PREVENTION OF ISLANDING IN DISTRIBUTION NETWORK WITH DISTRIBUTED SOURCES

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ABSTRACT

Evolution of the distribution grid which witnessed affects in all segments of distribution system, however the most prominent influence is in areas of protection and control of the distribution system. In the area of Elektroslavonija seven distribution power plants (DPPs) are in operation with nominal power above 1 MW. In this paper to past experiences with plants will be presented, especially their influence on control and protection of distribution system. Most attention will be given to the protection of islanding and the problems with which we are facing will be pointed out.

INTRODUCTION

Appearance of Distributed Energy Sources (DERs) has fundamentally changed distribution grid from the passive to active grid. Cognition which past engineers have used to provide consumers with a stable and secure supply of electricity is now no longer sufficient. Engineers who are dealing with operation management and with a relatively a small number of distributed sources have to manage and apply new skills that are primarily related to the new strategy in selecting and setting protection to medium voltage network. During the accession process of DPPs to network investor must make feasibility studies for protection and influence on grid. Producers of the feasibility study for the implementation of DPP protection are observed implementation of distributive power plant into the existing network towards full compliance of selectivity of existing protection with the protection of DPP. Distribution power plants with nominal power above1MWwind power, biomass power plants or biogas power plants are mostly located in rural areas that are connected with long airpower lines.Protection designed for passive radial networks is reliable, transient faults are solved using automatic reclosing. The biggest problem that occurs in networks with DPPs is to prevent islanding of DPP with part of distribution network.

This paper will present experiences with protection of DPPs in distribution network considering the types of power plants, and point out certain problems that occur. Besides standard passive protection features to prevent islanding will be shown and some advanced protection features for prevention of islanding.

ISLANDING

In Croatia at this moment islanding in distribution grid is not allowed. Danger situation can occur if a part of distribution grid is islanded and an integrated distribution power plant (DPP) is connected. This situation is referred to as loss of grid (LOG). Normally islanding is the consequence of a fault in the grid, during the islanding neither the voltage nor the frequency is controlled by the utility supply. If DPP continues its operation after the utility supply was disconnected faults may not clear since the arc is still charged.

Small DPP's usually don't have voltage control, therefore the voltage magnitude of an islanded grid is not kept between desired limits, and unwanted voltage magnitudes may occur during islanding. Another problem is frequency instability. Frequency will change due to active power unbalance, uncontrolled frequency represents a high risk for machines and drives.[1]

Since arc faults clear after a short interruption of the supply, automatic reclosure is a common relay feature. With a continuously operating DPP in the network, two problems may arise when the utility network is automatically reconnected after a short interruption:

1. The fault may not have cleared since the arc was fed from DPP, therefore instantaneous reclosure may not succeed.
2. In the islanded part of the grid, the frequency may have changed due to active power unbalance. Reclosing the switch would couple two asynchronously operating systems.

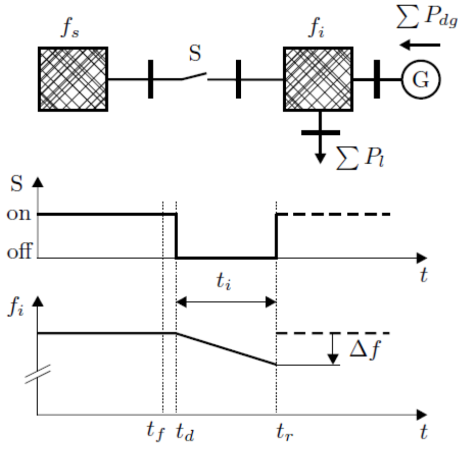

Figure 1: Auto reclosure procedure

Extended dead time (t_i in figure 1) has to be regarded between the separation of the DPP and the reconnection of the utility supply to make fault clearing possible. In Elektroslavonija common off-time settings of auto reclosure relays are 500 ms. Figure 1 shows an example for an auto reclosure procedure where DPP is not disconnecting although it is islanded with the local grid. Here it is assumed that there is a lack of active power after islanding, i.e. $\sum P_{dg} < \sum P_l$ therefore the island frequency decreases. LOG and automatic reclosure are some of the most challenging issues of DPP protection. The only solution of this problem seems to be disconnecting the DPP as soon LOG occurred.

EXPERIENCE WITH PROTECTION WORK

Protection settings in fields for separation and protection of DPPs in all so far constructed DPPs have been adjusted with protection feasibility study, which obligates the investor to provide before connection DPPs to network. According to the author, some of the most important objectives of those studies are:

1. Defining the value of protection settings of islanding that will quickly and reliably separate the DPP of the network during the islanding
2. Insurance conditions for the reliable operation of the AR and thus minimize the number of permanent faults on the feeder
3. Ensuring that during AR does not come to asynchronous link of network and DPP.

To accomplish the goal it is necessary for DPP to be equipped with protection from islanding. In all plants which are built until now a relay with passive functions was used as a protection from islanding. Those functions include integration of functions under/over voltage, under/over frequent protection and protection from movement of vector voltage, respectively, function for detecting speed of frequency change df/dt (ROCOF). Functions of voltage and frequency protection are redundantly located in fields for separation, which means that in case of absence protection work of plant, protection in field for separation will begin to work.
The hardest condition for work of protection in islanding might be situation by which the production of power plant in nearly equal to consumption of feeder. According to data from producers of relay for protection from islanding, required misbalance for reliable separation of power plant from network must be at least 15% of power plants rated power, which in case of power plant with rated power of generator from 1500 kVA amounts 225 kVA. This is a problem which was not considerate until now; neither in elaborates of optimal technical connection solutions, nor in elaborates about adjusting protection. But the fact is that this situation is very much possible and is likely to happen in DPP. The consequence of the lack of power imbalance in the contact point is a danger that the off line remains in isolated operation with the network for a long time, which might move to the line of minute size. Mitigating circumstance is that plants usually work with cos $\varphi \approx 1$, so due to an imbalance of reactive power ultimately leads to an increase or decrease voltage. This situation is however technically impermissible, because it disables work of AR, both quick and slow.
In the area Elektroslavonija in work is one aggregate with power of 4200 kVA powered by a steam turbine in a power plant which is fueled with wood biomass, while all the other six aggregates as a driving machine use a gas engine on biogas. Thus, in working with these aggregates some experience regarding to the behavior of aggregates in the island operation were collected.

Experiences with generators on biogas engine

Experiences with the separation of these aggregates from networks in island operation are very positive. The tests prior to probation work of plants show that these aggregates separate from the network and at very low power imbalance. Practical tests have shown that e.g. 1190 kW generator power disconnects from the network at the imbalance in power from 30 kW, representing just 2.5% of the rated power of the generator. The separation is accomplished by protection of the displacement voltage vector whose setting is $\Delta\theta = 8\,°$. Thereby, the time of separation is moving up to 300 ms. With time of dead time of APU from 500 ms remains still 200ms of real dead time, which is enough for arcing and successful switching. This indicates that the manufacturer's recommendations on the need for establishment appropriate imbalance of power (15-20%), at least regarding of the unit driven by gas engine, may be considered too strict. However, for technical correctness, the authors believe that it should be defined boundary of minimum power imbalance for this type of operation
Figure 2 shows the oscillogram of current and voltage in the experiment work of islanding DPP Mitrovac with imbalance power of approximately 30 kW, with the recorded time of disconnection from the network for a period of 260 ms and approximately 200 ms is required to complete the voltage fall to zero, i.e. about 80 ms to voltage drop to 0.33 UN. If we take a criteria for arching condition that voltage drops to one-third of the nominal voltage it leads to the required time of dead time of APU from 540 ms (260 ms + 80 ms + 200 ms).

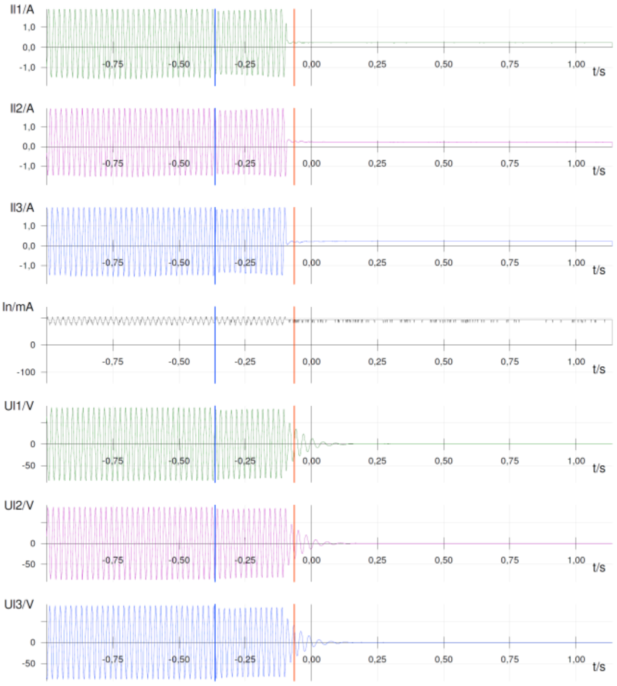

Figure 2, : Islanding of biogas DPP with imbalance of 3%

Experience with generators on steam turbine

In the area of Elektroslavonija in biomass plant Strizivojna Hrast in operation is one unit with power of 4250 kVA powered by a steam turbine. The aggregate has a nominal voltage of 6.3 kV and it is connected to the 20 kV network through the block transformers 6.3 / 20 kV. During actual operation, but also during the examination of plant operation, it was noted that there are problems in the separation of this power from the network. Experimental tests were performed with assumption of power balance in production and consumption in the supply point. The plant was equipped with protection from shifting of voltage vector during the experiment, and the measured separation time of plant from network amounted 90 s. But even after this time has elapsed the plant did not separate by the action of electrical protection, but by the action of non-electrical protection from excessive oil pressure.

Tests with the APU cycle has shown that the plant did not separate from the network during dead time, but only after restarting (possibly asynchronous) and that was by action of non-electrical protection from excessive speed of working machine.

Since it was established that the existing protection from the islanding of generator on voltage level 6.3 kV does not fulfill its function, on generator switch on voltage level 20 kV the function df / dt was activated, based on studies about protection setting, which determine that with the minimum setting of this protection from 0.2 Hz / s generator will be safely separated from the network for power imbalance greater than 600 kW, which is 14% of rated generators power. Practical tests have however shown that to the separation of the generator comes also at lower power imbalances. Thus by the imbalance of 200 kW it was recorded separation time of 308 ms, and by the imbalance of 400 kW separation time of 191 ms.

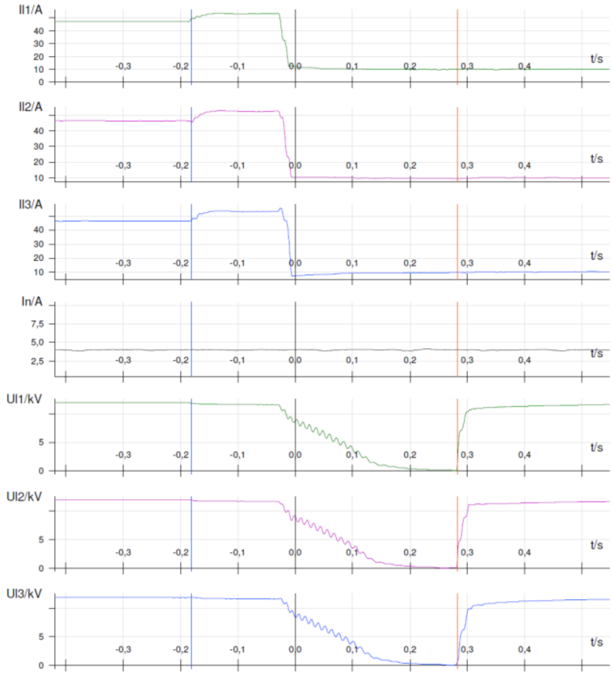

Figure 3: Islanding of biomass DPP with imbalance of 400 kW (10% Pn)

At the first glance, one might conclude that even with separation time of 300 ms there is enough time for deionize arc at the place of failure before automatic reclosing dead time is set to 500 ms. nevertheless, one should not forget the fact that the voltage on power line does not disappear in the moment of the exclusion of generator switch but it lasts for a while until the attenuation, which in this case amounted to 200 ms until complete voltage drop to zero. As the voltage on power line after 100 ms dropped only to about a third of the rated voltage, it was estimated that the conditions of drive should be adapted to the requirement that the time of separation is approximately 200 ms, which is ultimately achieved in the power imbalance of 400 kW.

Prevention of islanding without power imbalance of consumption and production

Operation without power imbalance in the supply point is certainly undesirable situation, in many networks it is very likely that to happen. In order to avoid the imbalance it is necessary to lead the network in such a way to avoid this situation. Redistribution of load on power line is often not possible, and sometimes it is the only choice to manage power of the plants. In the area of

Elektroslavonija problems have been reported with too small imbalance of power in the supply points in two power plants; power plant Tomašanci and power plant Strizivojna.
On the example of Tomašanci power plant (2x1 MW), in period of two months, middle 15-minute value of the labor force was observed (Figure 4). As it can be seen in the figure, power is often located in the area of balance production and consumption on connecting power line.

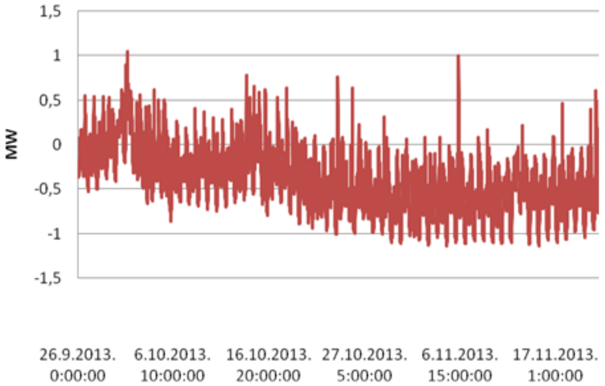

Figure 4: Power in main station on feeder of DPP

Statistical analysis of 15-minutes samples produced the data about the imbalance within the time period. Imbalance in feeder bay is less than 200 kW (Figure 5.) (That is 10% nominal power of DPP) in 23 % of time less than 50 kW, it is 2.5 % nominal power of DPP, 6 % of observed time. Mentioned data are thought provoking and give reason for justifiable doubts as to the availability of islanding protection in all conditions. The fact is that the islanding protection which is currently installed in the area of Elektroslavonija does not offer the possibility of tripping in complete balance of production and consumption. In the end we are not even familiar with which imbalance islanding protection is reliable. Although practical tests at biogas DPP give encouraging results that show high sensitivity protection, largely due to low inertia of these aggregates, one should be aware that the protection method of voltage vector shift cannot and will not work in the minor imbalances. This fact warns us that the protection in the observed DPP (Figure 5) most likely in 6% of the time will not work.

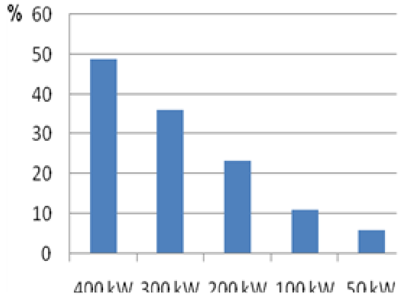

Figure 5: Time percentage of power imbalance in main station

Identical problem of imbalance was observed and the supply substation of Strizivojna Hrast. To prevent deficiency imbalance of consumption and production on feeder bay, to which is connected DPP StrizivojnaHrast (rated power 4250kVA, maximum power production limited to 3300kW), created alarm at the control center. Alarm" Power imbalance" is activated if the power to feeder bay Strizivojna within the interval ±400kW and if they met the appropriate logical conditions. As the alarm was initially without dead-time, first day of activation the alarm is tripped and reset a few dozen times in one afternoon, pointing to the fact that there are serious problems with the power imbalance.

ISLANDING DETECTION TECHNIQUES

To prevent islanding, the protection system has to detect islands quickly and reliably. This is the task of loss of mains protection. Island detection is divided into passive and active methods [2].

Passive methods:

- Under-/overvoltage
- Under-/overfrequency
- Voltage vector shift
- Rate of change of voltage
- ROCOF
- Rate of change of power and power factor

Active methods:

- Reactive error export
- Fault level monitoring
- system impedance monitoring
- frequency shift

In distribution area Elektroslavonija all DPPs have passive protection methods, under-/overvoltage, under-/overfrequency and voltage vector shift. The functions of overcurrent, voltage and frequency protection are redundantly located in fields for separation called cooperative plants. Only one DPP with steam turbine has activated additional protection function ROCOF set at 0,2 HZ/s. Our experience tells us that it is wrong to treat all DPPs equally. Passive methods are sufficient if the imbalance in the production and consumption of the feeder isabove20% nominal power of DPP. If is imbalance under 20% of nominal power, distribution system operator should require some active methods for island protection, or some new approaches in protection. Adaptive protection is “an online activity that modifies the preferred protective response to a change in system conditions or requirements. It is usually automatic, but can include timely human intervention” [55].Adaptive protection systems are systems which allow to change relay characteristics/settings due to the actual system state. There are several adaptive techniques which use online information of the system to optimize the protection system function [3]. Some of them are:

- adaptive system impedance modeling (an up-to-date impedance model of the network that provides input data for relay)
- adaptive multi-terminal distance relay coverage
- adaptive reclosure (prevent unsuccessful reclosure for permanent faults, high speed reclosure in case of false trips)

The basic requirements for implementing adaptive relaying concepts [4]:

- microprocessor-based relays
- appropriate software for relay modelling, relay coordination and communication
- appropriate means of communication.

Another approach is inter-tripping. In that case protection relay causes switching off the circuit breaker in main station, and using communication its giving signal to trip a circuit breaker at generation site. This type of protection is common in transmission power lines, but with DPP's in distribution system inter-tripping is one of the options.

CONCLUSION

Islanding in distribution system is a problem and issue that is difficult to solve. In practice we can see that the biggest problem is lack of imbalance in feeder, which hinders action of passive protection methods. In Croatia feasibility study of DPP is one of steps during the process of accession DPP to distribution grid. Feasibility study should show the need for active protection methods or some other solution(adaptive protection or inter-tripping).

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