Overview of the "Standard for Interconnecting Distributed Resources with Electric Power Systems", IEEE 1547 and it's potential impact on operation of the Distributed Generation (DG) systems and on the design of the switchgear intended for the transition of the distributed generation resources (DR) to and from grid connected operation.

Adoption of the IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Std 1547-2003 presents a significant technical resource for the individuals and organizations involved in interconnection of the distributed generation resources to the utility grid. As stated in the standards abstract *"IEEE Std 1547 has the potential to be used in federal legislation and rulemaking and state public utilities commission (PUC) deliberations, and by over 3000 utilities in formulating technical requirements for interconnection agreements for distributed generators powering the electric grid."*

As stated in the Introduction to the standard: *"There is a critical need to have a single document of consensus standard technical requirements for DR interconnection rather than having to conform to numerous local practices and guidelines. This standard addresses that critical need by providing uniform criteria and requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection.*

The intent of this standard is to define the technical requirements in a manner that can be universally adopted. The universality relates not only to the technical aspects, but also to the adoption of this standard as being pertinent across a number of industries and institutions, e.g., hardware manufacturers, utilities, energy service companies, codes and standards organizations, regulators and legislators, and other interested entities."

As we can see IEEE Std 1547-2003 attempts to provide all the answers in the complex field of interconnection of the DG resources with aggregate capacity of 10 MVA or less with the utility grid. For the purposes of this report, interconnection is defined as a combination of the equipment and electrical engineering services necessary to implement continuous parallel operation of the DG with the utility grid at one physical location. Continuous parallel operation assumes duration of the electrical connection of the DG to the utility grid for the duration longer than 100 mS. Universal adoption of this standard could substantially reduce typical cost of the interconnection as well as the installation cycle of the grid connected DG.

IEEE Std 1547-2003 defines and summarizes brought range of the defined issues identified by the power industry related to the parallel operation of the DG with the utility.

The following acronyms are used by the standard:

Area EPS -- Area electric power system

DG -- distributed generation
DR -- distributed resources
EPS -- electric power system
I -- current
IL -- load current
ISC -- short circuit current
Local EPS -- Local electric power system
PCC -- point of common coupling
TDD -- total demand distortion
TRD -- total rated-current distortion

The following are the major sections of the "*Interconnection technical specifications and requirements"* of the standard:

4.1 General requirements
4.2 Response to Area EPS abnormal conditions
4.3 Power quality
4.4 Islanding

"General requirements" section specifies that the interconnected DG installation shall follow common power systems design practices and meet the requirements of the other applicable ANSI/IEEE standards as it relates to the voltage regulation, surge withstand, flicker and electromagnetic interference. There is a requirement to provide connection status monitoring, real power, reactive power and voltage metering for the DG installations of 250 kVA or more.

The requirement of the section 4.1.4.2: *"Connection of the DR to the Area EPS is only permitted if the Area EPS network bus is already energized by more than 50% of the installed network protectors."* may need to be further clarified by the standard. Without complete understanding of the intent, it seems that depending on the power system configuration, this requirement may not be essential, but very costly to meet.

Another requirement of the section 4.1.4.2 is: *"The network equipment loading and fault interrupting capacity shall not be exceeded with the addition of DR."* The reason for this requirement is illustrated below in Figures 1, 2 and 3.

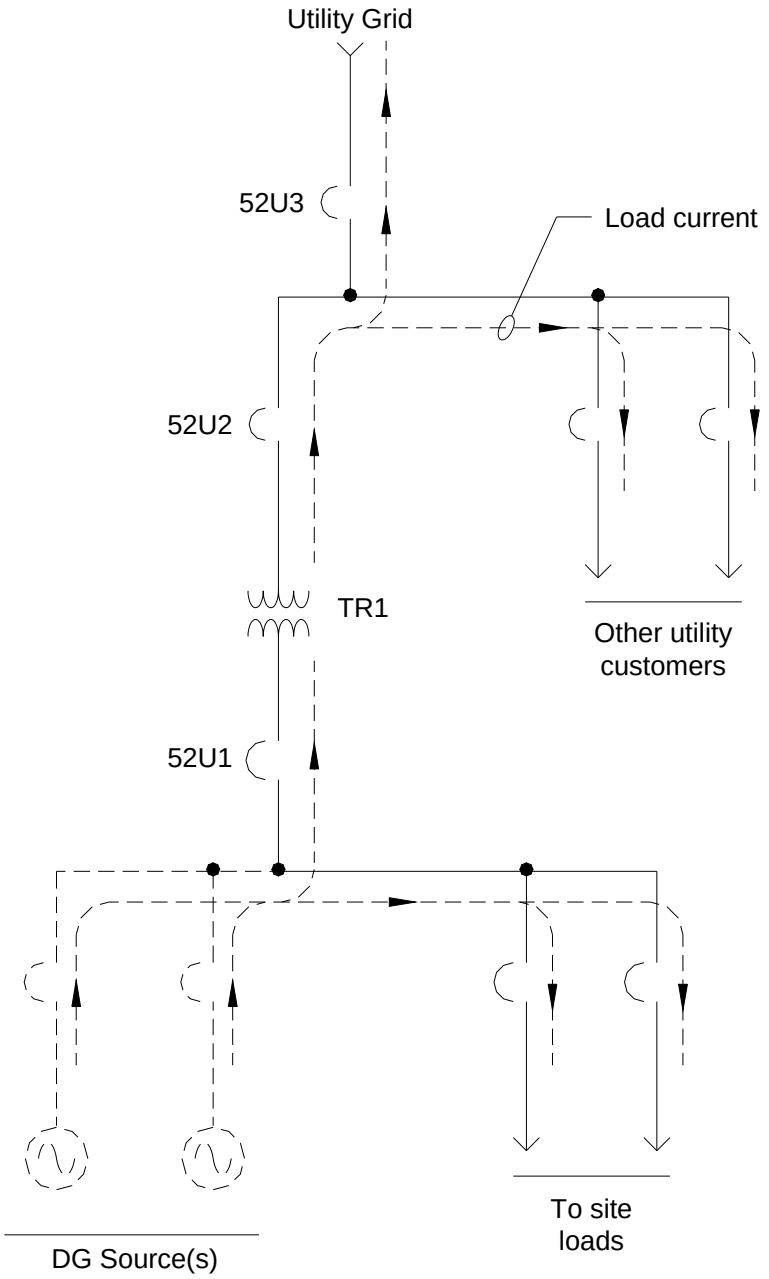

Figure 1.

The transformer TR1, network protectors 52U1, 52U2, 52U3 and corresponding power cables should be checked for adequate load rating, before DG sources can be added to the system.

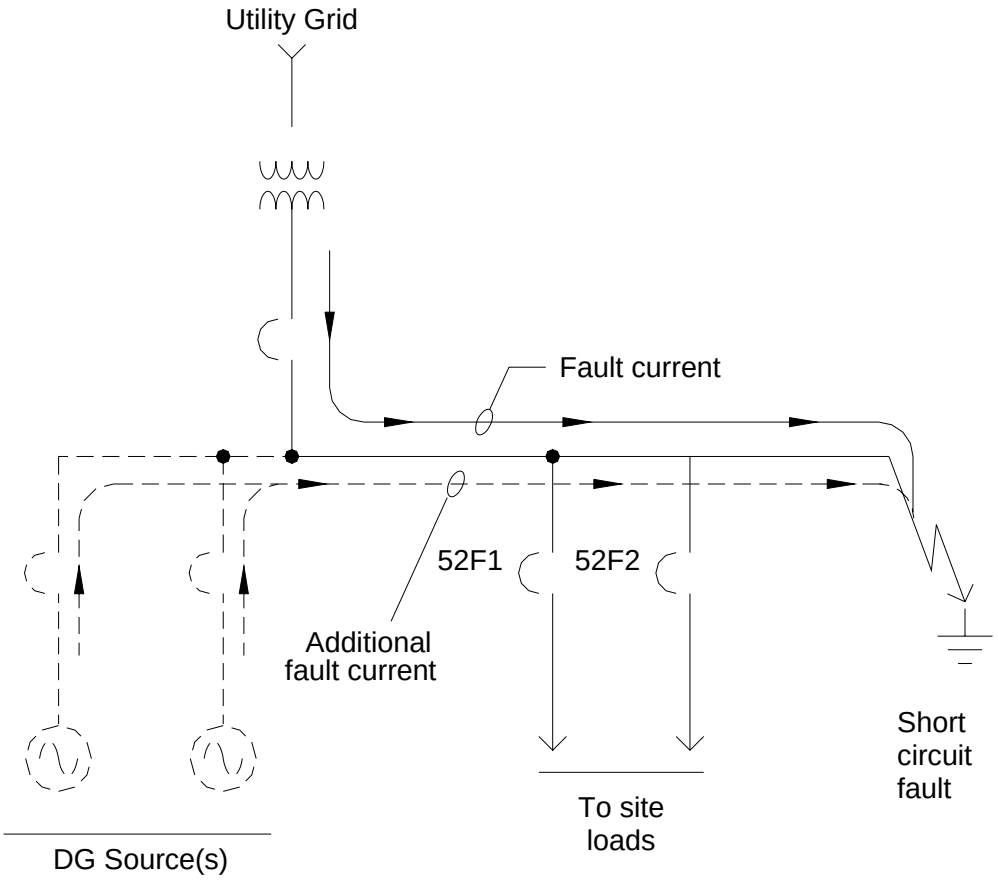

Figure 2.

New system fault study needs to be performed. The interrupting ratings of the network protectors 52F1 and 52F2 should be verified and compared with the new calculated available fault currents.

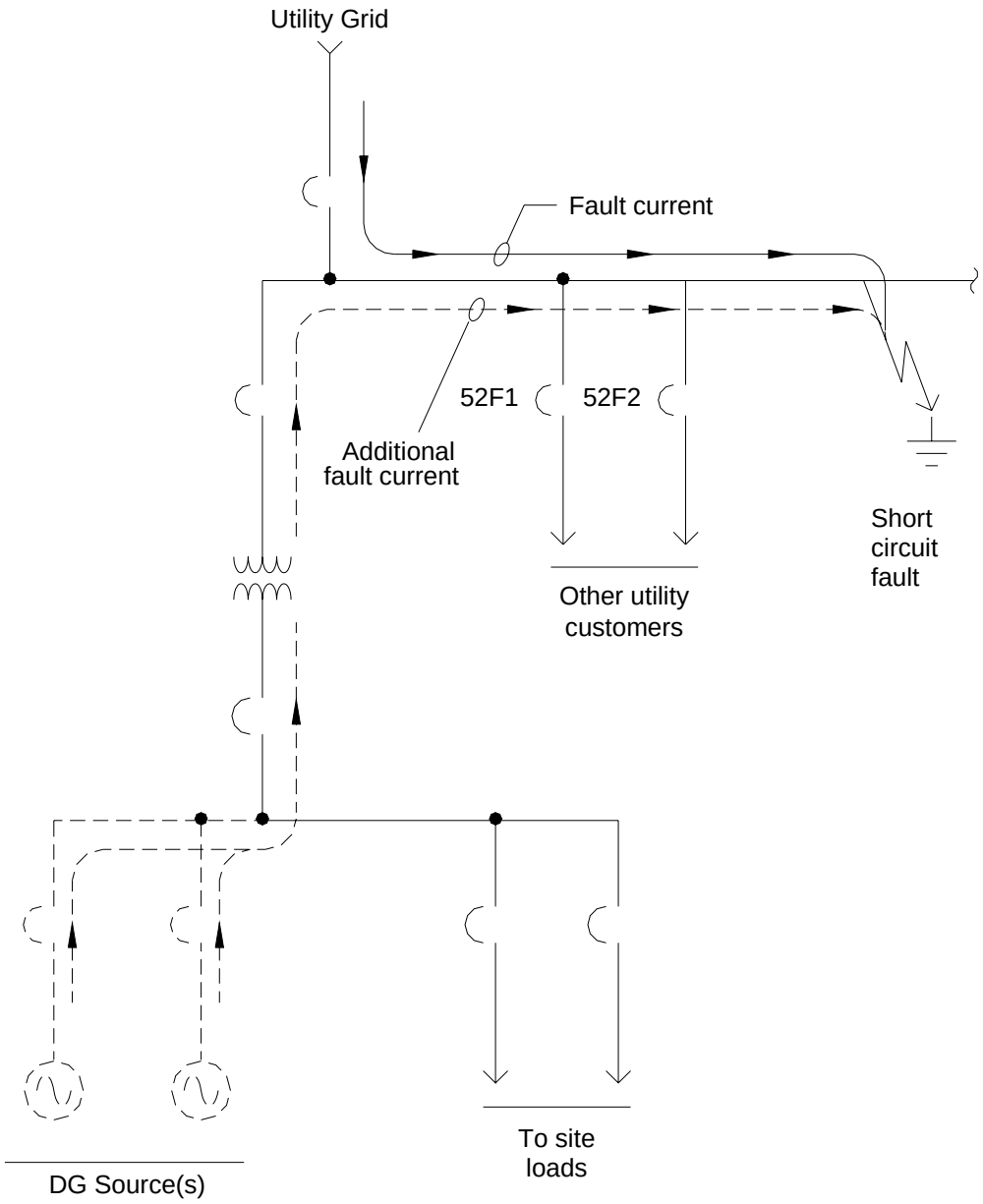

Figure 3.

New system fault study needs to be performed. The interrupting ratings of the network protectors 52F1 and 52F2 should be verified and compared with the new calculated available fault currents.

"Response to Area EPS abnormal conditions" section defines interconnection protection requirements. The protective functions addressed are over/under voltage and over/under frequency protection and reconnect enable time delay.

The following are the interconnection protection setpoint ranges according to the standard:

Table 1—Interconnection system response to abnormal voltages

Voltage range (% of base voltage a)	**Clearing time(s) b**
V< 50	0.16
50 ≤ V< 88	2.00
110 < V < 120	1.00
V ≥ 120	0.16

a Base voltages are the nominal system voltages stated in ANSI C84.1-1995,
b DR ≤ 30 kW, maximum clearing times; DR > 30kW, default clearing times.

Table 2—Interconnection system response to abnormal frequencies

DR size	Frequency range (Hz)	Clearing time(s)[a]
≤ 30 kW	> 60.5	0.16
	< 59.3	0.16
> 30 kW	> 60.5	0.16
	< {59.8 – 57.0} (adjustable set point)	Adjustable 0.16 to 300
	< 57.0	0.16

a DR ≤ 30 kW, maximum clearing times; DR > 30 kW, default clearing times.

In addition to the over/under voltage and over/under frequency protection the standard defines the following essential requirements to the interconnection protection in sections 4.2 and 4.4:

"*4.2.1 Area EPS faults*
The DR unit shall cease to energize the Area EPS for faults on the Area EPS circuit to which it is connected."

"4.2.2 Area EPS reclosing coordination
The DR shall cease to energize the Area EPS circuit to which it is connected prior to reclosure by the Area EPS."

"4.4.1 Unintentional islanding
For an unintentional island in which the DR energizes a portion of the Area EPS through the PCC, the DR interconnection system shall detect the island and cease to energize the Area EPS within two seconds of the formation of an island."

Operation of the utility distribution reclosures is one of the common cases of unintentional islanding, Figure 4. Typical utility non time delayed reclosing takes 200 – 300 mS, from the time the main contacts open to the time they reclose. This means that if the utility company uses non time delayed reclosing, despite the 2 seconds requirement of paragraph 4.4.1, the DG disconnection time shall be less than 200 mS.

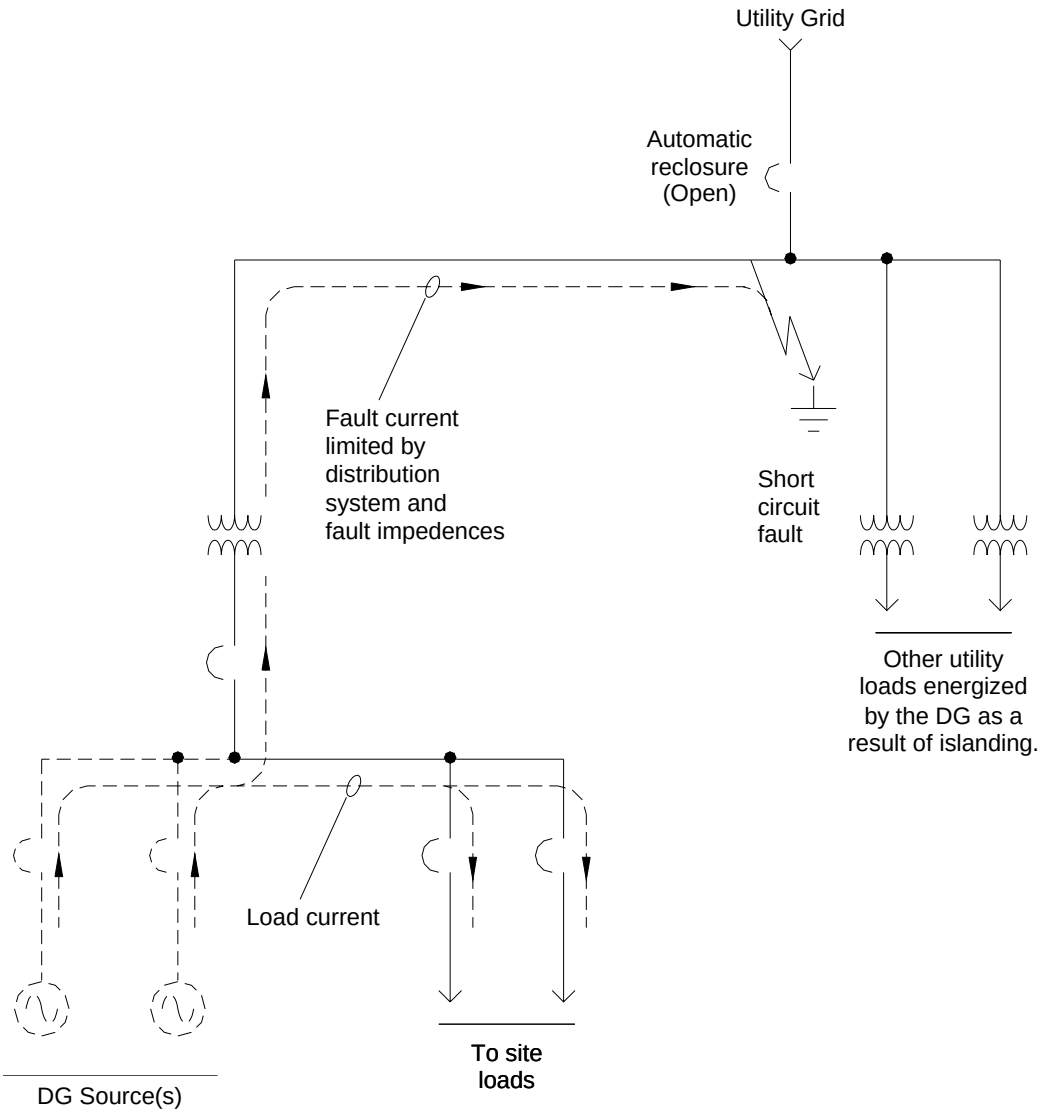

Figure 4.

The requirement of the paragraph 4.2.1: *"The DR unit shall cease to energize the Area EPS for faults on the Area EPS circuit to which it is connected."* generically describes the main purpose of the interconnection protection. One of the ways to meet this requirement is to rely on the utility company's protective relaying to detect faults in the utility power system and trip the appropriate network protectors. At this time if DG is still connected to the grid, an unintentional islanding condition will be created. Interconnection over/under frequency and voltage relaying will be in the position to detect the unintentional island and disconnect the DG from the grid. For the fast detection of the unintentional island condition by the interconnection over/under frequency and voltage relaying it is typically necessary that the total load connected to DG during unintentional island is greater or less than the DG load levels immediately before the unintentional island condition by at least 5-8% of the DG rating.

Additional protective functions used to disconnect the DG from the grid, upon fault in the utility grid system are:

- Time overcurrent protection , device 50/51
- Time overcurrent protection with voltage restraint or control, device 50/51V
- Directional current protection, device 67
- Directional power protection, device 32
- Distance protection, device 21
- Ground fault protection, device 50/51G and 59G
- Transfer tripping