Overview of the issues related to the operation of the Distributed Generation (DG) in parallel with the grid and transition of the DG to and from the grid connected operation.

It is common for a DG resource to operate in parallel with the utility grid continuously or from time to time for an extended period of time. Most of the issues defined below apply to the DG connected to the utility grid for a period longer than 100 mS.

1. Synchronizing.

Before any DG resource can be connected to the utility grid, its output voltage sine wave needs to be properly synchronized with the utility grid's voltage sine wave. In order to achieve proper synchronization the DG's voltage sine wave's **frequency, magnitude** and **phase angle** need to be appropriately adjusted.

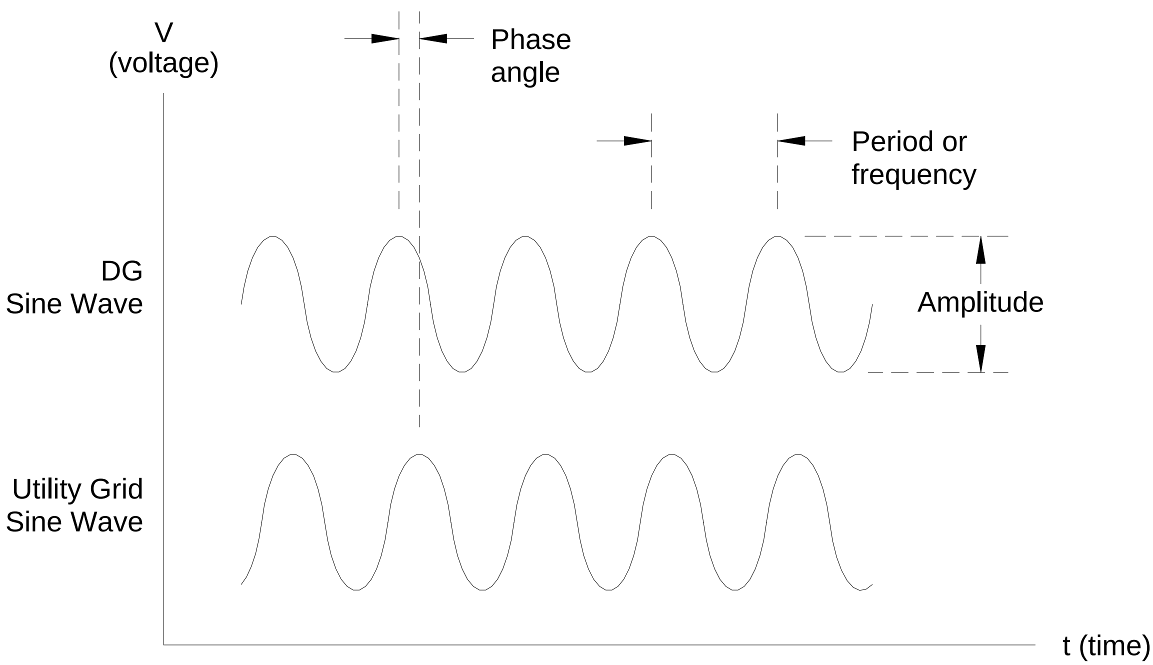

Figure 1. Illustration of synchronizing parameters

It is generally desired that at the time of connection of the DG resource to the utility grid the following synchronization parameters are met:

a. Voltage sine wave's **frequency** difference does not exceed 0.12 Hz
b. Voltage sine wave's **magnitude** difference does not exceed 3%
c. Voltage sine wave's **phase angle** difference does not exceed 10 degrees.

2. Fault contribution.

Once the DG resource is connected to the utility grid, its impact on the power system available fault current needs to be accounted for.

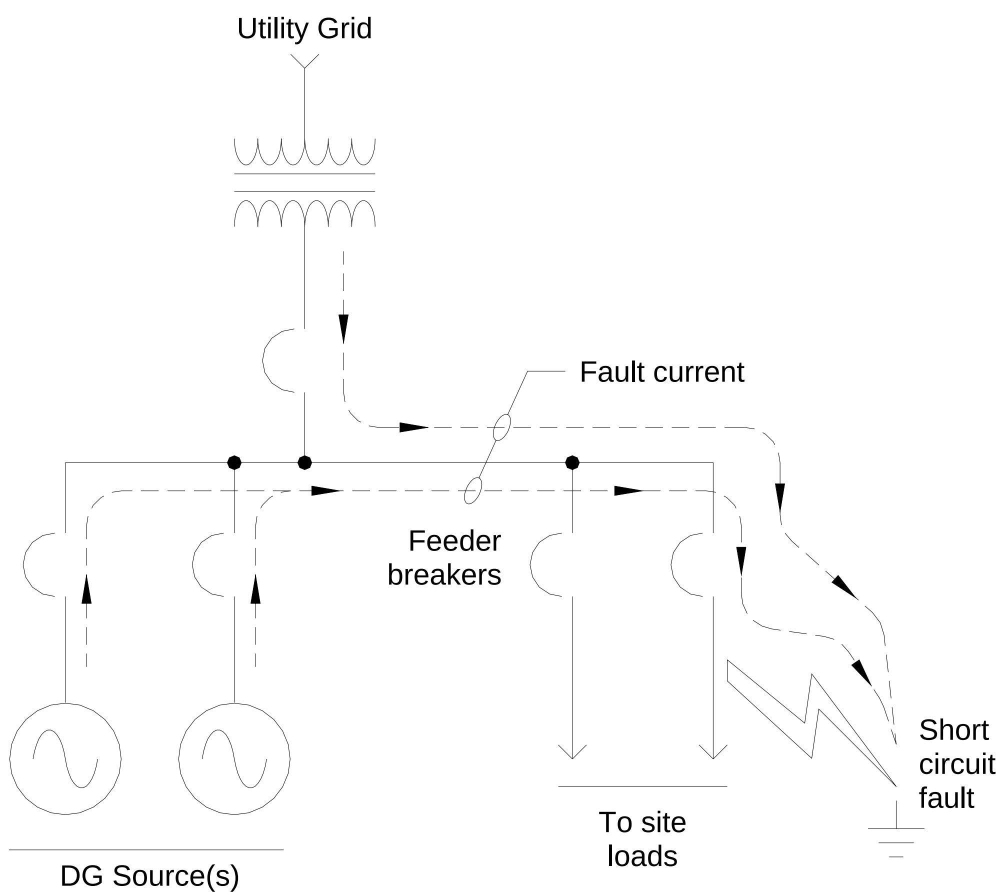

Figure 2. Cumulative effect of DG's and utility feeding a fault

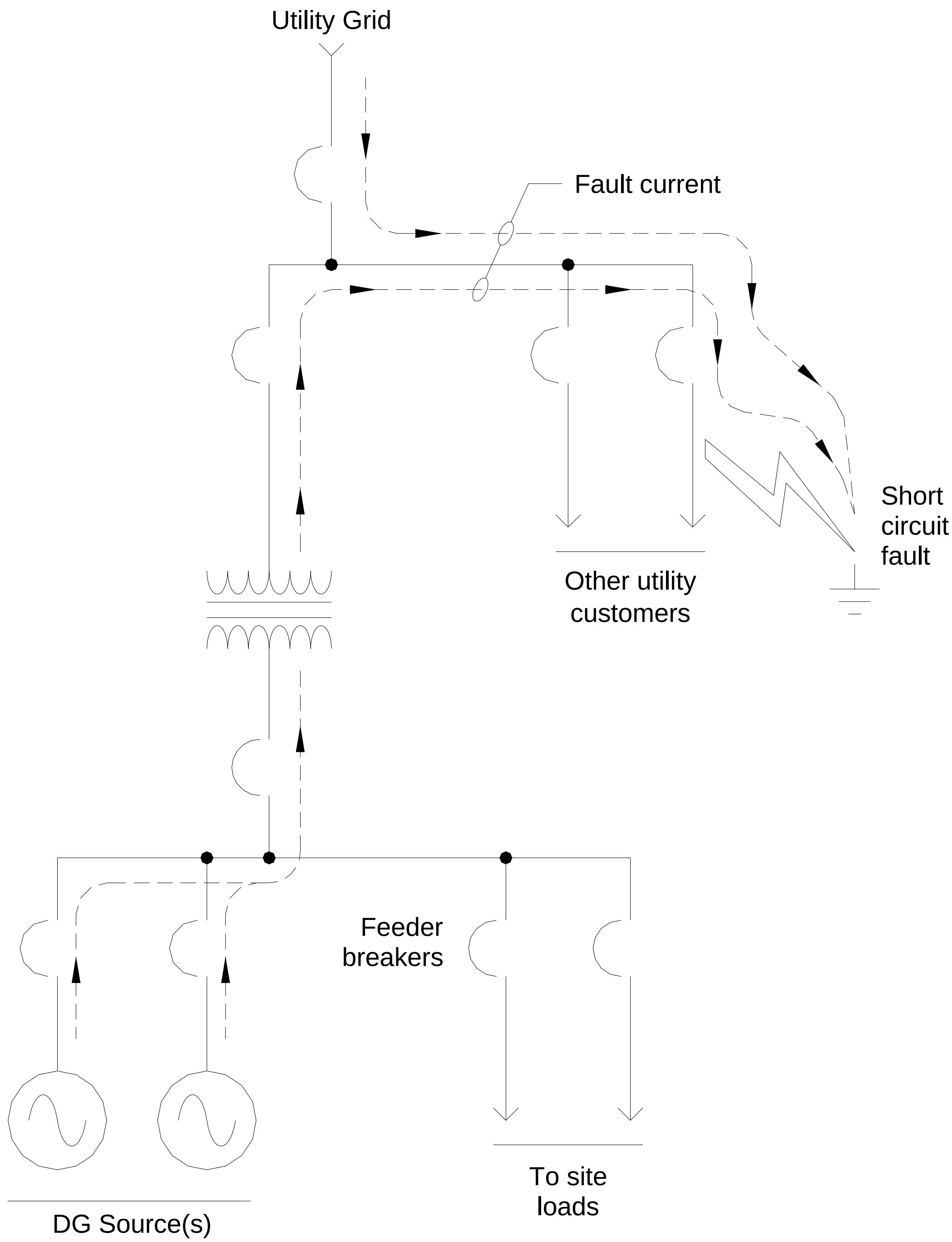

Figure 3. Cumulative effect of DG's feeding an upstream fault

The interrupting rating of the new and existing equipment needs to be evaluated to ensure its ability to interrupt the maximum available fault current as contributed from the utility and DG sources.

Time-overcurrent coordination between the utility and DG overcurrent devices needs to be performed to ensure proper system operation during short circuit fault on the utility side of the utility disconnect device, Fig. 4.

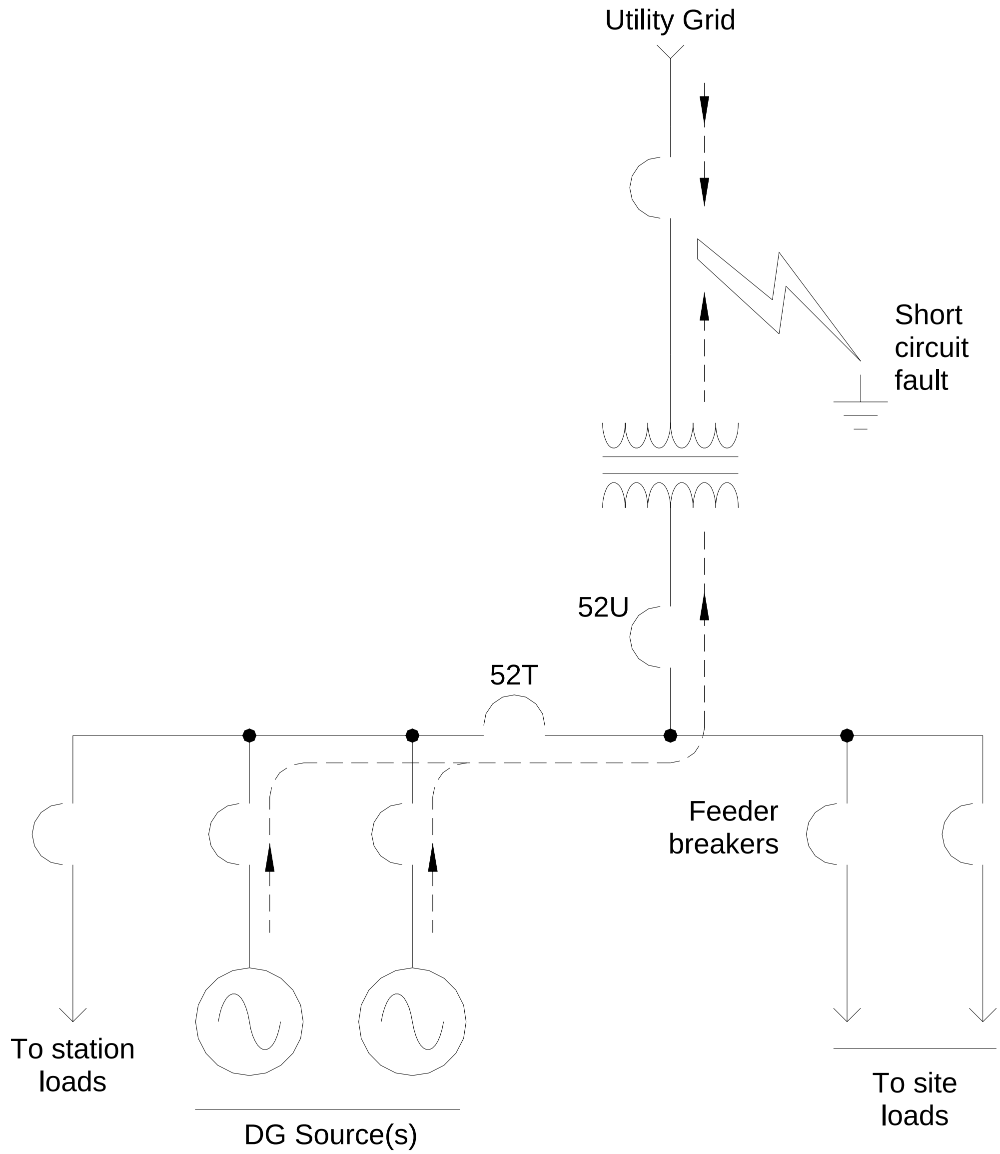

Figure 4. Coordination of breakers during fault

In this case (Fig. 4) the overcurrent protection needs to be coordinated in such a way that:

1. If the DG is intended to carry the site loads during the utility outage, than the circuit breaker 52U needs to trip before the circuit breaker 52T.

2. If the DG is not capable or intended to carry the site loads during the utility outage, than the circuit breaker 52T needs to trip before the circuit breaker 52U.

Appropriate protective relaying system needs to be installed to ensure that the utility company's equipment and utility company's other customers will not be negatively impacted by the DG installation.

3. Utility automatic reclosing and DG unintentional islanding.

Overhead electric power distribution circuits in the United States commonly use unsupervised automatic reclosing, to improve the reliability of service to the utility customers. As demonstrated in Figure 5, an overcurrent fault anywhere in the distribution circuit will cause opening and then automatic reclosing of that circuit with the expectation that the condition which caused the fault will self-extinguish.

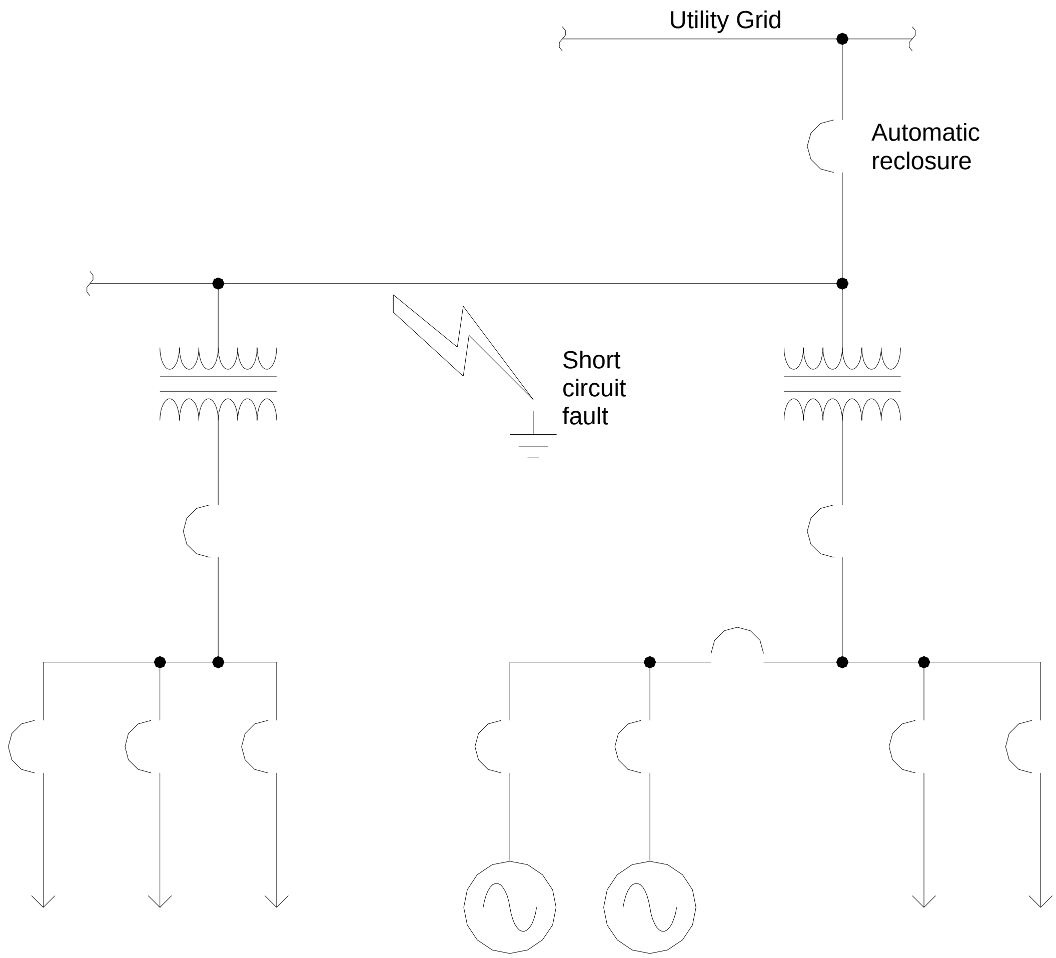

Figure 5. Automatic reclosure – during a fault as shown, the reclosure will cycle open and then re-close in an attempt to clear the fault.

During the reclosing operation (while the reclosing device is open) the DG resource will most likely drift out of synchronism with the utility source (Figure 6).

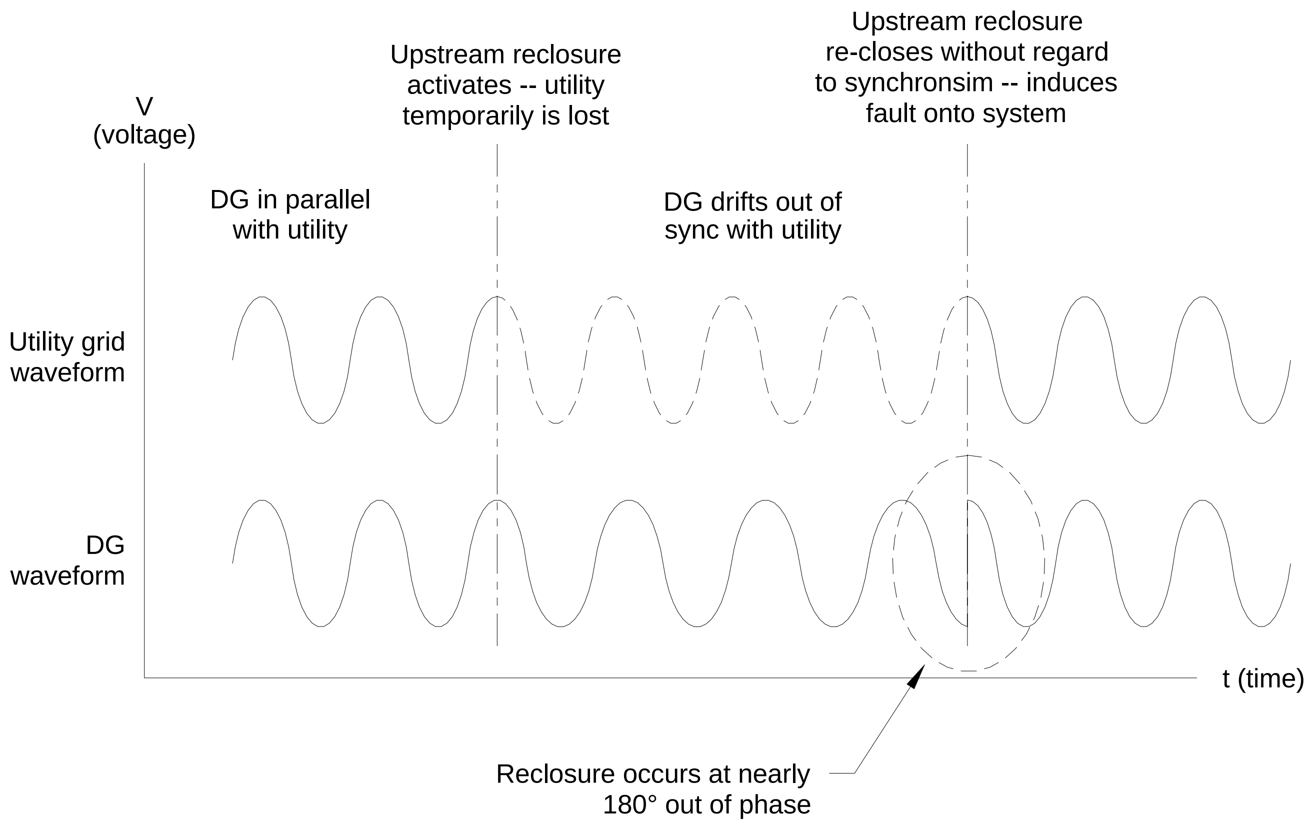

Figure 6. Loss of utility with DG connected

If the DG resource is still connected to the system when the automatic reclosing device closes, the DG will be connected to the utility grid out of synchronism. The most severe case of the out synchronism closing is when the DG is 180 degrees out of synchronism with the utility grid (Figure 6).

The power system impact of the out of synchronism closing is similar to the “bolted” short circuit fault, with most likely instantaneous trip of the up-stream overcurrent devices, voltage sag in the distribution circuit with likely disturbance of service to the other utility company’s customers. The other consequences of the out of synchronism closing could be: damage to the DG equipment.

The system condition when the DG resource is connected to the portion of the utility distribution system while the utility is disconnected – called **unintentional islanding**. Unintentional islanding can occur during automatic reclosing operation as well as during any other disconnection of the utility, upstream from the DG interconnection point (operation of the distribution protective relaying, circuit disconnection by SCADA or personnel, etc.).

If the unintentional islanding is caused by the operation of the distribution overcurrent or distance protection, it is possible for the generator to continue feeding the fault after the disconnection of the utility source.

Unintentional islanding, regardless of the cause, keeps portions of the distribution system unintentionally energized, potentially endangering the utility personnel or preventing the utility personnel from performing work on their lines, etc.

4. Intentional Islanding.

There are many cases when one of the purposes of DG is to prevent power loss to the site loads during the utility outage. When the utility outage is caused by a low impedance short circuit, electrically close to the point of interconnection, voltage sag caused by the short circuit fault is likely to affect some of the sensitive site loads (Figure 7).

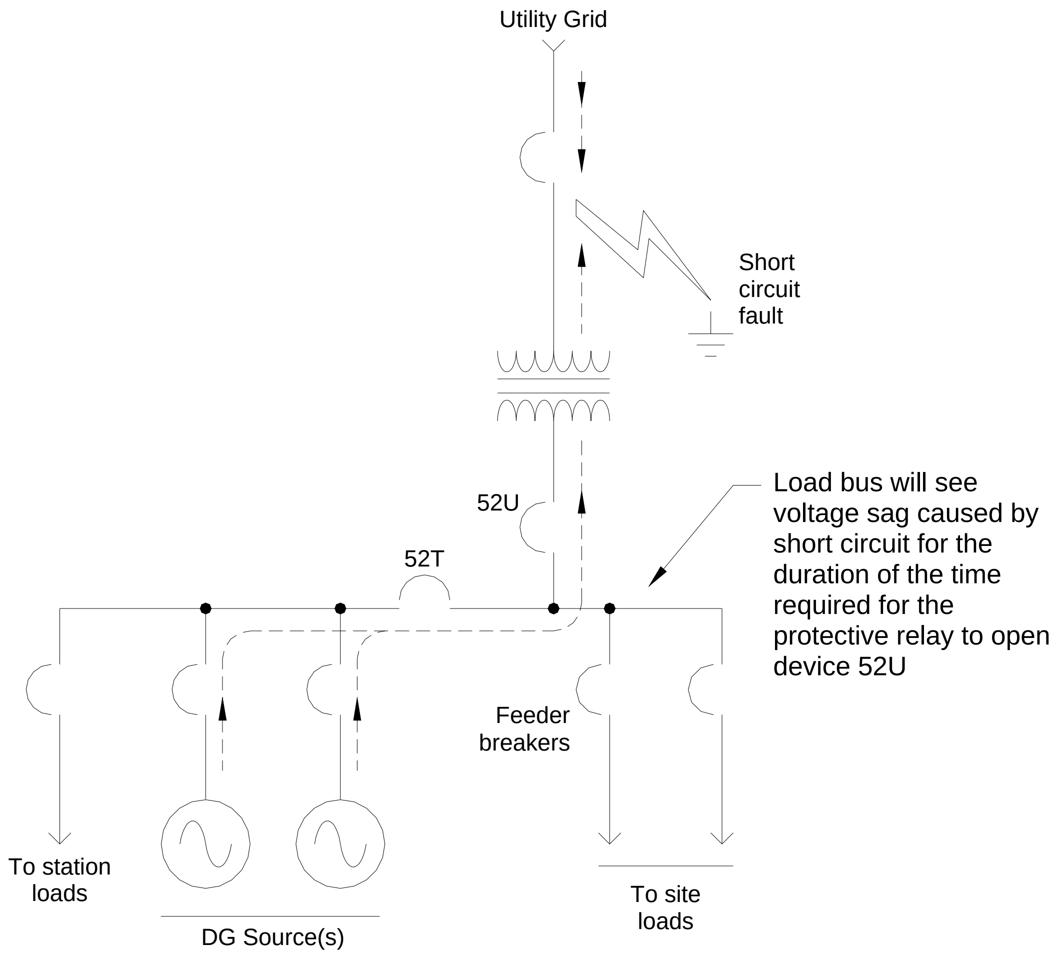

Figure 7. Fault causing voltage sag on load bus

5. Harmonics.

When DG is connected directly to the low voltage side (typically 480 V or 208 V in the US) of the utility distribution transformer, as shown in Figure 8, and DG produces even low level of 3^{rd}, 9^{th} or 27^{th} harmonics in voltage, high circulating currents in the neutral may result.

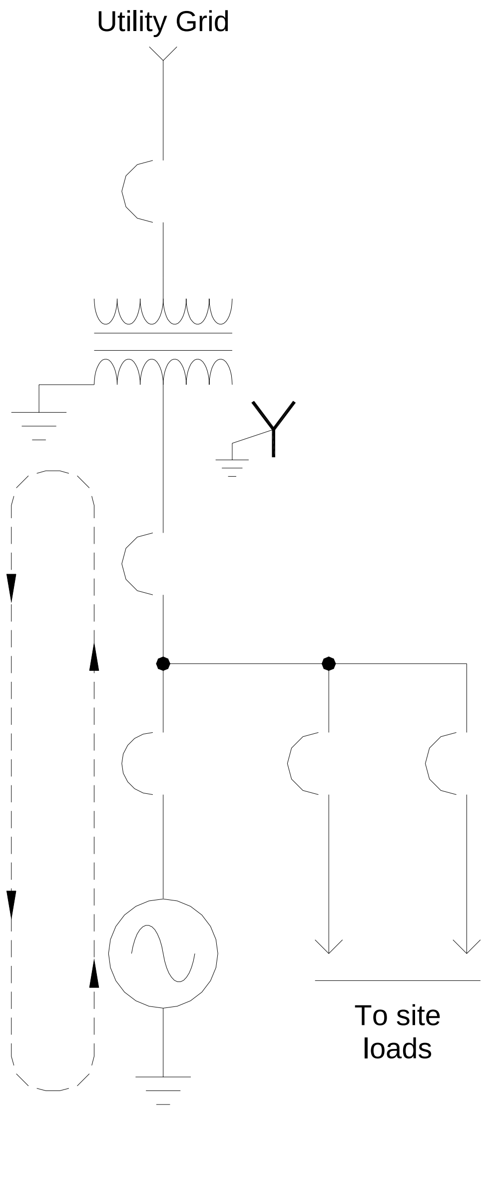

Figure 8. Harmonic current flow through ground connections

6. Circulating currents in ground.

When DG is connected directly to the low voltage side (typically 480 V or 208 V in the US) of the utility distribution transformer and the utility circuit breaker on the secondary of the transformer has to meet service entrance rating requirements of the NEC and UL, circulating currents in ground may result. This will happen if there is unbalanced line to neutral loads in the system. NEC and UL require for the neutral to be grounded at the point of service entrance. Most utilities will require grounding of the secondary neutral of the distribution transformer, at the transformer. The DG neutral will have to be grounded also, since it will carry 4 wire facility load in case of utility outage. This situation creates multiple grounded neutral, with part of the neutral current flowing through the earth. At the same time in case of ground fault, some of the ground fault current will flow through the neutral. This situation complicates the design of the appropriate ground fault protection for the system.