Renewable Power feeding to Distribution Networks protected by “Network Protection Relays”

Problem Description and possible Solutions

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For:

Deutsche Gesellschaft für
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1 Problem Description

The purpose of this document is the presentation and comparison of international standards for interconnecting small distributed generation units to the public grid of different European countries (Germany, Italy, Portugal and Spain) and the United States of America. From that recommendations for a simplified connection procedure in coherence with net-metering are derived.

Renewable distributed generation facilities like photovoltaic systems often feed their power to the low voltage distribution grid level. Most distribution grids are of a radial nature. In radial distribution grids the here mentioned problem does not exist.

Especially in downtown areas and in areas with high load densities distribution grids are organized in secondary grid networks or spot networks. The aim is to increase reliability of supply. As shown in illustration 1.1 the low voltage distribution grid (purple lines) is of a meshed nature and any customer load can be supplied via a number of different medium voltage or primary feeders (blue lines).

Note: The difference between Brazil (and e.g. the United States) and Europe is the operation scheme of secondary grid networks: in both cases there are secondary grid networks but in Europe they are separated in several radial distribution grids and only in case of a grid fault they are reorganized by new switch settings. So, the hereafter mentioned problem does not occur in Europe – but in Brazil and the US!

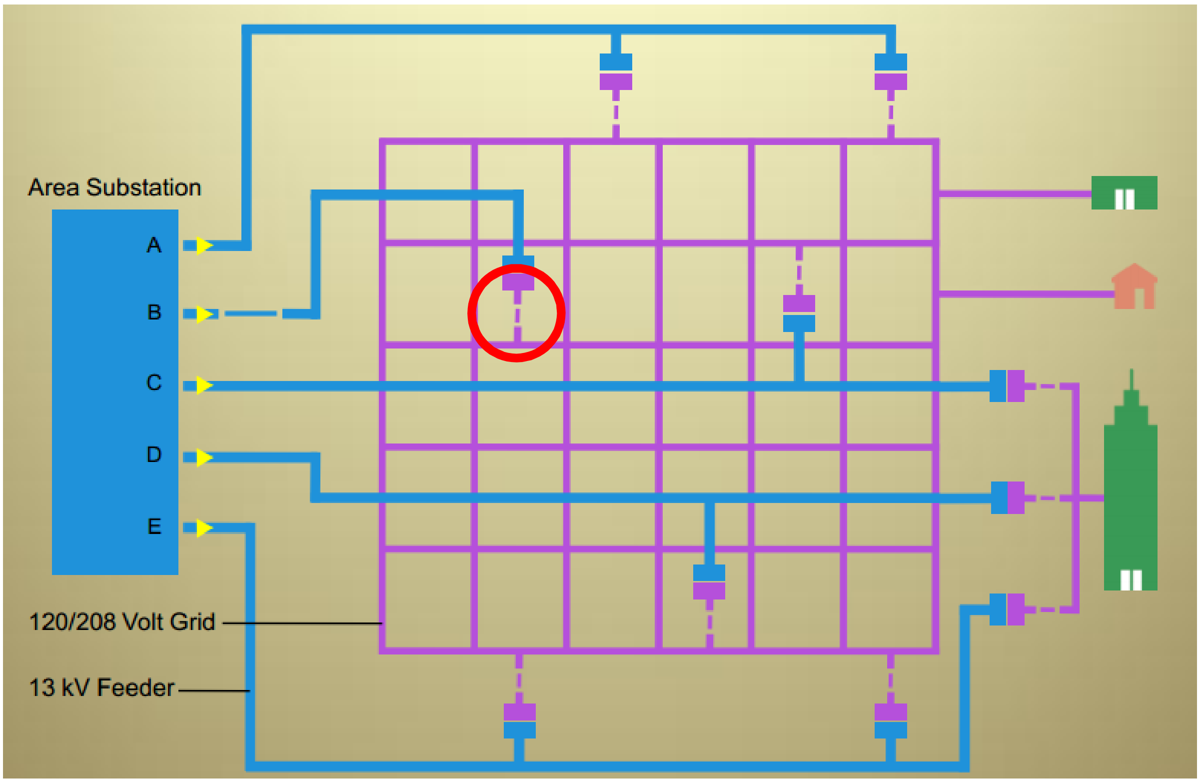

Illustration 1.1: Distribution Grid of a downtown area [Source: Con Edison]

In case of a grid fault in one of the feeders two short circuit currents flow towards the fault spot: one from the high voltage side and would be cleared by protectors in the medium voltage line (blue line and blue switch in illustration 1.1). A second current could be fed by through the low voltage grid that is fed by several other feeders supplying the secondary grid network. In order to avoid this in Brazil and the US so-called network units with network protectors are installed at any feeder station (red circle in illustration 1.1). This situation is also shown in IEEE 1547, illustration 1.2, with the "NU" blocks that stand for network unit.

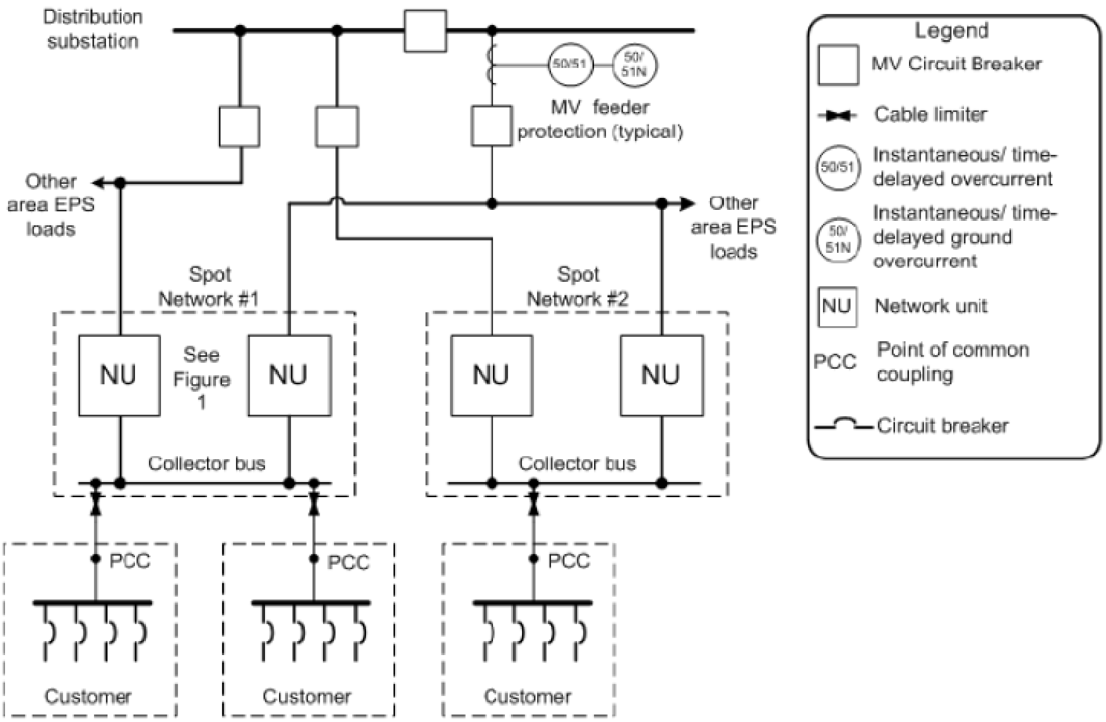

Illustration 1.2: Spot network configuration [Source: IEEE 1547.6]

The network protector itself is shown in illustration 1.3. The network protector measures the power flow direction within the feeder. In case there is a power flow from the low voltage side towards the primary feeder the network protector interprets this as a fault situation and opens a relay.

This works fine as long there is no generation capacity in the secondary distribution network. But in case there is a generation capacity at least theoretically the situation can occur that with low load condition a current is fed backwards into the primary feeder.

In this case the network protector would separate the line even there is no fault situation.

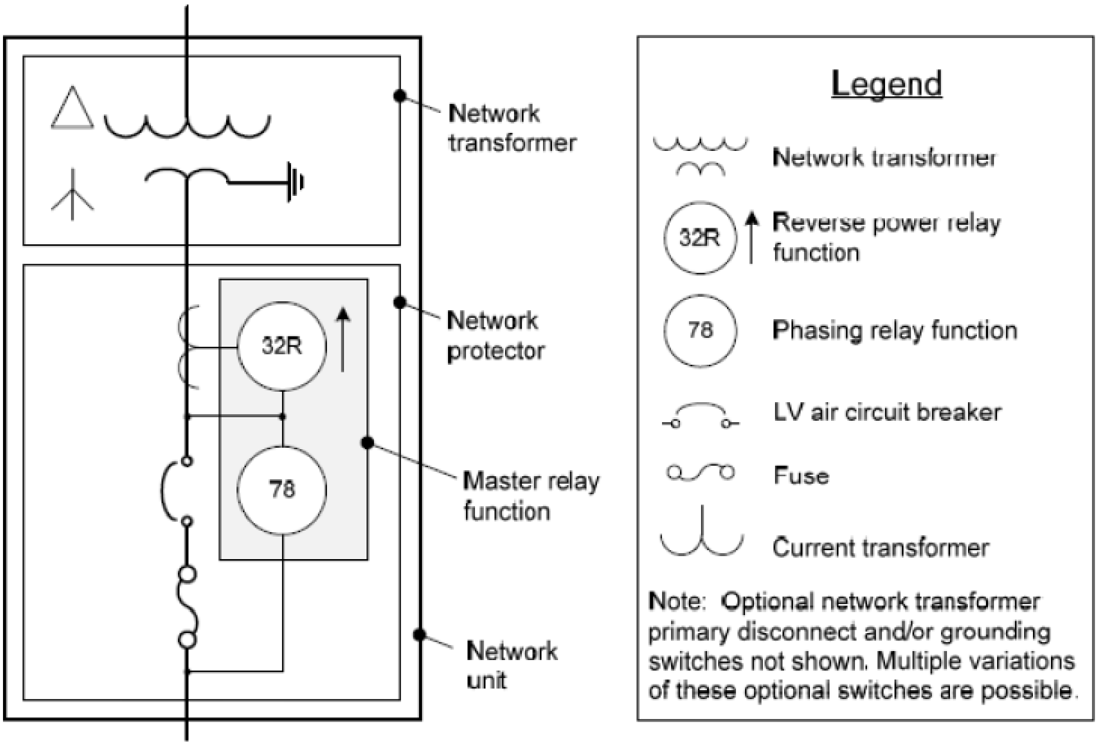

Illustration 1.3: Network Unit Components [Source: IEEE 1547.6]

Illustration 1.4 shows the correct network protector operation in case of a fault at the site of the red cross: from both sides the fault current is interrupted by relays.

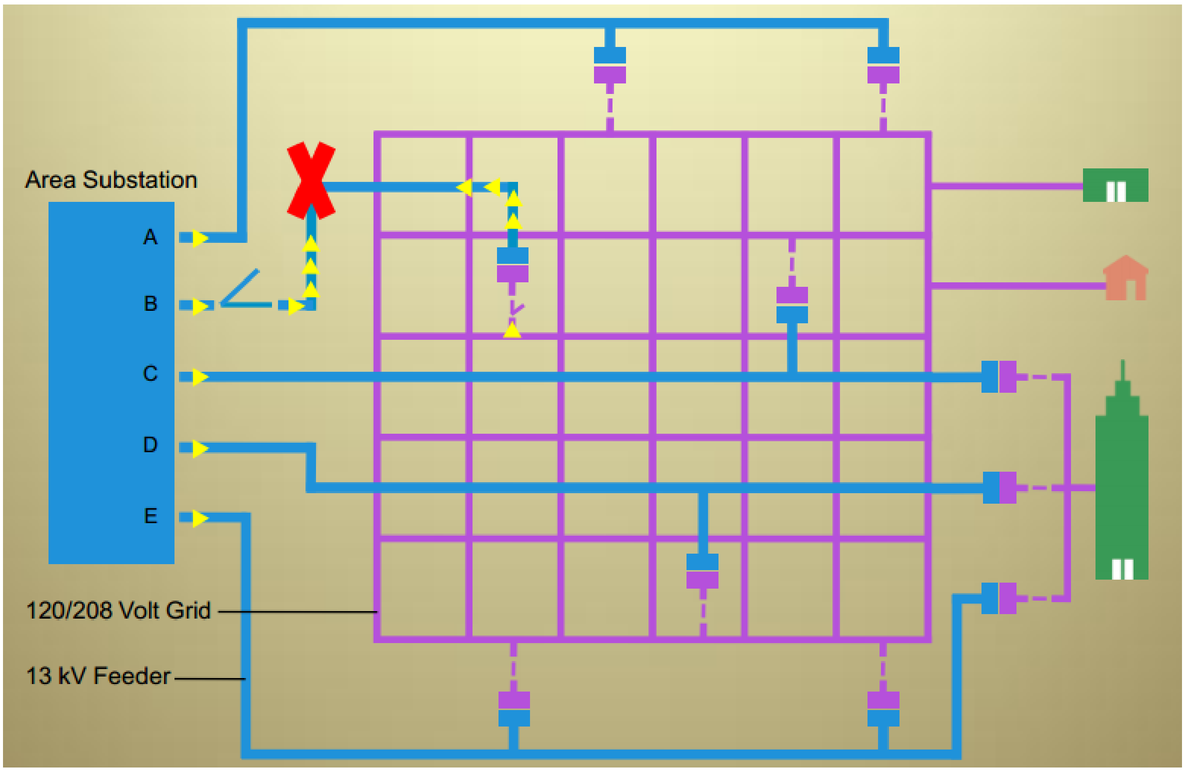

Illustration 1.4: Correct operation of the network protector in case of a fault in the primary feeder [Source: Con Edison],

Illustration 1.5 shows by mistake operation of network protectors. In the upper right corner in a complete area generation is higher than consumption and as a consequence several network protectors realize a reverse current and open the protection relay. This can be characterized as a real academic and improbable situation in dense downtown area with high air conditioning density.

A bit more realistic is the situation illustrated by the tall green building. Assumed that this is a real big and important building with a very high load this single building could be supplied by different primary feeder networks. Here, maybe a back feeding situation is more probable. Literature here deals with new type elevators that in case of driving big loads downwards feed electricity back to the grid like railway trains do when braking. Here, operation of the network protectors could bring the building in a islanding situation.

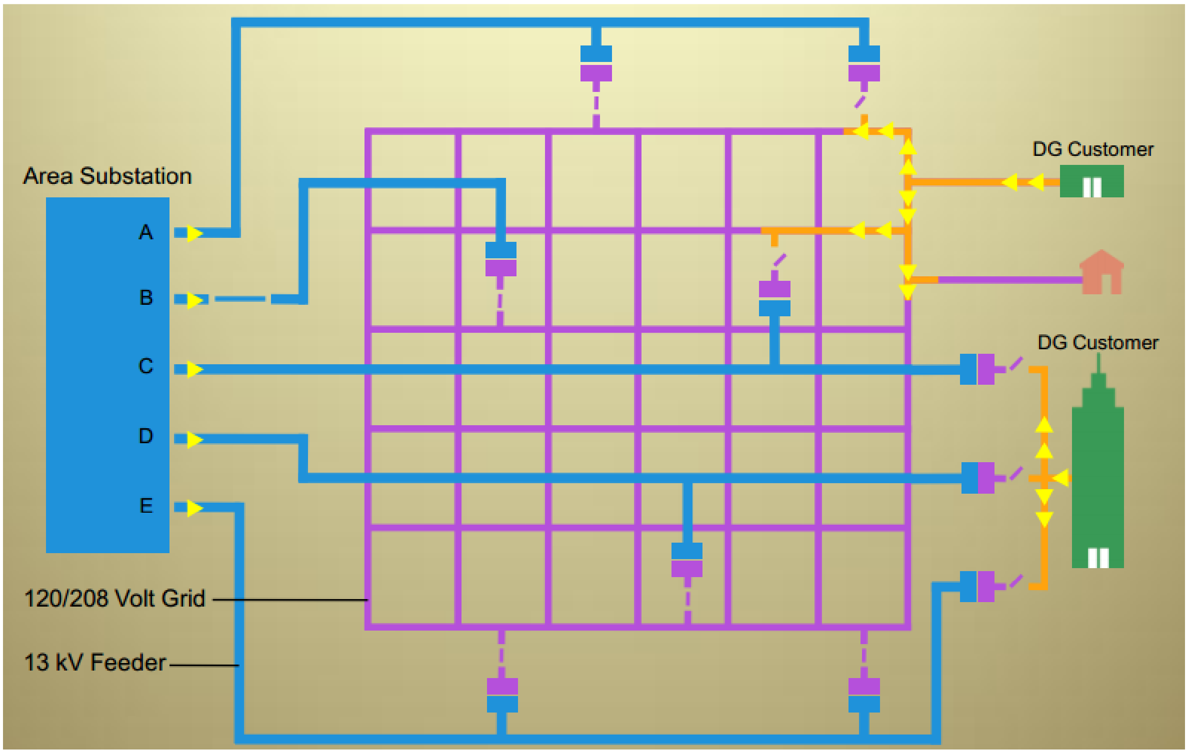

Illustration 1.5: By mistake operation of the network protector [Source: Con Edison]

2 Possible Solutions

2.1 Ignoring the Problem and non-smart Solutions

2.1.1 Ignoring the problem

The easiest way to deal with the problem would be to do nothing, to just ignore the problem as it is of a very academic and theoretic nature.

This might sound very cynical. But some thoughts, considerations or investigations could be made:

1. How does Brazil deal with back feeding power from elevators? Are they forbidden? Are problems known? How is it dealt with them?
2. The minimum load of very large downtown buildings and downtown areas could be studied and compared with the maximum power that could be produced by PV installations on those buildings

2.1.2 Allow only PV installations smaller than the minimum load

Resulting from measurements of the load curve of very large downtown buildings and downtown areas only PV installations could be allowed that are below the minimum load of those areas.

2.1.3 Use of Minimum Import Relays (MIR)

NREL suggests the usage of so-called minimum import relays (MIR) or reverse power relays. The MIR disconnects the PV system if the powers flow from the utility drops below a set value. The reverse power relay will disconnect the PV system in the secondary network from the utility if the power flow from the utility drops to zero or reverses direction.[1]

2.1.4 Inverter power control to make reverse power to zero

Dynamically controlled inverters could be installed to monitor the amount of power coming in the customer location and decrease PV penetration if the load decreases below a specific level. The energy flow is monitored at the main feeder and a control signal is sent to the inverter which initiates a reduction in generated power, if required.

Conclusion: All methods suggested here are not too smart. In any case power from PV is limited instead really dealing with the problem of a by mistake operating fault detection!

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[1] Coddington, M. et. al.: PV systems interconnected onto secondary network distribution systems, PVSEC, 2009, 34th IEEE, vol. no. pp.000405-000408, 7-12 June, 2009

2.2 Solution proposed by Con Edison

In the United States the utility that supplies New York, Con Edison, deals with the aforementioned problem in the following way:

The Con Edison specification that allows export across a Network Protector (NWP), which would otherwise open upon any backfeed includes the following:

- The NWP relay is set to 'insensitive' such that NWP will only operate if 1/2 the transformer loading is exceeded. For example protection for a 1000 kVA transformer will allow for 500 kVA of export/backfeed.
- The control room has two way communications between the NWP and the control room so the operator can open the NWP from the control room if needed.
- A (wrongly named) anti-islanding device ensures that at least one feeder stays in service to supply the customer (Con Edison design is N-2). This is because if, one feeder is out for work, a second opens due to a fault condition, the third should not be permitted to operate the NWP so the customer will stay in service. The anti-islanding device will shut down the generation if more the 1/2 the feeders supplying the customer are out.

According to information from Margarett Jolly (Con Edison) this setup costs the customer an additional ~U$ 70,000 and allowed for a 1MW PV installation that otherwise would only allow 400kW.

2.3 Adopted European Technology

As mentioned before, European secondary grid networks are operated differently and therefore the herewith dealt problem does not apply. Nevertheless, especially in Germany the pure amount of PV systems installed has caused a different problem. And this mainly to rural areas:

Even reverse power is not a problem in general but the amount of power in some areas brought the grid infrastructure to its limits. As a consequence the feed-in law demands at least for larger PV installations and their inverters, respectively, to have a communication towards the grid operator. So, in case of having a low load situation and sunny weather at the same time the grid operator remotely can shift down power injection from PV systems in order to avoid grid infrastructure from being overloaded.

The same equipment also could be used in Brazil in order to avoid a power feedback into the primary feeders in critical situations. Together with combining this information with the network protector operation even a feedback could be organized.