COUNTERMEASURES TO VOLTAGE FLUCTUATION DURING RECLOSING ISLANDED ENTITY TO UTILITY

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ABSTRACT

Nowadays, there has been a significant increase in distributed generation in the power system. The power quality issues need to be addressed as part of the overall assessment for the DG connection in the power system.

The paper reviews the phenomenon of voltage fluctuation caused by anti-islanding protection in grid with distributed generation (DG) and potential solutions to minimize this phenomenon. It solves one of common phenomenon to affect power quality in power system.

1. INTRODUCTION

Distributed generation (DG) have a much lower energy density than fossil fuels and so the generation plants are smaller and geographically widely spread. DG may be considered all type of power source connected to distribution system at a voltage level from 120/230 V to 150 kV [3]. Islanding refers to the condition in which a DG continues to power a location even though electrical grid power from the electric utility is no longer present. Islanding can be dangerous to utility workers, who may not realize that a circuit is still powered, and it may prevent automatics re-connection of devices. For that reason, distributed generators must detect islanding and immediately stop producing power; this is referred to as anti-islanding. When the temporary faults occur, all DG in an electrical island must be tripped by the anti-islanding protection [3],[5]. When the fault is clear, the island is reconnected to the network and the loads are energized immediately. But the DGs cannot be reconnected immediately [5]. Thus, it makes a load-generation imbalance and the power from the substation had been missing. It is the reason make voltage fluctuation, namely the voltage sags. Voltage fluctuations can be described as repetitive or random variations of the voltage envelope due to sudden changes in the real and reactive power drawn by a load. The characteristics of voltage fluctuations depend on the load type and size and the power system capacity. Voltage sag is the abatement between 0.1 and 0.9 pu in rms voltage in one or more phases of the electrical system at the power frequency for duration from 0.5 cycle to 1 minute [4]. This phenomenon caused by anti-islanding protection related power quality. It is very important for utility companies to understand the nature and contributing factors of this new problem [1].

2. PHENOMENON AND SOLUTION

2.1. Phenomenon

The phenomenon of voltage fluctuation caused by the DG anti-islanding protection is explained based on the system of Figure below.

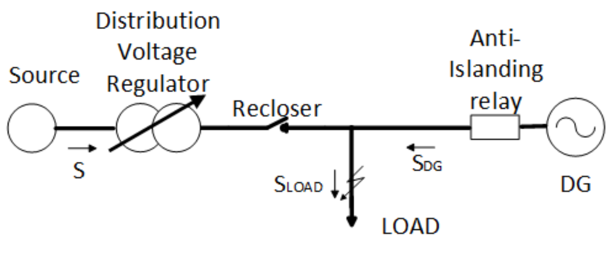

Fig.1. Power flow before fault.

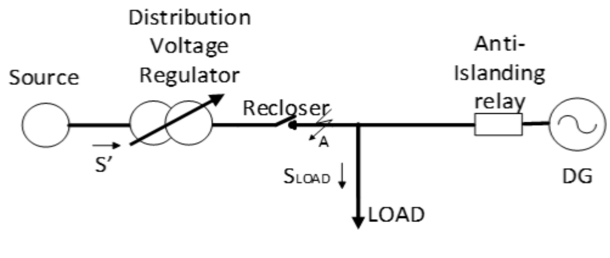

Fig.2. Power flow after reclose closed.

Under normal working conditions, the power flow through recloser is $S = S_{LOAD} - S_{DG}$. (1)

If a fault appear at A point, recloser will open and anti-islanding relay operation to disconnect DG before reclosing operation. After reclosing operation, the load are restored immediately but DG still disconnected. Thus, the power flow through recloser is $S' = S_{LOAD} > S$ (2). This is the reason to appear the phenomenon of voltage fluctuation in this network. The voltage need several times to restore the rated values.

The following potential solutions mentioned to solve the phenomenon of voltage fluctuation as follows: Using compensate capacitor to reduce values of voltage fluctuation; Control of regulation devices to minimizing voltage fluctuation; Using non-sequential tap change mode in step-voltage regulators; Using PV control mode to control DG; Load trip to reduce S_{LOAD} to $S_{LOAD'} = S$. The network is used to demonstrate the phenomenon has one 5 MVA synchronous generator connected to a bus with 4.5 MW load, and six loads connected to the 33kV level. In this network, there is a step-voltage regulator with time delay is 30s and each tap movement is 3s. In normal condition, the DG supplies 4.5 MW and the net load supplies 7 MW, therefore the total load downstream the recloser is 11.5 MW. The step-voltage regulator automatically adjusts to achieve acceptable voltage profile in the system [1].

When the fault occur, the recloser opens rapidly, and after that the DG gets disconnected by the anti-islanding protection. The result after the reclosing operation, the net load increases to 11.5 MW, it is higher than 7 MW-the net load before the fault occurred. In this situation, the voltage after the reclosing operation decrease 4.62% compare with the voltage before this point [1].

2.2. Solution

The following solutions are considered:

- Nonsequential Tap-Change Mode.
- Load Trip.
- Centralized Control of Voltage Regulation Devices.
- Even-triggered capacitor switching.
- DGs with PV control mode.

All solutions are based on load-flow calculations with Newton-Raphson load-flow method. It make them easy to implement and apply [2].

2.3. Advantages and Disadvantages of solutions [2]

2.3.1. Nonsequential Tap-Change Mode

The solution measures the instantaneous voltage during a certain period and calculates the average value when it violates the dead band thresholds [6]. After that, It calculates the number of tap changes necessary for the voltage to recover to the desired value. So, after an adjusted time delay, the tap changes directly to the calculated position without any delay among intermediary positions [6].

- Advantages: ΔT_R -the time taken for the voltage to recover to the steady-state condition can be reduced. This time can be used for other solutions;
  This solution is no need to install additional equipment or communication-based schemes.
- Disadvantages: ΔV_1 -is related to the tap position of the pre-disturbance condition is not reduced.

2.3.2. Load Trip

Load trip in distribution systems has been proposed by specialists as a potential solution to keep the node voltages within acceptable limits under emergency conditions. In a previous research show that, the voltage at the load bus depends on its active and reactive power when the DG gets disconnected by DG anti-islanding protection. If active and reactive power of load are reduced, the voltage sag reduced [1] .

- Advantages: Voltage depression magnitude can be significantly reduced;
  This solution is no need to employ complex schemes to disconnect the load. Voltage-based relays might execute this function properly.
- Disadvantages: It is difficult to select loads to trip.

2.3.3. Centralized Control of Voltage Regulation Devices

The basic idea of solution is to determine and control the tap positions of the voltage regulation devices that ensure no voltage violations after DG disconnection by DG anti-islanding protection. The conceptual idea of this solution is to decrease the voltage sag by adjusting V_S-the voltage magnitude at the terminal of the distribution voltage regular or Q_L-the reactive power by the load. Therefore, to regulate the voltage, SVR-Step Voltage Regulator or Capacitors can be used. For the centralized control scheme, the SVR or Capacitors need to be constantly monitored and controlled. So, the method considering an SVR as the voltage regulation is used in this solution [2]

- Advantages: The voltage depression after the recloser operation does not violate power quality requirements;
  Since voltage regulation devices are externally controlled, the DGs reconnection time can be reduced.
- Disadvantages: It can be an expensive solution, since there must be communication infrastructure to provide external control to the voltage regulation devices;
  The presence of various voltage regulation devices requires more sophisticated methods to determine the valid voltage

regulator devices operation bands.

2.3.4. Even-triggered capacitor switching

Modern approaches propose the coordinated control of capacitors with the DG capability of supplying or absorbing reactive power as an effective means of keeping the nodal voltages regulated, minimizing the active losses and increasing DG penetration [7], [8]. The conceptual idea of this solution is switching on capacitors to locally supply reactive power when the DGs get disconnected by the DG anti-islanding protection. The challenge is how to reduce the size of capacitors [2]

- Advantages: Voltage depression magnitude and duration after fault clearance can be significantly reduced;
  There may be fewer SVR tap changer operations than in the cases without the capacitors.
- Disadvantages: The capacitors may be too large if it is desired to reduce ΔV_1 to values near zero. This implies in high costs;
  Voltages fluctuation may occur if capacitors are not correctly sized.

2.3.5. PV control mode

The solution is changing the DG control mode to active power and voltage magnitude control (PV control mode), instead of active and reactive power control (PQ control mode). The main goal is to keep the voltage at the point of common coupling (PCC) constant and equal to the voltage calculated at the same bus, without the DG. Configure all DGs to PV control mode and set their voltage reference in the way that the PCC voltage be the same as the one calculated without the generators [2].

- Advantages: ΔV_1 and ΔT_R can be significantly reduced;
  There may be conditions in which no tap change operations are needed.
- Disadvantages: There may exist situations in which the DGs are not capable of injecting or absorbing enough reactive power to keep the point of common coupling (PCC) voltage at the desired value;
  Power factor at the PCC might violate required limits at steady-state operation;
  If not adjusted properly, the voltage reference of the DGs controllers may undermine the performance of the SVRs.

CONCLUSION

This paper has reviews the new style of power-quality phenomenon and potential solutions to solve this problem. This phenomenon caused by DG anti-islanding protection. It has been demonstrated through computer simulations and used load-flow calculations.

Potential solutions to solve this problem have been considered: Nonsequential Tap-Change Mode, Load Trip, Control of Voltage Regulation Devices, Even-triggered capacitor switching, DGs with PV control mode.

Summary the advantages and disadvantages of each solution.

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