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Fault Characteristics and Protection of Distributed Solar Generation

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Abstract *– Inverter-based distributed energy sources (DERs) are inverter-based distributed instruments for power, with a low current defect, negligible negative, and null series currents. In the analysis and protection of relays, an understanding of the fault properties of DER is necessary. Despite considerable work on DER modeling, no study was performed on the fault behavior of DER during actual fault events. This text addresses instances of faults of Dominion Energy. Stopper flaws are examined to show that the true response to DER errors could be different than before. A sophisticated simulation platform was used to simulate any contribution with the MATLAB setting to this analysis. Verification shall be given where the simulation findings can be checked with other results published. However, more research is needed to prototype and validates rigorously the theories built using real-world networks so that the efficiency of the contributions made to this thesis can be thoroughly evaluated.*

Keywords*:* **Inverter, Solar Generation, Fault Protection, DSG**

I. INTRODUCTION

The future active network would easily and securely link small to medium-sized energy sources to consumer requirements. As a backup power, DG is often used to improve capacity, delay maintenance in transmission and distribution networks, avoid network costs, reduce line losses, defer the development of large-scale generation projects, shift the expensive power from the grid supply system, provide customer alternatives and deliver environmental benefits. However, based on system architecture and management, these advantages cannot be valid. In recent years the DG has become an effective and fast-track alternative to traditional power sources, and modern technologies have made DGs commercially viable. [1]

One of the most important aspects of electricity planning is the design of protection schemes. Security algorithms observe and erase faults. An unintentional driving direction or current barrier is an electrical grid fault (open circuit). Typically, the most common short circuit mistake is that most people use the term defect, and it is commonly assumed. We narrowed our discussion to some short-circuit mistakes in this technical report. A loss occurs when another electrical component with a certain voltage is supplied with a power supply. This causes impedance between the two control elements to collapse to nearly 0, allowing current to flow down the original track. Orders over normal operating current may be the defective current of the short circuit. The event can generate big damaging energy (heat and magnet power) that can damage electrical equipment and cause problems of safety for both utilities and non-utility staff. [2]

Traditional feeders are radial systems of which the user is the key fault point. Mainstream mistake detection schemes are used. When the measured value crosses the default value momentarily or time lag, an over-current device operates in schemes that overflow. The duration between major and backup defensive systems is matched in order to allow the first to safely clear a malfunction before the least disruption. They are another cause of loss, as energy distributions Resources (DER), as they are put on delivery circuits. The DER fault current partially compensates for the tool's current charge, which tends to slow relay operations. Therefore, a detailed definition of the characteristics of DER fault is necessary with the impact of DER on the current fault analysis and safety relay environment. [3]

II. DISTRIBUTED GENERATION BACKGROUND

The term distributed or distributed generation refers broadly to any technology for an electric generation, which is applied near the point of use in distribution systems.

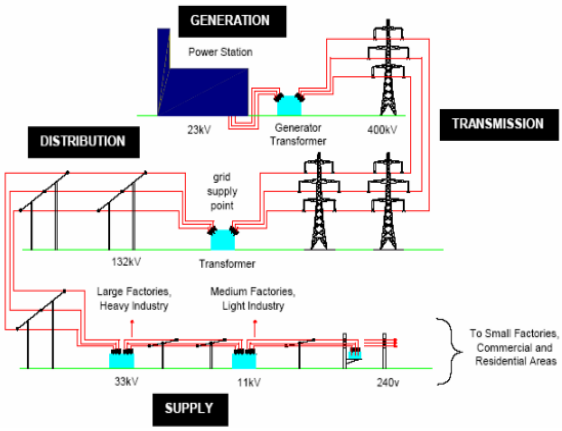

Figure 1 An electric power system

The DG model compares with a traditional central electricity generation system in which power is produced and transmitted to end customers through transmission

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and distribution lines. Although central power systems remain essential to the global energy supply, they have diminished versatility in order to satisfy changing power demands. Central power consists of a large power plant with capital strength and the T&D grid for electricity dispersion.

III. METHOD

3-phase transmission line: one of the core elements of an electrical power grid is the power transmission line. It primarily transmits electrical energy from energy sources to charging centers, normally separated by long distances, with limited losses. Three-phase electricity is the standard way to produce, transfer, and deliver electricity in alternating current. It's the most common approach used by electric grids worldwide for power transmission and a form of polyphase scheme. It is also used for driving big and other heavy engines. A three-wire, three-phase circuit is normally more economical to transfer a specified quantity of energy than an analogous two-wire single-phase circuit at the same line of the ground voltage. [44]

Transformer: In connecting power systems at varying voltage levels, transformers play a vital role. Without the capacitor, electric power may actually not be found in many ways today. Transformers thus hold major positions in the electricity grid and are a critical connection between plants and points for the use of electricity. In order to create a mutual coupling entre electrical circuit, the transformer ANSI/ IEEE was defined as a static electrical system composed of two or more windings, with or without the magnet core. Better transformer architecture and the use of high-quality electric steel, which is one of the main transformer failure components, will dramatically decrease the loss of no load. In some cases, no loss of load could be further minimized if normal electric steel could be replaced with amorphous metal. [45]

Feeder: Electric power delivery grid, since electricity is supplied to domestic and industrial customers, is a very necessary infrastructure. Its consistent performance is vital to the building of nations and the way of life of people. The shortage of power delivery services has a direct or indirect negative influence on the well-being of consumers in their day-to-day lives and the social economy. Feeders are electricity-carrying loops to sub-stations. The stability of electrical delivery systems is critical to their effectiveness and 24/7 consistent energy provision. Better feeder configuration and feeding automation delivers robust and over one supply route, while automation helps to define and locate the feeder length fault point. [46]

Load: The conventional single-source radial distribution network has been changed in recent years to a multi-source distribution system with a wide number of distributed generations (DGs). A special charge from the power grid, to form an off-grid power supply zone, can be isolated if the device fails. DGs can be used to improve stability for consumers in the energy supply area off-grid. The function of the distribution system is getting more complex with the vast volume of distributed generation in operation. A method to increase load stability is, therefore, required. [47]

POI Reclosure: The POI relay automatically insulates by the opening of a breaker (or recloser) circuit at the POI. The relay opens the POI when short loops, circuits, or conditions of feedback are detected. The relay is configured by expert engineers to identify disturbances within and outside the system to prevent disturbances. Opening the POI provides the microgrid safety and control mechanism with a vital indication. The POI-opening normally begins fast load shedding or the distributed energy resources (DER) to avoid blacking out of the microgrid. The POI opening indicator is often used to modify the relay safety configuration in the microgrid to conform to lower current failure rates, and DER control systems may also indicate a change in operating modes. [48]

DER: DER is steadily adding to the energy efficiency and reliability of the economy today. DER may also play a vital role, as a result of concentrations of consumer influence, in preventing dysfunctions in dynamic markets for electricity. The newly formed independent grid operators are starting to engage in demand control projects to better handle summer's peak loads. The DER Interconnection Mechanism consists of every device that forms a physical connection between the DER and the EPS, typically the local electrical distribution network (hardware and software). Since the interconnection mechanism is an electrical connection between the DER device and the EPS, it governs energy movement in one or both directions and is capable of providing separate and foundational functions to benefit EPS as well as DER operations.[20]

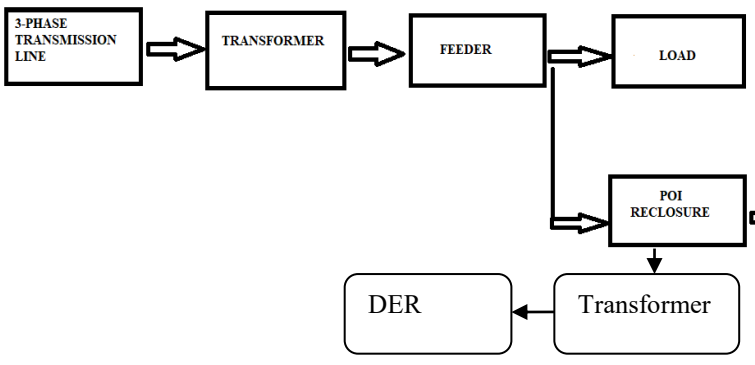

Figure 2 Different components used in proposed methodology

Working

The simulation of a three-phase photovoltaic transmission system is integrated by a preview technique of a courant short circuit PVA and load controller. The technique is based on the current rise and the magnitude in a DER-based solar PV device. A standard feeder is the model of the study method. The transmission line

delivers electricity from power sources to the load centers with limited losses. It's the most common approach used by electric grids worldwide for power transmission and a form of polyphase scheme. Next, the feeder is connected to the transmission line with a coupling transformer known as a transformer. In the electrical energy grid, transformers hold large positions as they are the critical connections between electricity generators and electricity usage points. The feeder from the transformer is then supplied with fuel. A feeder is a kind of transmission line that carries energy to the distribution point from the source station. They are similar to distributors in that there is no intermediary pressing, so both the transmitting and the receiving end have the same current flow. Power from the feeder is supplied to DER by means of POI reclosure and transformer. POI reclosure detects short, open, or back feed conditions of short circuits. The POI is an important predictor for the safety and control systems of the microgrid. Before DER, the POI recalibration is related to DER with the coupling transformer known as phase-down transformer. In the future, the DER stores PVA power. A PV array can provide direct power to light loads such as DC motors or lighting systems through the output current and stress.

PV Array

Obviously, their dependency on the temperature conditions, which significantly alter the power production, is the key issue of photovoltaic plates. This thesis generates a PV array via the MATLAB simulation, which in the various climatic conditions, is simple and efficient. Sunlight can be transformed directly into electricity by a PV system, and wind energy can be used to produce power that can be further filtered by some powerful electronic load controls. The basic unit of a PV device is a photovoltaic cell. To build PV panels and PV arrays, the PV cells can be ordered in series/parallel. For commercial usage, the energy provided from one single module is seldom sufficient to group together the modules in the form of a photovoltaic range that can provide the need for the load. A PV array can provide direct power to light loads such as DC motors or lighting systems through the output current and stress. More challenging power applications need power converters to fulfill the demand for PV array power. [41]

IV. RESULT

The studied faults are located on feeder and outside of a solar farm. Data on faults are obtained by the POI recorder, which calculates DER inverters' fault current contribution. The coordinated control system consists of a group of sensor devices, equipment controllers, data input devices, and systems, as seen in the following figure 3. None of the sites were operating at full power capacity when the fault events occurred.

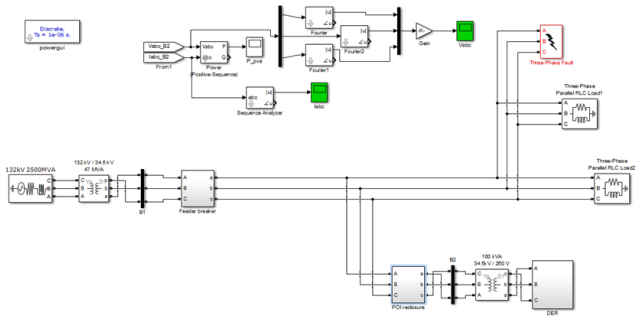

Figure 3 Simulation model without relay

A circuit breaker is an electronically controlled electric interrupter intended to guard an electrical device against any disruption due to excess current in combination with overload or short circuit. Its primary purpose is to disrupt the flow of the current after a fault has been observed. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.

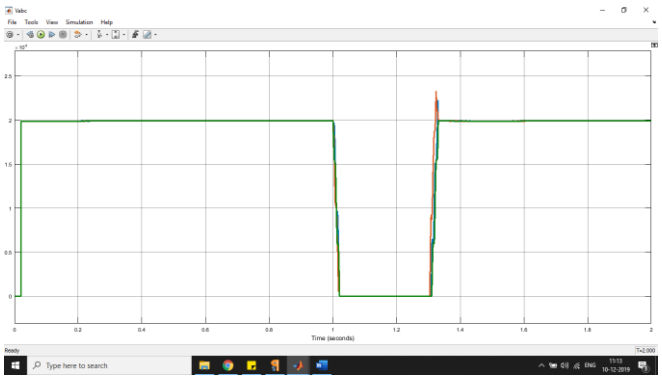

Figure 2 PVA voltages with no relay protection with fault from 1 to 1.3sec

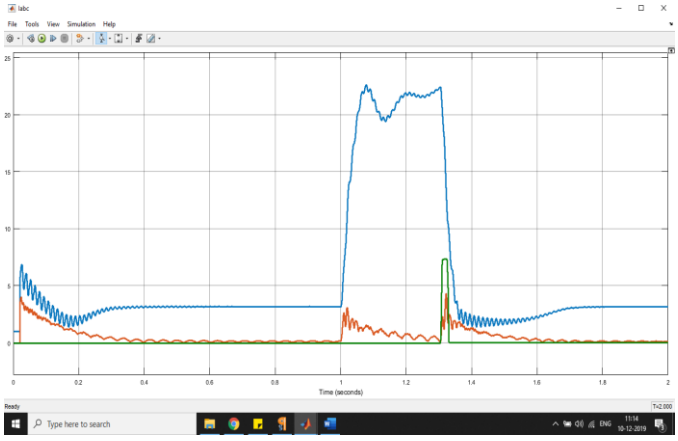

Figure 3 Sequence currents with no relay protection with fault from 1 to 1.3sec

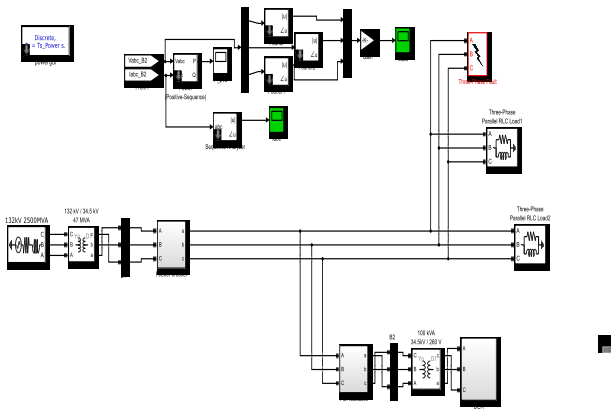

Figure 4 Simulation model with over current relay

The over-current relay is an important relay for the security of feeders, transformers, bus couplers, etc. It may be used for the security of main or backup relays. In the research into the effects of network parameters and configurations on the performance of these relays, the modeling of overcurrent relays and other safety relays is relevant. The present relay using the MatLab/Simulink program is explored in this study shows in the image. The simulation model over the current relay shown above shows the simulation model. Relay is a sensor that short-circuits and unreliable. If a device breakdown occurs, the high-current flow of the circuit and relay belt is energized, and an operating signal is transmitted to the breaker, which connects the circuit breaker and protects the circuit by the insulation of the defective portion. The current transformer (CT) and potential transformer (PTs) are respectively used for the supply input and voltage relays. The amplitude and phase relationship of the producer or builder depends on the device conditions of a predefined value.

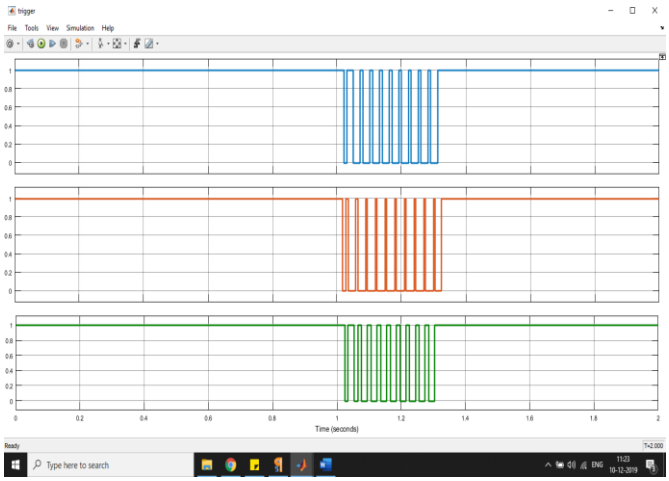

Figure 7 Triggering pulses of over current relay

The number of triggers is very high as the fault is persistent the relay cannot eliminate the fault permanently.

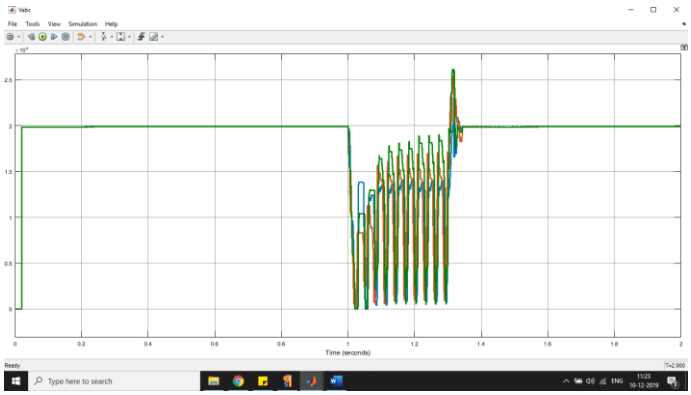

Figure 8 PVA voltages with over current relay protection with fault from 1 to 1.3sec

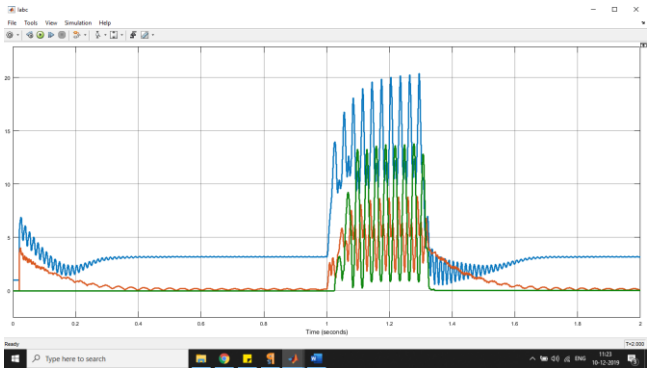

Figure 9 Sequence currents with over current relay protection with fault from 1 to 1.3sec

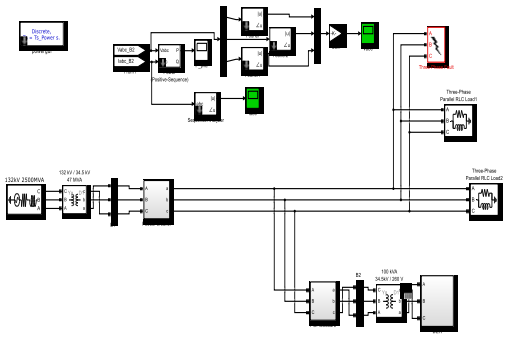

Figure 50 Proposed simulation model of counter set reclosure over current relay

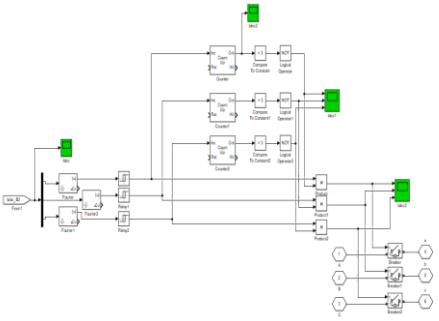

Figure 11 Circuit breaker with counter set reclosure over current relay

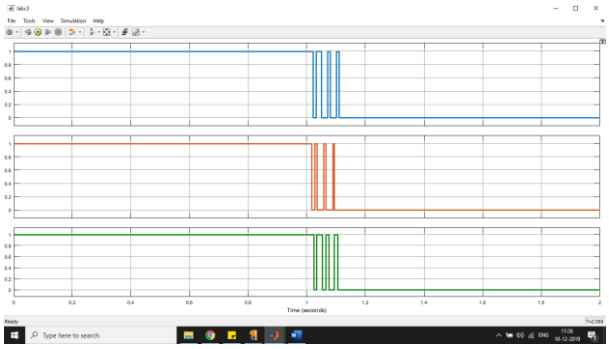

Figure 12 Triggering pulses of over current relay

The restricting times is limited to 3, after three times the relay completely triggers OFF and eliminate the fault from DER.

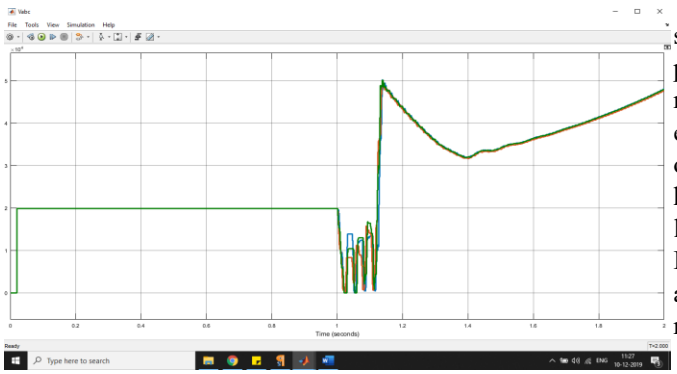

Figure 13 PVA voltages with over current relay protection with fault from 1 to 1.3sec

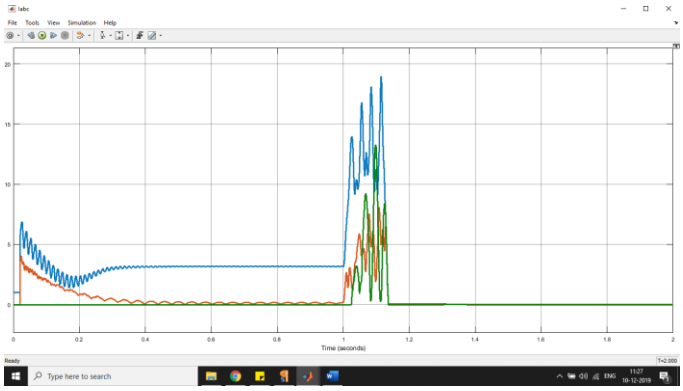

Figure 14 Sequence currents with over current relay protection with fault from 1 to 1.3sec

In figure 14, the number of constraints is seen with the counter set reclosure over the current relay to three cycles, which activates the circuit breaker OFF entirely while the loss persists beyond three reclosure times.

V. CONCLUSION

There are limits on all numeric models, e.g., mathematical models. A mathematical simulation model can have proper simulation outcomes with the form of the phenomenon to monitor or analyze with the part of the model (such as protections, controls, and capabilities). Therefore, power system engineers in academia and industry can conduct the right selection of the mathematical simulation model. However, it is not an easy job to choose the right mathematical model of Simulation.

The cost of investment also looks like clean energy such as solar energy. On the other hand, the ongoing price increases combined with the reduced operating and repair costs are a way of generating energy in an environmentally sustainable manner. One important part of their work is also that they create power every day in hours, which can be used mostly directly to prevent a lack of storage.

Energy storage systems such as batteries and fuel cells are controllable and scalable components and can boost reliability and power efficiency.

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