OPERATIONAL BEHAVIOUR OF ELECTRICAL EQUIPMENT IN ISLANDED LOW VOLTAGE GRIDS CONCERNING SAFTETY ISSUES

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ABSTRACT

The supply with electrical energy in low and medium voltage grids is entering a period of significant renewal and requires a technological change due to the increased integration of distributed low and medium power generation equipment. In those future oriented grids – smart grids, micro grids or isolated (islanded) grids – the guarantee of personal safety is of great interest because of the reduced short circuit power supply of most of the decentralised generators. So analysis regarding the grid system and the associated protection measures by means of analytical investigations, simulations, test set-ups under controlled lab conditions and field tests are necessary to evaluate the safety performance of those grids.
In case of parallel supply (distribution grid and decentralised source) a line-to-earth fault does not influence the reliable and secure operation of the protection device. In an islanded grid configuration (supply only by decentralised sources) the sufficient short circuit power and the neutral point treatment of the decentralised source becomes more important. In case of a missing neutral point to earth connection the common protection measures may not react sufficiently and the personal safety cannot be maintained.

INTRODUCTION

With the increasing number of several kinds of decentralised generation systems islanding grid configurations become possible and along with the growing number of distributed generation facilities questions regarding the personal safety in islanded low voltage grid structures are important. Depending on the neutral point treatment the specified grid structure (TT, TN, IT-system) can change to a different kind of system in case of islanding and requires either the change of the used protection measure or additional protection measures.
The treatment of the neutral point connection is determining the used protection measure and in future the operator of the decentralised generator will possibly be responsible for the neutral point treatment to maintain the personal safety requirements in islanded grids. The following paper address the new challenges for the future power supply and shows the importance of the neutral point treatment in case of islanded grid structures.

SMART SYSTEM / MICRO GRID / ISOLATED GRID

In the international context different definitions about a smart system, smart building, micro grid, isolated grid and smart grid are used. In the following the keywords for a possible future power supply from the point of view of the authors are defined - see Fig. 1.

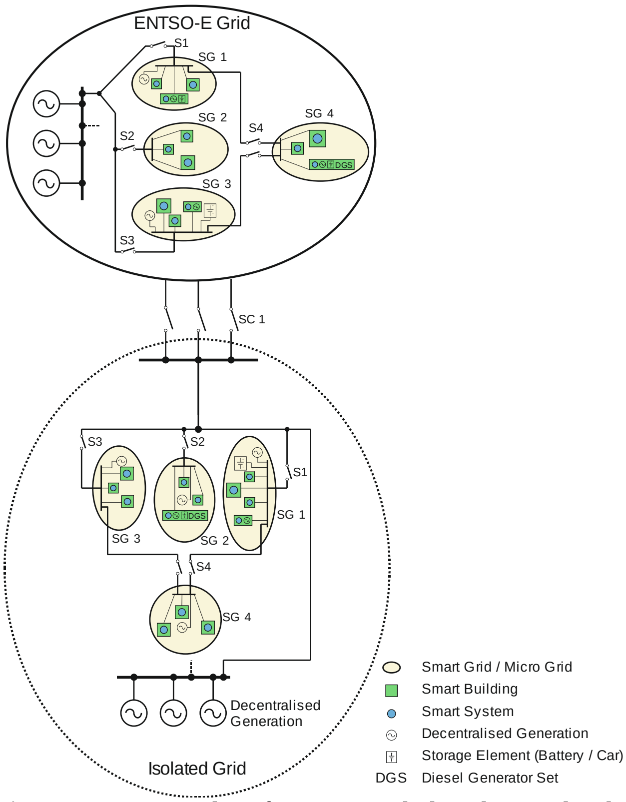

Figure 1: Future grid configuration including decentralised generation, diesel generator sets and storage units

Smart System

A smart system is characterized by an optimized electrical installation (including generation) and automation system inside a smart building. The smart system includes energy-, load-, process- and cost management and smart meters as well as visualisation units for an optimized load management are part of future oriented smart systems.

Smart Building

A smart building is characterized by the fact that most of the own energy consumption (electrical and thermal) is produced with decentralised generation units (e.g. photovoltaics, stirling engines, CHP, thermal solar cells, batteries, cars, diesel generator sets, thermal storage equipment, ...). Intelligent load control units (smart systems) as part of the building enable an optimal and efficient use of energy. A smart building - including a smart system - is the smallest unit of a smart grid which means that several smart buildings can be added to a smart grid and under special circumstances they can act as a micro grid [1].

Micro Grid

A micro grid is a restricted and decentralised supplied grid structure which is connected in the normal operation mode through defined interfaces to the public power supply [1], [2]. In case of a fault in the upstream distribution grid the micro grid is able to be self-supplied through decentralised energy sources and is operated as an islanded grid.

Isolated Grid

Under certain conditions parts of the low voltage grid can be operated independently from the public power supply (distribution grid) as an isolated grid. In case of a power outage from the public power supply isolated grids enable the maintenance of autonomous islands.

All these listed grid structures require analysis to guarantee the personal safety in case of decentralised power generation.

Smart Grid

The following definition is based on the definition originated in [3]:

A Smart Grid is an electricity network that can intelligently integrate the actions of interconnected user - generators, consumers and those that do both - in order to deliver efficient, sustainable, economic and secure electricity supplies.

A Smart Grid combines innovative products and services with intelligent monitoring, energy management, control, communication and self-healing technologies. It

- facilitates connection and operation of generators of all sizes and technologies;
- allows consumers to play a part in optimizing the operation of the energy system;
- provides consumers more information
- provides the consumer the choice of supply;
- reduces the environmental impact of the whole electricity supply system significantly by using locally available regenerative energies;
- delivers enhanced reliability and security of supply.

The deployment of Smart Grids contains not only technology, market and commercial considerations, environmental impact, regulatory framework, standardization usage, ICT (Information & Communication Technology) and migration strategy but also societal requirements and governmental edicts are considered.

SAFETY PERFORMANCE OF ISLANDED GRIDS

Personal safety and safe functionality of electrical installations are one of the key elements for the operation of islanded grids. The difficulty is that in the most common low-voltage grids (TN-C-S), when operated as islanded grid, the fault currents are often not high enough to trip the protection devices sufficiently.

To keep the operation conditions of protection systems in islanded grids in mind two criteria have to be obeyed:

1. A low loop-impedance of the closed fault loop has to be provided so that an occurring fault can be identified and cleared.

2. Decentralised generators or other sources have to provide high enough short circuit power (the short circuit current must be high enough so that a protection system placed at the worst case location in the electrical grid can operate sufficiently in time) or in the case of a fault the generator voltage and the fault voltage is reduced to an acceptable value (electronic protection equipment is also thinkable but not yet available at a low price).

Especially in islanded grids in case of a missing neutral point to earth connection the two mentioned criteria cannot be met.

The first condition can be fulfilled e.g. by short connections or the integration of a neutral earthing transformer. The second condition can be fulfilled by supply of high enough short circuit power and can be maintained e.g. by an electric machine (synchronous or asynchronous machine). The functionality and optimization of these elements must be further investigated and evaluated by appropriate research work in the laboratory.

NEUTRAL POINT TREATMENT OF DECENTRALISED SOURCES

A missing neutral point to earth connection of the decentralised generator can lead to a significant risk potential for the personal safety in a smart system. In the following several neutral point connections from decentralised sources and the flow of the fault current in case of line-to-earth-fault are shown.

Parallel Supply with Decentralised Sources

In case of parallel power supply (public power supply and decentralised generation units, switch S closed) a missing neutral point to earth connection of the decentralised source does not influence the safe operation of the protection measure because the common grid provides the needed short circuit power. The required protection measure in low-voltage grid structures is working and personal safety can be guaranteed [4].

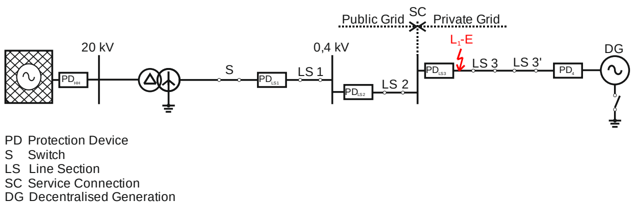

Figure 2: Parallel grid operation with a missing neutral earthing of the decentralised source

Islanded Grid Operation with Decentralised Sources

In case of an islanded grid supply (switch S open) with decentralised sources the question occurs if personal safety can be ensured in case of disconnecting from the distribution grid.

Case 1: Defined Connection of the Neutral Point

In case of a defined neutral point to earth connection - see Fig. 3 two options regarding the neutral treatment occur.

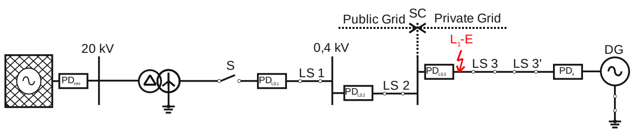

Figure 3: Islanded grid operation with a defined neutral earthing of the decentralised source

On the one hand the neutral point of the decentralised source is connected with the protection earthing wire and coupled with the equipotential bonding - see Fig. 4. On the other hand the neutral point of the decentralised source is connected with the neutral wire and is not coupled with the equipotential bonding - see Fig. 5 [5].

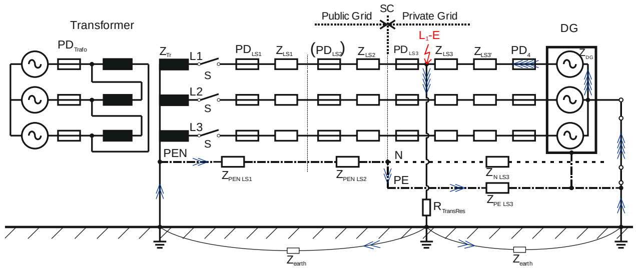

Figure 4: Islanded grid operation with a defined neutral earthing of the decentralised source – connection with earth wire

Fig. 4 shows the current sharing depending on the loop impedance (blue arrows) in case of the connection of the neutral point of the decentralised source with the earth wire. Protection device PD 4 is working sufficiently and the fault is cleared in time. The personal safety is guaranteed.

Fig. 5 shows the fault current sharing in case of a connection between neutral point of the decentralised source and the N-wire. In case of a connection of the neutral point of the decentralised source and N-wire the protection measure does not fulfil in most cases the requirements for small generators for a secure clearing of the fault because of the larger loop impedance. In that case an additional RCD has to be implemented.

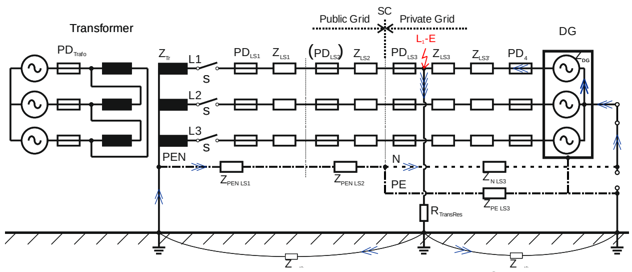

Figure 5: Islanded grid operation with a defined neutral earthing of the decentralised source – connection with N-wire

Case 2: Missing Connection of the Neutral Point

In case of a missing neutral point to earth connection - see Fig. 6 the fault current is not able to trip the protection device PD 4.

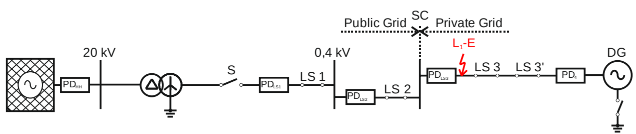

Figure 6: Islanded grid operation with a missing neutral earthing of the decentralised source

Fig. 7 shows that the protection device PD 4 will not be tripped. In that case additional protection measures like an isolation monitoring system gets necessary to maintain personal safety in case of a line-earth fault, the overvoltage in case of a fault has to be considered.

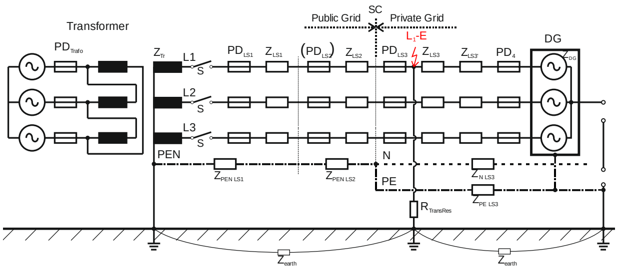

Figure 7: Islanded grid operation with a missing neutral earthing of the decentralised source

Defined Neutral Earthing through a Neutral Earthing Transformer

Fig. 8 shows the implementation of a neutral earthing transformer in case of a missing neutral to earth connection of the decentralised source.

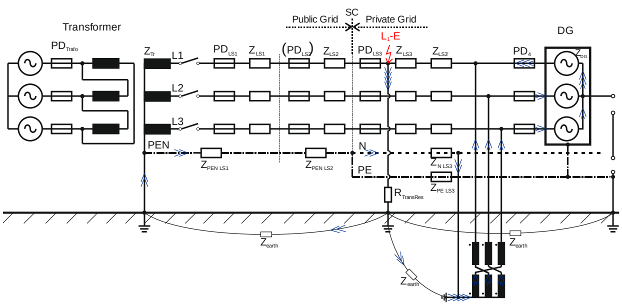

Figure 8: Islanded grid operation with a neutral earthing transformer

In the case of the implementation of a neutral earthing transformer a current path as shown in Fig. 8 exists.
But still the supply of sufficient short circuit current must be considered

SUMMARY

In islanded grids the neutral point treatment of decentralised sources is of high importance for the safe functionality of future grids. In low-voltage TN-C-S-systems, which are smart islanded grid orientated, originally designed protection measures are not sufficient in all cases.
The protection system of the islanded smart grid can convert to a protection system different from the protection system of the common grid and depends on the short circuit and / or voltage characteristics of the generator and on the short circuit power as well as on the treatment of the neutral point of the decentralised source. In small grids the IT-system can be used but special attention must be payed on the short-circuit power of the voltage characteristic of the generator. Otherwise TN- or TT-systems have to be preferred whereby the treatment of the neutral point and the load situation (symmetrical or unsymmetrical) has to be considered. E.g. a missing neutral earthing in islanded grids requires additional protection measures like RCDs or an earth-leakage-monitoring system. Difficulties can occur when the loop impedance of the fault loop is too high or short circuit power cannot be maintained for the required tripping times of the protection system. If the neutral point of the generator is connected with the earth wire problems with RCDs positioned in the vicinity of the generator can occur if currents evade via the earth wire to the neutral point of the source pretending a fault current.

In connection with the mentioned issues the question who is legally responsible for the earthing of the neutral point of decentralised sources in the area of the private grid and in combination with diesel generators sets has still be answered. Further the short circuit current has to be guaranteed and / or an electronic protection system has to fulfil the requirements in islanded grids.

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