Protection of Power Distribution Networks with High Penetration Level of Distributed Generation

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Abstract—Conventional power distribution systems are radial in nature, characterized by a single source feeding a network of downstream feeders. Traditionally, protection schemes for distribution systems have been designed assuming the system to be radial. Since the need for green power keeps rising, more and more Distributed Generation (DG) is connected to the utility grid. DG units are small generation units, p.e. photovoltaics, wind turbines, hydropower, small cogeneration units, fuel cells, etc., which are connected at the customer side of the utility network.

After connecting DG, parts of the system may no longer be radial, which means the coordination between the protective devices could fail. A lot of the newly installed DG units at low voltage level are connected through a power electronic converter. This paper suggests a low cost solution for the protection problems based on the adaptation of the digital control of the converter.

Keywords— Distributed Generation, Distribution Networks, Protection, Convertor Control

I. INTRODUCTION

DISTRIBUTED Generation covers a wide range of technologies and primary power sources. The cost of transmission and distribution of electricity is rising, on the other hand the costs of DG technologies are falling. The amount of DG units connected to the utility network is steadily growing. Studies predict that DG may account up to 20% of all new generation by the year 2010 [1]. With this amount of power generation situated at the low voltage end of the distribution system a reversed power flow is inevitable. This situation will cause several protection problems since the protection of distribution systems is designed for one directional power flows only. Nowadays the most common solution for this problem is to disconnect all DG units if a disturbance in the utility grid is noticed. This philosophy will not be acceptable any more with a high penetration level of DG since the amount of disconnected power will be too high to be taken over immediately by the traditional power plants. The balance between delivered and consumed power would be disturbed, this leads towards a sequential shutdown of power plants caused by the frequency- and voltage variations with a total blackout of the utility grid as a final consequence.

II. OCCURRING PROBLEMS

As DG units will need to stay connected during disturbances of the utility grid, several problems arise.

A. Failure of interruption devices

Due to the connection of distributed generation units there is a change in the short circuit power in the distribution network. In most of the cases the short circuit level rises. In the traditional situation the whole network impedance is situated between the fault and the power source. The fault is considered to occur somewhere at the low voltage level of the distribution system. The distance between the fault and the DG unit is very small, as shown in Fig. 1. The short circuit current might become that large, due to the contribution of the DG unit, that it cannot be interrupted by the existing circuit breakers in distribution systems.

![Fig. 1. Raised short circuit level](image1)

B. Undetected faults

In contrast with the previous case it is also possible to reduce the short circuit current at the protection device by introducing a DG unit in the utility grid, see Fig. 2. This might prevent the protection device to detect the fault, as the short circuit current through the circuit breaker may be smaller than the maximum load current.

![Fig. 2. Divided short circuit current](image2)

C. Disturbance of recloser operation

A recloser is a switching device that temporarily interrupts a faulted feeder. By interrupting the fault current it is possible to prevent unnecessary power interruptions for the customer, since 80 to 90 % of the faults on overhead lines disappear when the voltage is interrupted for a very short time [2]. If a DG unit still feeds the fault while the recloser is switching, this will result in much more power interruptions, causing a decreased system reliability.

D. Disconnection of a healthy feeder

The placement of a rather large DG unit at a short distance from a substation on a lightly loaded feeder may result in the
disconnection of a healthy feeder. If a fault occurs on an adjacent feeder it is possible that the feeder with the DG unit is switched off. See Fig. 3: circuit breaker no. 1 blows instead of no. 2, the phenomenon is referred to as nuisance tripping. This is a major drawback for the quality of power delivery. Most protection units in distribution networks are not sensitive to the direction of the current. A simple but very expensive solution to this selectivity problem is to replace all protection equipment by directional sensitive devices.

A. Reaction in case of faults

If a fault condition occurs near a DG unit, the voltage at the network side of the converter drops. The inverter tries to deliver a constant power and rises the output current. This increases the short circuit level. If the inverter is controlled to decrease the output current proportional to the output voltage, the short circuit level decreases at the moment of the fault condition. This solves a great deal of the above-mentioned problems:

In Fig. 1 the short circuit current delivered by the DG becomes very small (due to the voltage drop), the total short circuit current is reduced to a level similar to a situation without DG. If the protection devices in the distribution network are well designed, they should be able to interrupt this short circuit current.

In Fig. 2 the measured short circuit current at the circuit breaker augments due to the control strategy of the inverter, the fault current can thus be detected.

In Fig. 3 the short circuit current through circuit breaker no. 1 will become smaller than the current through no. 2 due to the greater part of the short circuit current delivered by the substation.

In order to prevent the malfunction of the recloser the controlling action should be very fast.

B. Reaction in case of flicker

A supplementary benefit of the control strategy is the possibility to damp flicker in the network. This is an important asset because of the injection of flicker by several types of DG units, for example the tower shadow effect in wind turbines [3] and the nuisance level off some power electronic converters. In our laboratory (EELAB) there has been done a lot of research on this domain [4], [5], [6].

In order to damp the flicker level it is necessary for the inverter to lower the output current with rising voltages, and to increase the output current when the voltage drops. This is in contradiction with the desired reaction on faults. The controller needs to be implemented in a way that different actions are carried out depending on the network situation. The time dilatation introduced by the output current control needs to be very small to prevent an increase of the flicker level in the case of high frequent flicker as illustrated in Fig. 4 and 5 for a fixed time dilatation.

III. CONVERTOR CONTROL

Most DG-units at the low voltage level of the distribution network are grid-connected through an inverter. This inverter is digitally controlled and can react on certain events in the network. The analysis and implementation of the desired reactions in a digital controller will be investigated.

REFERENCES