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Analysis of Fault Characteristics of Distributed Solar Generation

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Abstract- *Inverter-based distributed energy resources (DERs) are characterized with low fault current and negligible amount of negative and zero sequence currents. Understanding DER's fault characteristics is critical for fault analysis and protective relay setting. Despite the abundant work on DER modelling, few research studies have been done to analyse DER's fault behaviours during actual fault events. This paper explores recorded fault events collected by Dominion Energy. Fault magnitude, angle, and sequence components are analysed to show that actual DER fault response may differ from previous understandings. The general reclosure over current relay is replaced with counter set reclosure over current relay which completely triggers off when the restricting number crosses 3 times. So, the over current relay only closes to short transient faults but not long-time faults. The analysis with respect to different conditions is checked using a DER (PVA) connected to this counter set reclosure over current relay.*

Keywords:- Photovoltaic Array OverCurrent Relay, Counter Set reclosure over current relay, MPPT, PWM Generator, Buck -Boost converter.

Introduction

With the increased demands of the electrical power systems and events of electricity shortages, power quality issues, rolling blackouts and spikes in electricity price have led to research of alternate sources of energy.

This led to the development of Distributed Energy Resources (DER) that is a small-scale power generation source located close to where electricity is used and primarily acts as an alternative to or an enhancement of the existing electric power grid.
With consideration to the construction of large, central power plants and high-voltage transmission lines, DER is a faster and less expensive option. It offers higher reliability, increased power quality, high energy efficiency and energy independence. The utilization of renewable distributed energy generation methods and green power like wind, biomass photovoltaic, geothermal or hydroelectric power provides a noteworthy environmental benefit.

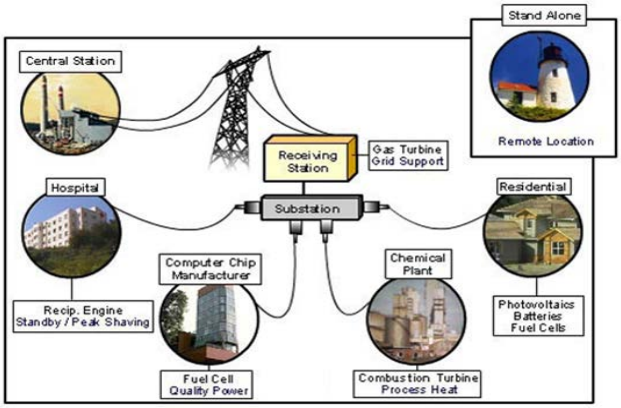

Fig. 1.1: Types of distributed energy resources and technologies.

DER has been in the field for many years and is commonly known by names such as generators,

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back-up generators or on-site power systems. But within the electric industry the requisites that have been used are distributed generation (DG), distributed power (DP), and DER.

Distributed Generation: technology that produces power outside of the utility grid like fuel cells, micro turbines and PV cells

Distributed Power: technology that produces power or stores power such as batteries and flywheels

Distributed Energy Resources: combination of technology included in DG and DP as well as demand-side measures. In this configuration power can be fed back to the grid.

1.1.1 Components of DER Technologies

A DER technology mainly consists of energy generation and storage systems placed at or near the point of use which usually includes fuel cells, reciprocating engines, micro turbines, load reduction and energy management techniques. DER also engages power electronic interfaces, communications and control devices so as to obtain higher efficiency and for the operation of single generating units, multiple system packages and collective power blocks.

1.2 Fault Analysis in Power Systems

A healthy power system operates under balanced conditions with normal load currents and bus voltages, which can be disrupted due to faults. If these faults exceed the interrupting rating of the protective device, there can be devastating consequences which can also be a serious threat to human life as well.

Usually short circuit fault current is much larger than normal current. A low resistance connection between the two conductors that supplies power in a circuit is termed as short circuit. Short circuit fault results in large amount of current flow through low resistance path in the power systems and may cause heat, fires and even destruction of power source. Therefore, the fault analysis of a power system is required so as to get information for the selection of switch-gear, conductor size, relay setting, rating requirements and verifying system stability.

II. Proposed Methodology

2.1 Working of Proposed system

Transformers occupy important positions in the electric power system, being the vital links between power generating stations and points of electric power utilization. After this, the power is provided to the feeder from transformer. Feeder is a kind of transmission line which transports power from source station to the distribution point. They are similar to distributors except the fact that there is no intermediate tapping done and hence the current flow remains same at the sending as well as the receiving end. Through POI reclosure and transformer, the power from the feeder is supplied to DER. POI reclosure detects short circuits, open circuits, or back feed conditions. The POI provides a crucial indication to the microgrid protection and control systems. Before DER, a coupling transformer known as step down transformer is connected between the POI reclosure and the DER. The DER stores power in PVA for future use.

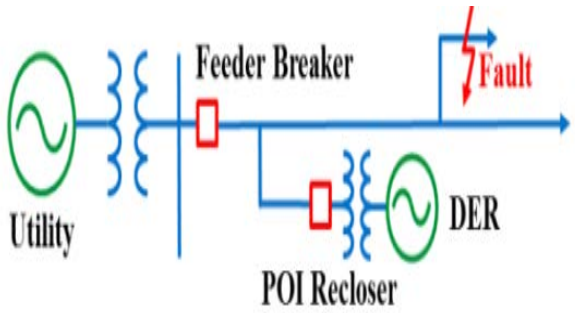

Fig. 2.1: Proposed system of Fault Characteristic of DER System.

2.2 POI Reclosure: The POI relay accomplishes automatic islanding by opening a circuit breaker (or recloser) at the POI. The relay opens the POI when it detects short circuits, open circuits, or back feed conditions. The relay is configured by skilled engineers to distinguish internal from external system disturbances and to avoid nuisance tripping. Opening the POI provides a crucial indication to the microgrid protection and control

systems. The POI opening commonly initiates fast load shedding or distributed energy resource (DER) runback (curtailment) to prevent the microgrid from blacking out. The POI opening indication is also used to change relay protection settings throughout the microgrid to adapt to reduced fault current levels, and it can also signal DER control systems to change their modes of operation.

2.3 DER: DER is playing an increasing role in providing the electric power quality and reliability required by today's economy. It has also become clear that DER can play a critical role in avoiding the dysfunctions in competitive electricity markets caused by concentrations of market power. DER systems are beginning to participate in demand reduction programs recently established by independent system operators to help meet peak summer loads. DER interconnection systems consist of all of the equipment (both hardware and software) that makes up the physical link between DER and the EPS, usually the local electric distribution grid. Because the interconnection system is the means by which the DER unit electrically connects to the EPS, it controls power flow in one or both directions and can provide autonomous and semi-autonomous functions supporting the operations of both the EPS and the DER facility.

2.4 Circuit breaker with counter set reclosure over current relay

A circuit breaker, whose tripping and reclosing functions are programmed and controlled automatically by an intelligent control unit called as "AUTO RECLOSER". Auto Recloser can interrupt fault currents, and also programmed to reclose, to restore the supply. For a traditional over current relay the number of re-closures are numerous as the circuit breakers continuously trips ON after the current magnitude gets below the threshold value. For a temporary fault for few milli seconds the traditional over current relay works fine with less re-closure times. Considering a permanent fault on the line the traditional over current relay trips ON and OFF continuously until the fault is removed. As it is a permanent fault where the lines are sabotaged by direct contact to each other or to ground. This continues tripping of the breaker by the relay will damage the equipment connected to the system. To avoid this damage to the system the traditional over current relay is replaced with counter set re-closure over current relay which permanently trips OFF the circuit breaker after specific number of re-closures. When the fault is removed manually, the breaker is tripped back ON. This protects the system from temporary faults and also permanent faults. The counter set re-closure over current relay trips back ON for temporary faults and permanently trips OFF for permanent fault.

III. Simulation Result and Discussion

The complete design related to the project is created in MATLAB & Simulation using Sim Power System Toolbox and. This designing is conducted in two stages:

- To design a simulation model with over current relay.
- To design a proposed simulation model of counter set reclosure over current

3.1 Simulation result and discussion

Case 1: Simulation model with over current relay

Here we can see in the simulation model that in addition to above mentioned model an over current relay has been included in the circuit. On analysis of this circuit we can see that during the occurrence of small transient faults the system may work appropriately but in times of persistent faults where there may be many continuous triggers this over current relay may not work or in other words is not able to handle the situation and thereby leads to high voltage spikes and high valued sequence currents for the time of fault interval and leads to the malfunction or total damage of the system.

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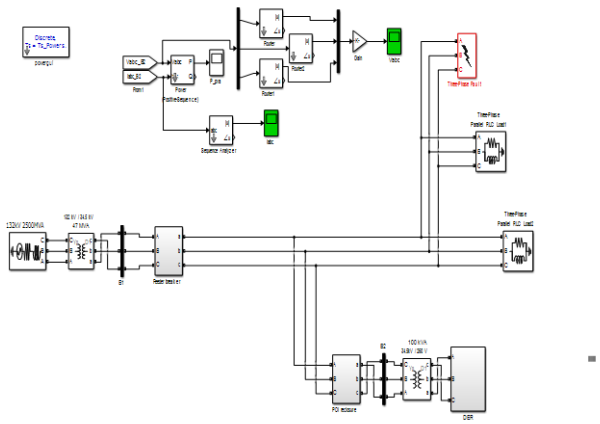

Fig. 3.1: Simulation model with over current relay.

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

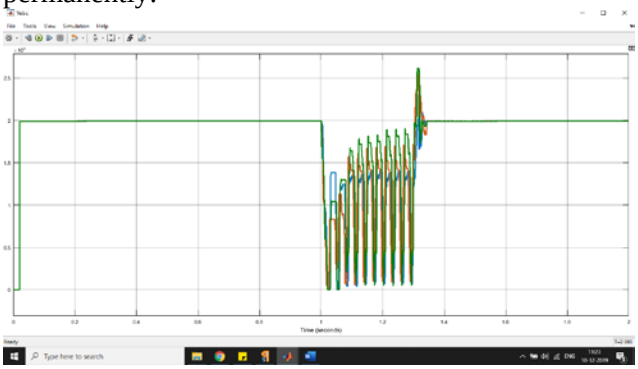

Fig. 3.2: PVA voltages with over current relay protection with fault from 1 to 1.3sec.

Case II: Simulation Model with Counter Set Reclosure Over Current Relay

The below shown model (Fig 3.3) is the proposed model of the dissertation that is been analysed. This model consists of a set reclosure over current relay that is designed in such a way that it triggers off completely over 3 times crossing of restrike. This setting of relay not only limits the voltage spikes but also limits the sequence currents in such a way during fault that if the nature of faults is persistent then it gets triggered and switches on the over current relay thereby protecting the whole system the same working is followed for small transient faults also. The whole system can be controlled by setting the trigger value of the set reclosure over current relay.

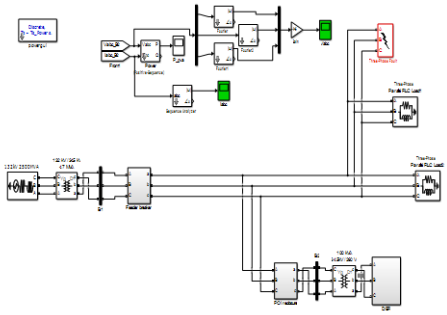

Fig.3.3: Proposed simulation model of counter set reclosure over current relay.

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

Fig. 3.4: PVA voltages with over current relay protection with fault from 1 to 1.3sec.

IV. Conclusion

In the given comparison the reclosure over current relay has less fault current converging at the fault location as compared to over current relay and no relay models. However, the no relay model is a completely failed model as the fault remains in the line and the modules are damaged. The overcurrent relay continuously triggers ON and OFF during the fault and damages the modules connected to the test system. The reclosure over current relay helps the breaker to shut OFF completely after some restrickings and the test system is protected from the fault and the modules remain intact.

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