Setting the Standard

PRC-024-2 & LVRT requirements – differentiation between internal and external faults in wind and solar farms

by Augusto Morando

THE FEDERAL ENERGY REGULATORY COMMISSION (FERC) APPROVED Reliability Standard PRC-024-2; this standard requires power plants to set their relays so that the plant remains connected during power spikes. PRC-024-2 ensures that plant owners set their generator protective relays so that generating units remain connected during defined voltage excursions, including the operation for 9 cycles (150 ms) at zero voltage, measured at POI (Point Of Interconnection). In other words, protection relays must not trip the generators within the "no trip zone" for faults happening at POI, or beyond the wind or solar plant. (Figure 1)

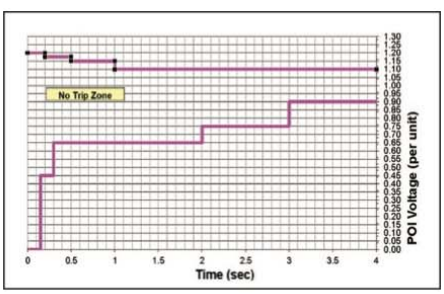

Figure 1: *Voltage Ride-Through Time Duration Curve.*

POI means the transmission side starting on the high voltage side of the substation main transformer of a wind or solar power plant substation.

In order to comply with the standard, power generation asset owners have been resetting their protection relay of their wind and solar power plants. But faults also happen inside the wind or solar farm, so there is a need for differentiation between internal and external faults, and that is what VDH/GSMI provides.

In order to study the FERC PRC-024-2 requirement effectively, a PSCAD tool was used to simulate how the voltage would behave at the mains of the Generator in a farm equipped with VDH/GSMI – first, in the presence of an External Fault, and second, in the presence of an Internal Fault. (Figure 2)

For our External Fault simulation, we will consider that voltage will drop instantaneously to zero at POI for a period of 150 ms. (Figure 3)

When an External Fault happens, there is voltage drop at the terminals of the Generators (in our PSCAD model, that drop was 83%). After 150 ms the fault disappears. Although 83% is a huge drop, it is not as robust as the voltage drop caused by the combined circuit breaker and high-speed grounding switch (VDH/GSMI) tripped during an Internal Fault.

Simulating an Internal Fault, the combined circuit breaker and high-speed grounding switch (VDH/GSMI) trips, opens the feeder circuit, clears the fault, and, in less than a cycle, makes a balanced three-phases short to ground on the collection circuit. This causes a robust voltage drop at the terminals of each generator unit. (Figure 4)

In case of an Internal Fault, in our PSCAD modeled farm, the voltage measured at the terminals of the Generators dropped more than 90%.

The difference in voltage drops between Internal and External faults is given by the impedance of the main plant power transformer. In both cases the system is in presence of zero volt; in one case said zero volt is outside the farm (External Fault), and on the other case on the collection circuit (Internal Fault).

Figures 5 and 6 show voltage drop on a per-unit basis. In Figure 5, the voltage drop is measured at the terminals of the Generator, caused by a voltage drop to zero for a period of 150 ms at POI (External Fault). In Figure 6, the voltage drop is caused by the action of VDH/GSMI after clearing the Internal Fault. Figure 7 is an overlap of figures 5 and 6, showing the difference of voltage drop at the terminals of the Generators. At near full power for the wind or solar power plant, the delta in voltage between the two fault locations is 8%, a clear signal for the Generators to stay online, or shut down.

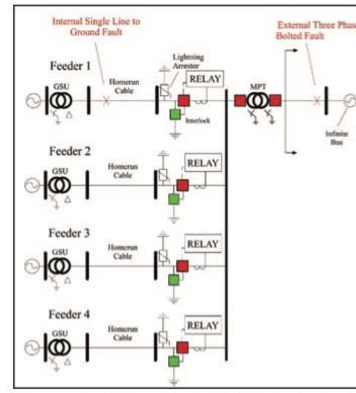

Figure 2: *Faults locations for PSCAD simulations in a Wind or Solar Power plant using VDH/GSMI.*

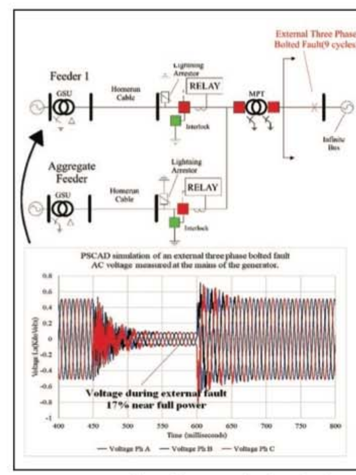

Figure 3: *External Fault location (top) and Voltage measured at the mains of the Generator (bottom).*

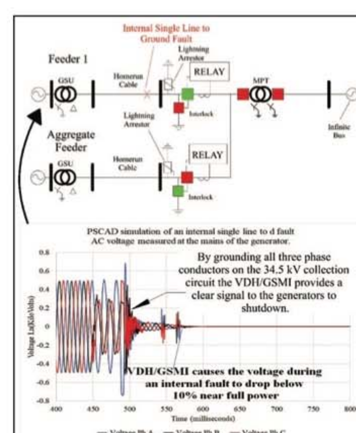

Figure 4: *Internal Fault location (top) and Voltage measured at the mains of the Generators in a farm equipped with VDH/GSMI (bottom).*

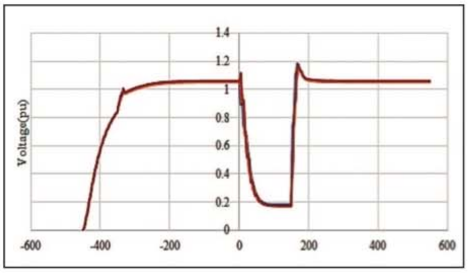

Figure 5: *Voltage drop at the generator terminals subjected to an External Fault.*

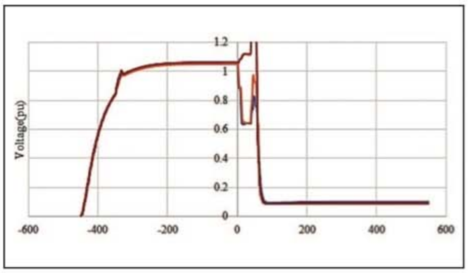

Figure 6: *Voltage drop measured at the terminals of the Generator, caused by the fast action of VDH/GSMI after clearing the fault.*

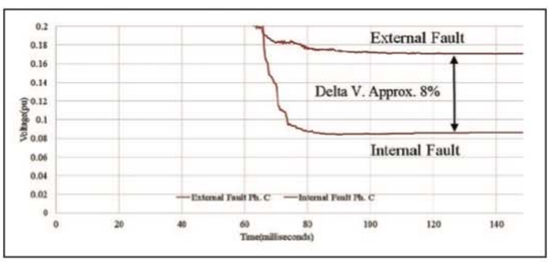

Figure 7: *Comparative of voltage drop at the generator terminals – Amplified overlap of Figure 5 and 6.*

The result of these simulations shows that this rapid impedance change, made by the combined circuit breaker and high-speed grounding switch (VDH/GSMI) as a feeder breaker, can help design engineers provide PRC-024-2's required functionality and protection systems by making it easier to differentiate between Internal and External Faults.

This special feeder breaker signals the generators that the fault is inside the plant, and shuts them down when under-voltage ride through is not necessary. This provides a valuable discriminatory function that regular MV circuit breakers do not.

The balanced three-phases short to ground, caused by VDH/GSMI, dropping voltage to zero at that point, should be treated as a shutdown signal. This signal starts at the substation, and goes through the power cables to all the generators of the collection circuit - faster and safer than any other means - and gets to all of the connected generators at the same time.

By measuring voltage at generator terminals, it's possible to identify a fault outside the plant and keep generating power, while complying with PRC-024-2.

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