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TECHNICAL SWOT ANALYSIS OF DECENTRALISED PRODUCTION FOR LOW VOLTAGE GRIDS IN FLANDERS

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ABSTRACT: The increasing energy prices, combined with high funding by the government, has resulted in a massive integration of decentralised electrical energy production units in Belgium. These systems are mainly PhotoVoltaic systems and the sudden increase of both number and power ratio of the DG systems has put additional stress on the distribution network. In this paper a technical SWOT analysis is presented. The researchers believe that the solution to decompress the stress can result in additional benefits for both, end user and distribution network operators.

INTRODUCTION

Belgium has no own resources to primary energy sources such as oil, coal, gas or uranium. Furthermore there is absence of large height differences which prohibits hydro energy. Uranium has proven to be the most energy-dense material and this has resulted in the fact that more than 55% of Belgium's electrical energy consumption today originates from two centralised nuclear power plants [13]. On the other hand, Belgium has a very high density of population in urban areas, and some more rural areas with a reduced population density. This has also influenced the physical construction of the electrical transmission and distribution grid [14].

As global warming is being felt globally, this has resulted in an increased environmental awareness and in a desire to reduce the consumption of natural resources such as oil and gas. Due to recent tragic events in Japan, public opinion is enforcing the nuclear phase out. Renewable energy systems are believed to answer to these problems, without decreasing the quality and quantity of electrical energy. Solar Power has been heavily promoted in the E.U., especially in the Flemish region. As a result there has been an exponential growth in PV systems [5].

If the nuclear phase out is indeed enforced and a high focus is placed in renewable energy sources, the volatile nature of production of these sources could endanger both quality and stability of the distribution grid [13]. Smart Grids have a high level of automation which would result in a very dynamic electrical grid. It is believed that this high integration of automation will result in a stable dynamic grid, with reduced energy losses. Although this can be an answer to the majority of the problems, this hypothetical grid is still in an experimental stage.

In this paper SWOT analysis is presented for a short timeframe of ≤ 10 years for decentralised electric power generation (DG) in the L.V. distribution grid, resulting in some technical feasible solutions for maintaining the supply quality and reduce the stress on the distribution grid. It is imperative to stress that neither a detailed economic analysis is given within this paper nor are smart grids regarded as a solution to the problems. Possible solutions are presented with currently commercial available products.

SWOT ANALYSIS

Strength

The physical strength of the current Medium Voltage grid is namely determined by the short circuit power. For strong power grids, the short circuit power is >500MVA. For “weak” grids the short circuit power is still >180MVA [1]. If production is tightly matched to loading, these loads will not significantly influence the voltage and frequency. Not only the short circuit power is determining the stability of the grid, for sudden load changes, the grid will dynamically react to this.

Mechanical inertia is imperative to maintain transient stability. As a lot of generation is still done with mechanical generators, mostly synchronous machines, and the grid consists of a lot of direct online machines, the rotating inertia results in sufficient transient stability. Complementary to the physical strength of the distribution grid, a large amount of reference have been established to ensure stability in distribution grids such as the C10-11 [5] and the EN50160 [4].

Weakness

Both over- and underproduction of electrical power can result in a reduced quality/quantity of power. Mainly the volatile nature of decentralised production, combined with the fact that the coincidence of production is equal to 1, will result in a overvoltage in case of overproduction [1]. As Flanders has two types of grids, rural and urban grids, the hosting capacity will be different for these two types of grids. The voltage at the end of the feeder is mainly determined by the cable resistance. For urban grids the feeder is often a EAXVB 4X150mm², for a more rural feeder often a BXB 3x95+54.6mm² is used. The reduction of the neutral conductor section has a significant influence on the overall hosting capacity. A detailed analysis is presented in [1].

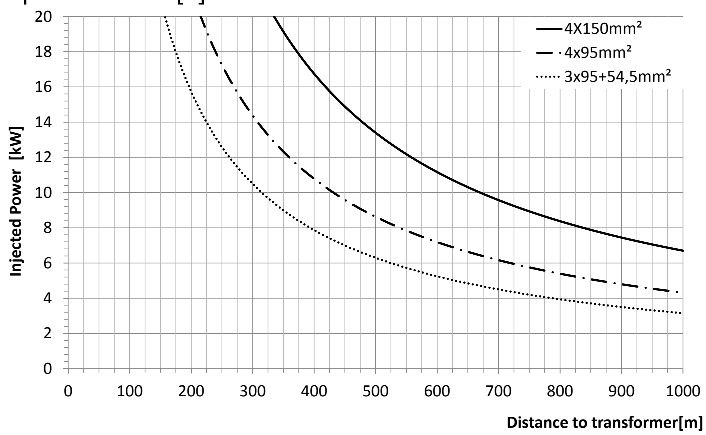

Figure 1: hosting capacity for 10% over voltage limit for different grid types.

This overvoltage problem can be eliminated by decreasing the amount of injected power, reactive power compensation or changing the voltage at the transformer [3]. In [2] it is elucidated that a battery buffer is the most economical and technical feasible possibility to reduce local overvoltages at Point of Connection (POC).

With the exponential growth of PV systems, the follow up to the actual integration of these generators has been of lesser concern. This has resulted in an uncoordinated approach which can result to a high voltage unbalance. However, studies indicate that appropriate balancing of the sources on the individual phases can result in a decrease of the voltage unbalance and the resulting overvoltage [1]. Recent adjustments to the C10-11 have been adopted that require a three phase connection for PV installations with a power rating of >5kW.

In case of under production congestion management is being proposed. When congestion management is implemented this results in switching of less power critical grids, in order to maintain overall grid stability. Although from a technical point of view this is a good option, public opinion is against this solution as residential grids will be the first to be switched off. In a survey of the regulator VREG 70% of the population is opposed to congestion management, even if there are financial benefits [6].

Opportunities

If the integration of the Smart Meter is to become a fact, this could also be the ideal moment to correctly balance the houses among the three phases. This simple and low cost effort, if practical applicable, could lead to a significant decrease of voltage unbalance and the resulting overvoltage problems.

If the supply continuity is to be questioned, due to the stress on the distribution feeder (overvoltage or unbalance problems), lack of power (eg. nuclear phase out) or intentioned disconnection (congestion management [6]) the mentioned battery buffer in [2] could be used as a backup supply system. Note that in this case the solar inverter/battery combination is used as a Uninterruptable Power Supply.

A survey was performed to both technical as non-technical individuals in which the interest was poled. Both questions and the results are listed in *Figure 2, Figure 3 and Figure 4.*

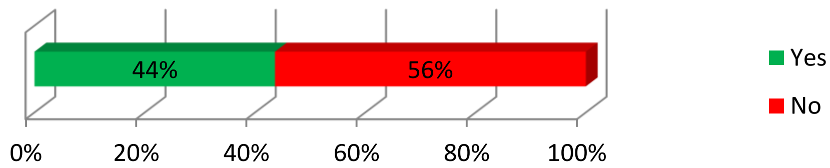

Figure 2: Results to "Do you have solar panels?"

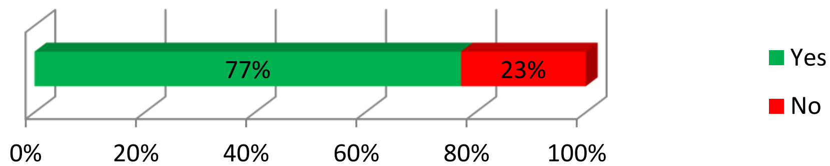

Figure 3:Results to " Suppose you have solar panels, would you be interested in a small additional cost (<500€) which would enable you to have power, even if the distribution grid fails?".

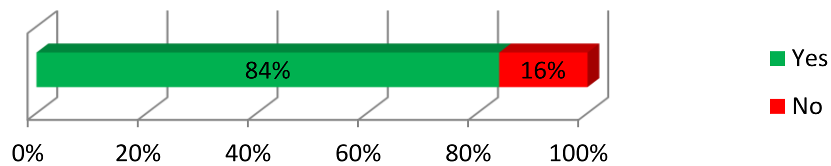

Figure 4: Percentage of PV installation owners who are interested in ride through capabilities.

From this survey it is noticed that 84% of the owners of PV installations is open to a small investment if this would guarantee power at end user. Specific for the Flemish region this implies that with a current 180331 installed units, this results in a capacity of 151478 units which could be used to both control the power injection and as a result decompress the grid as guarantee power at end user in case of a power failure. The technical feasibility is presented in the latter.

Threats

From a technical point of view, decentralised production has little to no threats. However, from an economical perspective several threats can result in a reduced implementation of DG. The large financial funding of the government has ceased, as a result in the first quarter of 2012 the PV market has collapsed. Due to the massive production of PV panels, and the resulting large over-stock, prices for PV installations have dropped from a €2.27/Wp in the second quarter of 2011 to €1.7/Wp in the first quarter of 2012. Legislation also poses a threat and should be revised for further integration to allow technical solutions to the problems of DG. First steps have been made to change legislation to create a stabile grid (amendment to the DIN VDE 0126-1-1), although further steps are needed. Although these aspects are of interest, this paper focuses on the technical aspects of decentralised production.

One of the motivators for DG was the forecast of implementation of Electrical Vehicles (EVH). The EVH could be charged with the DG and the battery buffer could be used for auxiliary services. Although again of interest, the economical disadvantages of EVH, and mainly the large cost of the batteries, has resulted in the temporary abortion of production of EVH's of several automotive constructors [12].

As a lot of machines are retrofitted with a power electronic drive, and wind/PV generators are generally coupled to the grid with power electronic inverters. The mechanical inertia in the grid reduces drastically, and if centralised production is replaced with a large amount of electronically controlled DG, this will result in a reduced transient stability.

TECHNICAL FEASABILITY

As pointed out in the section “Opportunities” the concern of supply continuity has resulted in a new market in which a lot of potential is present for DG which is able to work both connected and disconnected of the distribution grid. In the latter the technical feasibility is presented.

Hardware integration

From a technical point of view the use of battery systems has been extensively researched. Uninterruptible Power Supplies (UPS) have been around for quite a while. These systems have all the possibilities that are required for both grid connection/island operation and it also possesses synchronisation possibilities. Therefore this research will start from the proven UPS technologies. When UPS systems are evaluated three types of UPS systems are distinguished according to the IEC 62040-3 [*Figure 5, Figure 6, Figure 7*].

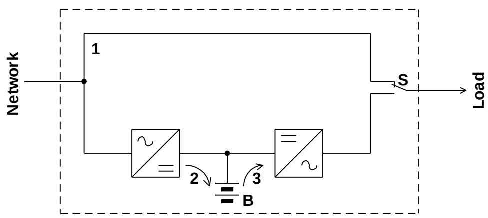

Figure 5: passive standby UPS

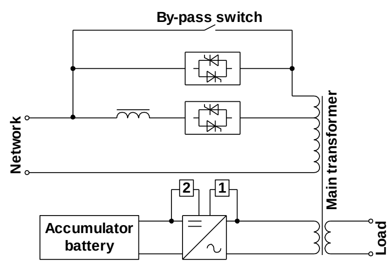

Figure 6: line interactive UPS

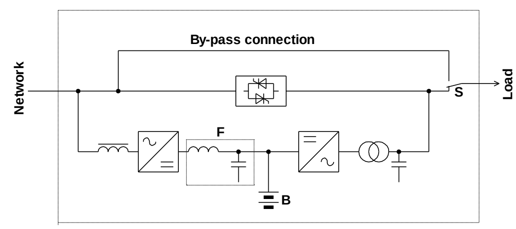

Figure 7: double conversion UPS

From a technical point of view a “line interactive UPS” topology as presented in *Figure 2* seems ideal for integration of decentralised production in UPS topologies. As most of the residential connections are single phase connections, only two legs of a three leg IGBT bridge have to be used. The other two IGBT’s can be used as boost converters for the batteries and PV modules [9]. The passive standby UPS system and the double conversion system are not considered because there is no need for a rectifier, these systems also have a reduced efficiency and a higher initial investment cost.

In case of absence of power from the distribution grid, the Power Triac disconnects the mains and the inverter is used as a back-up power supply. The use of the transformer has several advantages. First of all it inhibits the reduction of the DC inverter voltage and the presence of a large inductance results in a good damping of the harmonic voltage components at modulation index. Additionally this also gives a possible earth connection point, which is desirable for implementing a residual current protection.

Control loops

If inverters are designed to be suitable for both island as grid connected operation, this inverter should be equipped with additional control loops. When the inverter is grid connected, a PLL algorithm is implemented in order to synchronize the injected current with the present grid voltage [10] [11]. Current inverters only inject active power in the power grid. However, if the inverter disconnects from the grid, an algorithm should be developed for island operation. This algorithm should be able to also deliver reactive power as the grid is unable to deliver reactive power.

Besides both island and grid operation and supply of reactive power, this system has to be able to resynchronize with the grid once the grid is present. All these control loops are already present in current UPS systems. If the inverter is fitted with these control loops additional control loops can be integrated.

Reactive power compensation (both fundamental or higher harmonic power) could be delivered by the inverter, reducing stress to the distribution grid. It has also been stated in Section “Weakness”. Research has been performed to additionally control power electronic inverter to simulate rotating inertia [6] [8] [10]. If innovative inverters are implemented these additional control loops can support grid continuity.

CONCLUSIONS

In this paper a SWOT analysis is presented for DG in LV distribution grids in Flanders. In this SWOT analysis it is assumed that the integration of the “Smart Grid” will be slower than the nuclear phase out. As nuclear energy is very important in the overall electrical production of Belgium, 35% of the installed production capacity and 55% of the consumption, this can give rise to substantial shortages of power. However, these problems could actually introduce innovative inverters who combine both grid connected operation as island mode. A survey has indeed indicated that there is a market for these types of inverters.

When these innovative inverters are used, they can also be used for additional services to the distribution grid. As a result there are mutual benefits for both the distribution network operator, as for the end user. For the end users there is in increase in power delivery continuity and for distribution network operators these inverters can be used for reactive power compensation (both fundamental as harmonic) and increasing stability by programming inertia.

In this paper a SWOT analysis has resulted in some specific and concrete benefits for future power inverters. These inverters are not yet commercially available and grid interaction should be tested both on a simulated basis as should these solutions be evaluated by practical measurement. At this moment a real life distribution feeder of 1km is being installed, which will consist of 18 individual nodes each representing a residential connection. This flexible programmable distribution grid, in combination with a 240kVA programmable power supply and a programmable inverter, are to be used for practical validation. This test grid has numerous possibilities such as testing of smart meters, research on interaction of DP in the grid, research on power quality, communication (Ethernet, PLC, …), …

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