show that the specified electricity quality requirements are met.

According to Gotlands Energi, the most critical criterion for the connection of a wind generator has been the rapid voltage variations (0.5 - 2.0 V measured at 230 V). The voltage variations originate from power oscillations of the power plants that are speed-dependent.

Measurements have shown that conditions are often at the limit of what SS 421 18 11 recommends, which is the standard used as reference. The problem of these voltage variations are best solved by intimate cooperation between the network owner and the wind generator manufacturer.

Due to the special nature of the Gotland network, frequency dips down to 49.5 Hz sometimes occur. This leads to the synchronous speed of the asynchronous generators dropping which, in turn, leads to the working torque moving towards the peak torque. If the peak torque is exceeded, the generator unit will overspeed, and the generator protection will therefore trip for overspeed. This has happened on some occasions on Gotland.

Specification:
Gotlands Energi has drawn up a technical specification to which the wind generators in Näs should conform. The specification applies only to the Näs region. The demands made on wind generators vary depending on where in the network the wind generators are to be sited.

Harmonics	The plant must not generate current harmonics in excess of 2.5% THD.
Capacitor banks	The banks must be provided with filters for the 5th harmonic and must not reduce the ripple control signal by more than 20%. The frequency of the ripple control signal is 175 Hz.
Power variations	The power output must not vary by more than 10% of the connected power, with a frequency of between 0.3 and 5 Hz.
Peak power	The power output must not exceed the agreed connected power (in this case 600 kW) in any one-hour period, and must not exceed this by more than 5% in the mean value of any 15-minute period.
Reactive demand	The plant must not consume more than 130 kVAr (22% of the connected power) and must never generate (capacitive) reactive power based on a 15-minute mean value. The plant must not be selfexciting. The plant shall have reliable detection and shut- down functions, so that it will not be able to run on its own network.
Miscellaneous	DAMP and TAMP shall be employed in relevant parts (including protective functions). We assume that the plant is designed in such a manner that it will conform to the EMC standard as regards immission and emission, other than the above exceptions. We do not guarantee the quality of electricity in accordance with the Swedish standard at the connection point. If demands are made on voltage quality, this shall be specified before the order is placed.

1.4 CHP generating plant in Oskarshamn

Oskarshamn Energi has a combined heat and power (CHP) generating plant with an engine that can be run either on diesel oil or LP gas and that drives a synchronous generator. The generator rating is 7 MW and it is connected to the 10 kV network. Calculations and computer simulation have been undertaken to determine the stability following various short circuits in the network (Ref. 1). The study shows that, in the event of short-circuits in the network, there is risk of the generator slipping out of synchronism. This risk is due to several factors:

- Fault type (three-phase or two-phase short-circuit). Three-phase short circuit is the most difficult case.
- Fault duration (time from the instant that the short circuit occurs until it is isolated). A longer fault duration increases the risk of the generator coming out of synchronism.
- The inertia constant of the unit (the relationship between the kinetic energy stored in the unit at rated speed and the rated power of the generator). This particular unit has a relatively low inertia constant (H = 1.2). This means that the generator is quickly affected by external disturbances.

In order to establish the opportunities available for the generator stability to be maintained in the event of short circuit in the external network, dynamic simulations have been made with three-phase short circuits in the 10 kV network (close to the generator) and in the 50 kV network (close to the 130/50 kV station). The simulations were carried out with varying fault durations. In the event of three-phase short circuit in the 10 kV network close to the generator, instability will occur if the fault duration is longer than 0.14 s. For a corresponding fault in the 50 kV network, the critical fault duration is 0.16 s. In the case of two-phase short circuit, stability is maintained also following longer fault durations. However, simulation shows that short circuits in the 10 kV network would have to be isolated instantaneously in order to guarantee stability. In the case of back-up isolation, longer fault durations cannot be avoided. The risk of the generator coming out of synchronism must therefore be expected.

No recorded measurements have been made of the load variation tolerance of the generator. On the other hand, a visual check of the frequency (frequency meter reading on the control panel) was made on one occasion following a load change from 2 MW to 135 kW. The frequency rose to 52 Hz for about 1.5 s and then reverted to 50 Hz.

It can thus be stated that the short-circuit tolerance (particularly three-phase) with regard to stability is limited. On the other hand, experience gained in Oskarshamn shows that abrupt changes in load affect the frequency only briefly.

2 Operational aspects related to distributed generation in distribution networks

This section discusses on the operational questions that would arise if distributed generation in our distribution network should increase. In a scenario in which the DP content is extensive, the conditions for controlling and supervising the networks will probably change. Light is shed on the following factors:

- Would metering change if both generation and consumption are included in the distribution networks?
- Replacement matters and load rating.
- Operational supervision.
- Voltage control.
- How would the relay systems be affected?
- Responsibility questions in the event of loss of generation capacity.
- Electrical safety.

The network utilities have the best experience of these particular matters, since they face them virtually daily.
The following three utilities that have experience of DP plant operation in their networks were therefore contacted: the Electric Power Plant of Landskrona Municipal, Engineering Department, Gotlands Energi AB and Sydkraft Eldistribution AB.

2.1 General

Questions of an operational nature become more accentuated as the proportion of DP plant in our networks increases. Since the extent of DP plant was initially fairly marginal, the operational requirements previously made on DP plant were not the same as those made on larger power plant. There are naturally several reasons for this:

- In the event of system faults, the small power plants could be isolated without causing any problems.
- It was hardly economically feasible to make the same demands on both small and large power plants.

Existing DP plants have not been adapted for being regulated within our existing electrical systems. The units are not designed to meet the dynamic forces to which they can be subjected from the electrical system. If the proportion of DP units should increase significantly in our networks, the current power plant specification should be revised in order to avoid future problems in the system.
In Denmark, short-circuits in higher voltage networks have led, on a number of occasions, to tripping of several decentralized DP units. It is not unusual for DP units to be tripped within a radius of 30 km from the fault location (Ref. 8). This problem should therefore be borne in mind if the DP capacity is expanded.

How the electrical system will ultimately respond to DP plant naturally depends on the demands we make on the generator units as regards control capabilities, availability and reliability. In the final analysis, these demands are made by the market (the customer) on the basis of the expected reliability of supply.

2.2 Network operation and metering matters

The energy generated is normally metered at the generator units. If the number of DP units is sufficiently large, the situation may arise in which the energy generated exceeds the local consumption in the network. Power and energy will then be transmitted further up into the network. If this situation should arise, two-directional metering should be arranged.

Network owners have so far not found any major need for being able to control or supervise smaller generator units in their distribution networks. However, conditions differ somewhat between rural and urban distribution. As an example, the Landskrona Municipal Engineering Department supervises the operation of its network generators, since signal cables have been run throughout. The additional cost of supervising the generator units is therefore reasonable.

An important aspect is the possibility of isolating groups of generator units in the event of a fault occurring in the network. This is done by means of remotely controlled disconnectors. In the event of a fault, the network can thus be sectionalized and can then be successively switched back in until the fault has been identified.

2.3 Replacement and rating matters

The cost of reinforcing the networks as a result of the generator units being installed must be met by the generating utility. The network utilities that were questioned in this matter do not have exactly the same costing approach, but the differences are merely in detail. The cost is met by a connection charge. The generator must basically reimburse the network owner for any measures that may be necessary on both the 10 kV network and the higher voltage networks. The cost should be based on the minimum amount of work needed, and if any form of extra upgrading is required to meet future needs, the cost is met by the network owner.

Conventional calculation methods and also DAMP and TAMP are used for rating the network. Out of the network utilities contacted, Gotlands Energi differs somewhat, since they have developed their own calculation routines and rating criteria for their networks.

The question of whether the generation utility is to be reimbursed for reduced network losses is not entirely clear. This could normally be regarded as natural, but would it be equally natural for the network owner to receive reimbursement if the opposite situation arose? A wind farm located in an area with low loading would probably cause increased losses in the network. This situation has arisen on Gotland. This question should be investigated further, so that recommendations can be made for how this should be regulated.

As regards scheduled and unscheduled outages in the networks, the network owner should hold himself contractually free from liability to the generation utility. The protection equipment of the generator should ensure that the generator's plant is not damaged in the event of isolation. If disturbances should occur in the network and these are caused by the generator's plant, the latter is responsible for the costs associated with restoration.

For other particulars, reference should be made to the report entitled "New generation utilities with distributed generation systems" (included in project 6045) concerning financial settlement between local generators, network owners and delivery concessionaires.

2.4 Voltage regulation

The Danish DEFU has carried out a simulation (Ref. 9) of how the power generated by a wind farm affects the voltage regulation on a 60/10 kV transformer. A number of different cases were simulated, in which the degree of power factor correction, operating current, etc. were varied.

The simulations demonstrated that a wind farm (without power factor correction) with a total output of up to 6 MW and connected to a 60/10 kV main transformer (10 MVA) gives rise to a maximum of one extra tap changing operation per 10 hours. On an increase in power to 8 MW, the tap changing rate will increase by a maximum of one tap changing per hour. If power factor correction is employed, the calculations show that the tap changing rate will increase by 0.22 per hour at 8 MW.

The study shows that the establishment of a wind farm with power factor correction increases the tap changing rate only marginally. No unacceptable voltage quality was revealed. On the other hand, if power factor correction is not employed and the wind power output amounts 70 - 80% of the transformer rating, the tap changing rate may be unacceptable.

Gotland Energi (GEAB) has noted that voltage regulation has changed fairly markedly since wind power was established on the island. The network utilities contacted did not otherwise have any major voltage regulation problems caused by DP plant.

2.5 Technical requirements

DAMP is usually applied in rating, and a check is simultaneously made to determine whether the transmission capacity is sufficient in the network to accept the power generated in various loading situations.

If the rating requirements of DAMP are not met, the network owner should make special demands such as, for example, the demand on the short-circuit power at the connection point. In some cases, the network owner has included the proviso in the agreement that if the generation utility did not meet the requirements of the technical standards or the electricity industry recommendations specified by the network owner, the latter shall have the right to isolate the power plant from the network until the generation utility has attended to the problems at its own expense, so that the demands are met. Typical demands that can be made, over and above those in DAMP and TAMP, are as follows:

- The power plants shall quickly and reliably be isolated in the event of earth fault or short circuit in the network.
- The power plant must not continue to feed the fault current to a fault in the network, even if one unit in the fault isolation chain should be out of operation.
- Redundant relay protections are required if there is risk that the power plant could conceivably run part of the connected network as an island.
- The power plant shall be capable of being subjected to reclosing or fast automatic reclosing of circuit breakers.

2.6 Fault isolation - relay protections

Our existing electrical networks have been built for a certain direction of energy flow. When DP units are connected to our networks, power may flow in the opposite direction under certain circumstances. The protections in the plants consist largely of different (and old) protection devices. The 10 kV networks normally include overcurrent protections and oriented earth fault protections. In distribution stations, the protections are usually fuse links on the high-voltage side. No studies on the subject had been found, but according to experts in the field, existing relay protections are very unlikely to be disturbed by a reversal in direction of power flow in the networks. At a number of points, GEAB has added oriented overcurrent protections in its network. No problems that are difficult to solve and that could have been caused by DP plant have been identified.

Statistical calculations and dynamic simulations have been performed for 50 and 10 kV networks on the southern part of Öland. These support the contention that the contribution of asynchronous machines to thermal stresses in the event of short circuit can be ignored. On the other hand, it is often assumed that asynchronous machines contribute to the surge current that determines the mechanical strength of the equipment.

2.7 Responsibility and electrical safety matters

An increasingly serious problem to the network owner is that the number of generator plants in the network is increasing. The "larger" power plants, such as hydro and wind power plants, are almost invariably well known and well documented on maps and in diagrams. These plants must normally also be isolated in the event of loss of the supply network. On the other hand, many small generator units are in operation, above all on farms and also in industrial plants, and these are not always known to the network owner. Whenever some form of work is to be done on the network, e.g. on a radial feeder, there is risk of sectionalizing being done only on the supplying power line. If a subscriber connected to an adjacent tapping then starts his local generator unit, the line may be energized, thus placing the network owner's personnel at risk of sustaining injury. Such accidents have unfortunately occurred. Small, portable generator units often employed by farmers must therefore be connected across alternative selector switches which make it impossible to energize theexternal network. However, inspections carried out have revealed that it is fairly common for the installation contractor to connect the alternative selector switch incorrectly, so that both the internal and external networks are energized, and thus also the line on which work is being done.

The network owner should endeavour to make an inventory of all generators and alternative selector switches (since several consumers may employ one unit collectively) and document them on their maps. When work is being done on the networks, isolation and earthing should be carried out in accordance with the Swedish EL-SÄK-FS electrical safety regulations.

3 DP plant as an alternative to network reinforcement

It is always in the interest of the network owner to optimize his plants, which can obviously be done in a variety of ways. As the opportunities for measuring, supervising and controlling the networks are being improved, better scope becomes available for delaying investments which would otherwise have been made in order to be "on the safe side". The traditional measures adopted in distribution plants when increased transmission capacity is needed may consist of:

- Area reinforcement of existing line (overhead line)
- Laying cables in parallel
- Running an entirely new line (cable or overhead line)
- Replacing the transformer
- etc.

The need for generation capacity in Sweden will probably increase in the future in order to make up for the scheduled decommissioning of nuclear power. The cost of electricity will then be higher than it is today, and the benefit of coordination between different investment requirements will be even more pronounced. A typical example is that if small-scale generation capacity is established at a suitable point in the network, the need for network reinforcement may be eliminated or reduced.

According to the directives for this study, a "conversion rate" between distributed generation and new distribution capacity was required. Unfortunately, it would be difficult to generalize the operations in this manner, desirable though it may be. Every measure should (must) be calculated separately. However, it can be established fairly simply that it would generally be more expensive to invest in local generation as an alternative to a new (or reinforced) distribution system. The values stated are based on the 1996 standard cost catalogue of the Swedish electricity utilities, (Ref. 7) in which overhead lines are designed for 24 kV but can naturally also be used for 12 kV. Class A corresponds to running lines within (or to) urban areas in a 24 m wide lane. Class B is a rural network with a lane width of 8 m.

New construction	New construction
Overhead line	Overhead line
Al59 3x157	A159 3x241
class A	class A
SEK 237 000/km	SEK 266 000/km
”	”
FeAl 3x157	FeAl 3x241
class B	class B
SEK 198 000/km	SEK 229 000/km
Cable	Cable
PEX 3x1x150	PEX 3x1x240
12 kV	12 kV
SEK 327 000/km	SEK 371 000/km

Compare the above costs with investments in generation plant:

1.0 MWth, 0.9 MWelec, 4-stroke diesel generator running on natural gas	SEK 6.5 million
5.0 MWth, 2.4 MWelec gas turbine running on natural gas	SEK 14 million
0.5 MW wind generator	SEK 4.5 million

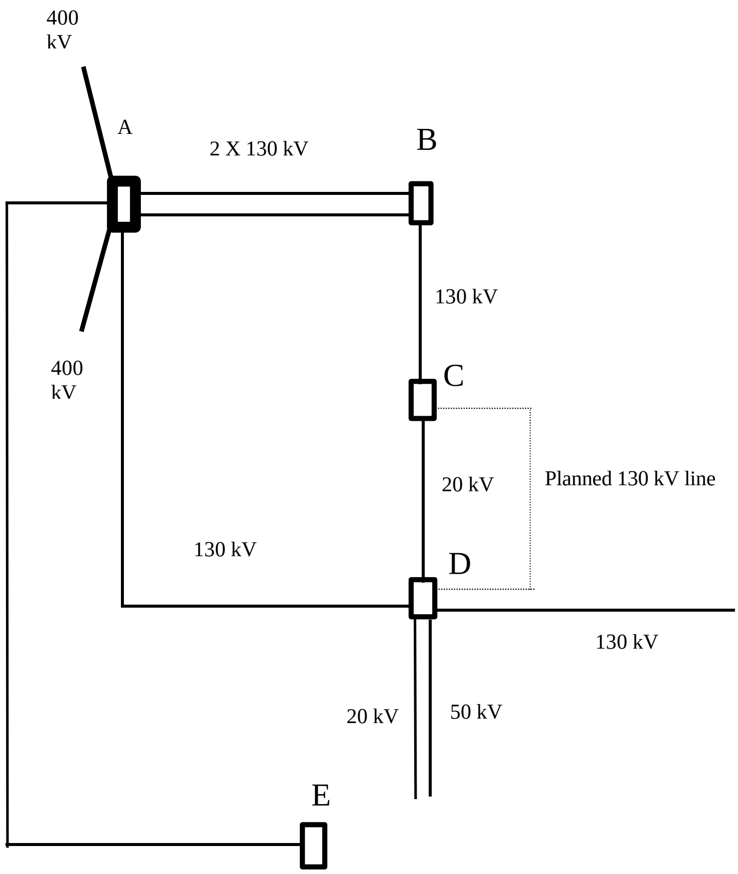
Even if the comparison is not entirely relevant, it is still clear that the distribution network investment costs are lower than the cost of investing in local generation capacity. The cost of running a 30 km long overhead line is the same cost as that of installing a 1.0 MW thermal and 0.9 MW electrical diesel-generator unit. Moreover, the overhead line can carry much more power than 0.9 MW. However, we should bear in mind that the comparison is not entirely fair, since electricity generation has an inherent value, which does not emerge from this comparison.

Distributed generation can often lead to an increased demand for network construction. As an example, wind farms could conceivably be established in places where the network is weak. This creates a need for reinforcing the distribution network for transmitting the electrical energy generated to consumers in more densely populated areas.

Niches in which distributed generation comes into its own as replacement for new distribution networks include industrial plants, islands (such as Gotland) and other major consumer areas that are far from a suitable large transformer station. In such cases, network reinforcements (or new lines) may be expensive to the customer or the plant owner. The alternative is thus local electricity generation which is credited by eliminating the need for network investments, while any surplus that may arise can then be sold back to the electricity supplier. This naturally presupposes that the network can handle the surplus.

A question that remains to be answered is whether and how network pricing is linked to DP. Should consideration be given to DP in the connection charge and in the annual network cost?

An example has been taken from Sydkraft to illustrate the case, although it has been partially modified so that it would be more generally applicable. Double 130 kV lines are run on the same supports between points A and B. Power is supplied to A mainly by two 400 kV lines. A 130 kV line runs between points B and C. An old 20 kV line runs between C and D.



The district, which has an area of around 2500 km2, includes good opportunities for small-scale generation, particularly by wind power.

The main reason for reinforcement is to safeguard the supply to C when line B - C is out of operation. In addition to this, there are three secondary reasons:

- To safeguard the supply to D and the network beyond (to the right).
- Line A - D is regarded as weak. An area E is considered as having a weak supply today and would thereby be provided with an improved supply.
- Further improvement of the supply to B if both the 130 kV lines (on double supports) A - B should trip.

The cost of a new 130 kV line between C and D is estimated to be SEK 13.5 million. As an alternative, we could connect at C a highly reliable generator unit (such as a gas turbine generator) with a short starting time (one minute level) and with a rating of 12 MW. The cost of this alternative is estimated to be SEK 70 million.

Considering only the back-up for the 20 kV line, a low-price alternative would be to run a 20 kV underground Al cable (240 mm2) which can carry 12.7 MVA at 65°C and 15.3 MVA on back-up operation as described in the next paragraph) at a cost of around SEK 7 million.

It is thus clear that the costs of installing additional generation capacity are much higher than those of network construction. Whether it would be advisable to solve the back-up capacity problem by installing wind power is doubtful, due to the unknown availability performance and the costs (probably more than SEK 100 million in the above case).

4 Load control as an alternative to line reinforcement or distributed power generation capacity

The electrical distribution network is planned, rated and built for a long service life (around 40 years). At the planning stage, it is assumed that the network must be capable of transmitting peak loads and providing a certain back-up operation capacity (as described below). However, the load profile may change in time, so that it will not be possible handle all operating cases without the network being overloaded. Upgrading measures designed for dealing with such cases are often costly, while the need for backup operation, for example, is rare.

Load control is an alternative to traditional reinforcement measures. The purpose of load control is to provide the means, at relatively low investment cost, for handling fault situations with existing cabling, thereby increasing the capacity utilization of the network. The possibility of assessing the capability for carrying additional loads is usually restricted to using the annual energy consumptions of connected customers and their simultaneity factors as a basis for a load assessment. Since the actual power demand is the design parameter, the result produced by methods based on annual energy consumption is uncertain, and a relatively wide margin of safety must therefore be allowed. Very frequently, the result of the assessment will be that network reinforcements are necessary. This may lead to radical impairment of profitability.

Successful load control measures can thus be highly valuable per kW of controllable power, since the alternative would represent the cost network reinforcements. Load control can be achieved by supervising the "bottleneck sectors" in the network and linking the supervision to automatic selective switching in and out of customer loads. This function can also be used for the restoration of local networks.

The introduction of load control based on local criteria also provides entirely new means for additional sales, since customers can be offered electricity deliveries, the availability of which is controlled by the combination of generation capacity and local transmission capacity in a totally different way than it has been in the past.

It is very difficult to make any general usefulness estimates of load control or "bottleneck sectors", since each case must be calculated individually. But if we were to try to create a typical case, we could consider reinforcement measures corresponding to an investment of SEK 800 000. If modern information technology is used instead for load control, two-thirds of this expenditure could be delayed by five years, while the remaining one-third of the investment would be rendered unnecessary. With a real estimating rate of interest, a present-day value of SEK 352 000 would be obtained for load control, instead of SEK 800 000. In this particular case, load control would clearly have been profitable.

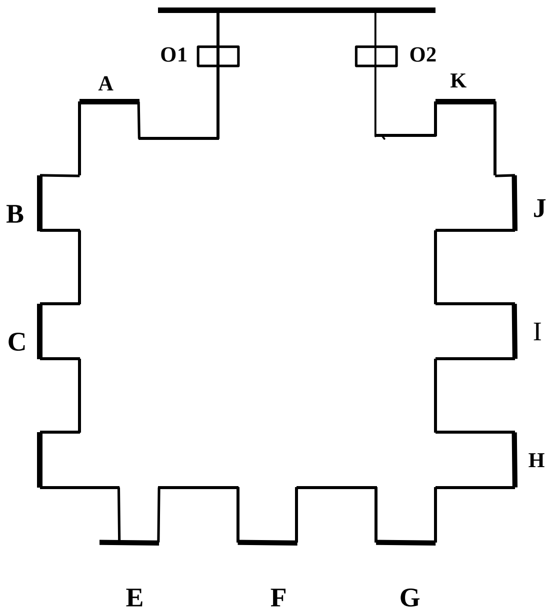
4.1 Pilot case

For a number of years, Sydkraft has been running a development project (known as the IDA project) which included field trials in which the possibilities offered by load control were studied.

In this project, modern IT is used for communicating on the existing electrical network. GSM techniques can be used, for example, between network stations and distribution stations.

The network studied is shown in the figure below, in which a distribution station supplies a number of network stations in a 10 kV loop. In normal operation, the loop is open at one point. Power is thus supplied from two directions (O1 and O2). In the event of a fault in the loop close to the distribution station, it must be possible to supply the loop from only one direction (back-up operation).

Distribution station



On back-up operation, several sections will be overloaded, although the highest overload will occur in the cable section between stations B and C. The cable on this section will be overloaded by around 40% on back-up operation. A conventional measure designed to avoid overloading of the relevant cable sections on back-up operation is to bury a cable (700 m AXCE 3x1x240) between B and H. The cost of this work amounts to SEK 560 000.

Load control could be applied as an alternative. To achieve sufficient power reduction, the following loads would be shed:

2 large electric boilers
22 water heaters in private houses
9 direct electric heating systems in private houses
11 electric boilers in private houses
14 electric immersion heaters in private houses
2 make-up electric water heaters in private houses
6 make-up electric water heaters in apartment blocks

The total load that can thus be shed (disregarding simultaneity) amounts to around 950 kW. This involves an investment cost of around SEK 350 000, and the annual operating and maintenance costs will be SEK 30 000.

Converted to present-day value at an estimating interest rate of 8% and a 10-year estimating period, the sum is around SEK 550 000. The two alternatives are thus equivalent. However, it should be borne in mind that the costs of the new technique will probably drop radically in the future.

5 References

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