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Review on the Distributed Solar Generation's Fault Characteristics

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ABSTRACT –

This paper presents power analysis and simulations of Inverter Based Distributed Energy Sources (DER) is an inverter based distributed energy meter with low fault current negative negative series current and zero series current. In the inspection and protection of relays needs to understand the DER fault. This chapter deals with the example of Dominion Energy failure. Stopper's error analysis showed that the actual response to DER errors may differ from the previous.The current relay lock is replaced by the car door lock, all of which provide the relay current until the upper limit is exceeded three times. The current relays are no longer switched off due to delay, but only for minor change faults. For different situations, check the display by setting the DER (PVA) to reverse with the relay's counter. Use the best simulation platform to simulate an integrated MATLAB configuration for this analysis. However, more research is needed to model and carefully evaluate hypotheses developed using real-world networks to validate the effectiveness of participation.

Index Terms- DER System, Sequence component, protection system, MATLAB, Simulink Solar Power Generation Fault.

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[1].

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.

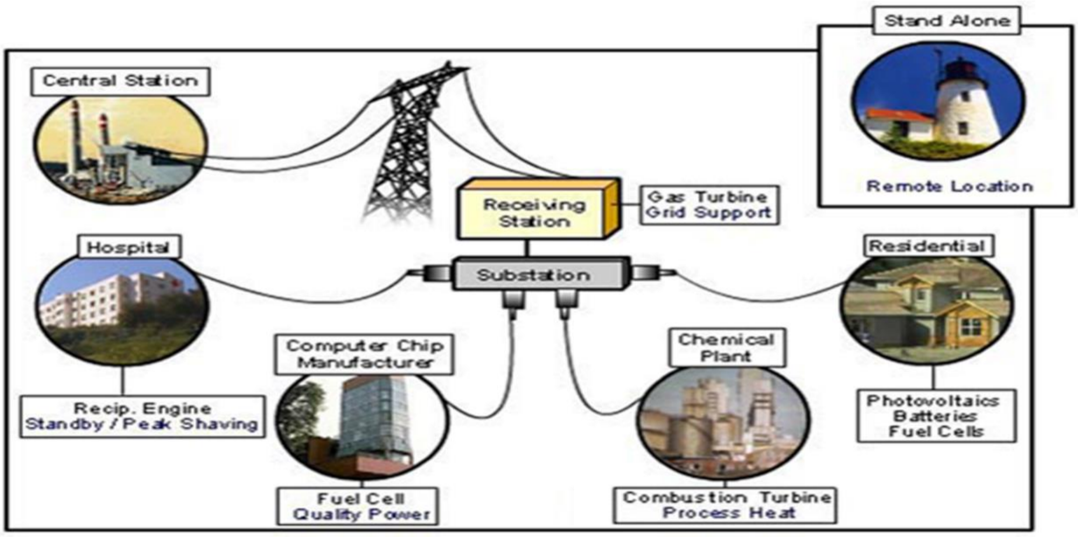

Fig. 1 Types of distributed energy resources and technologies

II. 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[3].

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.

CHARACTERISTICS AND APPLICATION OF DER

The primary application of DER includes:

- Premium power: lesser frequency variations, voltage transients and other disruptions
- Back-up power: used as a back-up in the event of an outage
- Peak shaving: used when electric use and demand charges are high
- Low-cost energy: locally available and economical primary power source
- Combined heat and power (cogeneration): increase the efficiency during power generation by using the waste heat for existing thermal process

Basically, the DER provides better reliability, helps to reduce overloaded transmission lines, adequate power quality, manage price fluctuations, build up energy security and provides superior stability to electric grid.

SOLAR ENERGY POWER GENERATION

The conversion of sun's radiation into electricity via the use of solar photovoltaic cells is termed as solar power generation. Photovoltaic effect is the basic principle of this power conversion[5].

A minimum number of steps are included in the power generation as compared to conventional generation methods which paves way for wide range of applications. Converting sunlight into electricity can be mainly done in two ways. First method is where solar energy is used as a source of heat which is further used to produce the steam that drives the steam turbine.

This method of power generation is termed as solar thermal power generation. Second method makes use of silicon PV cells to directly convert solar energy into electricity and is termed as solar power generation.

Major factor for choosing the solar power generation are:

- free availability
- lesser time is needed for installation of solar power plants
- clean energy production
- economical as only one-time initial investment is needed

PV CELLS

A PV cell also termed as solar cell is a semiconductor device which converts the sunlight energy falling on it into electricity without carrying out much energy conversion steps. This conversion takes place by photovoltaic effect and thereby they are called Photovoltaic (PV) cells. It generates voltage and current at its terminals when sunlight is incident on it [4].

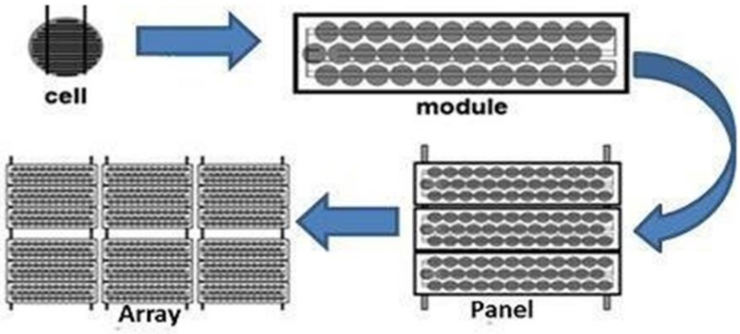

Fig. 2 PV CELLS

POWER SYSTEM PROTECTION

- The main objective of power system protection is to isolate a faulty section of electrical power system from rest of the healthy system so that this portion can function suitably without any serve damage because of fault currents.
- The circuit breaker isolates the faulty system from rest of the live system as they automatically open during fault condition because of its trip signal which comes from the protection relay.
- The system cannot be fully prevented from fault currents but we can prevent the continuation of flow of fault current by quickly disconnecting the short circuit path from the system for which the protection relays should have following functional requirements[4].
- **Reliability:** Relays remain inoperative for a long time before a fault occurs; but it must respond instantly and accurately during fault occurrence.
- **Selectivity:** The relay must be operated only in those conditions for which relays are custom-made in electrical power system i.e. at some fault point it should not be operated or must be operated at some definite time.
- **Sensitivity:** The relaying equipment must be sufficiently sensitive to operate precisely when level of fault condition just crosses the predefined limit.
- **Speed:** The protective relays must operate at the required speed i.e. it should neither be too slow which may result in damage to the equipment nor it should be too fast which may result in undesired operation[6].
- 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 thesis 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.

Objective of the work

The following are the objectives of this thesis

1. To develop a distributed solar energy with circuit breaker but without relay.
2. To develop a distributed solar energy with circuit breaker and over current relay.
3. To develop a distributed solar energy with circuit breaker and Counter Set reclosure over current relay.

TYPES OF FAULTS IN POWER SYSTEM

The faults in power system are generally classified into two types:

1. Open Circuit Fault
2. Short Circuit Fault

1. Open Circuit Fault

Open circuit faults result from the breakdown of a single or double conductor. These errors have a significant effect on system dependability and are known as series faults because they occur in direct connection with the line. We may further categories the open circuit failure as:

- Open Conductor Fault
- Two conductors Open Fault
- Three conductors Open Fault

2. Short Circuit Fault

In general, short-circuit faults may be broken down into two categories: symmetric and asymmetric. They are, from most common to least common:

- Asymmetrical Faults: has to be done independently for the positive, negative, and zero sequence parts.
- Single Line to Ground Fault: happens when the ground is shorted to phase A, phase B, or phase C.
- Line to Line Fault: happens when a phase is "shorted" with another (A, B, or C).
- Double Line to Ground Fault: happens when both phases are connected to ground in a short circuit (A-B-G, B-C-G or C-A-G)
- Symmetrical Faults: sequence values that are always positive since they are properly balanced and can never generate zero sequence or negative sequence components.
- Three Phase Line to Ground Fault: are breaks in the circuit when all three phases (A, B, and C) are connected and grounded together.
- Three Phase Line to Line Fault: occur without ground being present when the A, B, and C phases are shorted simultaneously.

3. Transient fault

For example, an insulation problem that only momentarily alters a device's dielectric characteristics but returns them to normal once power is restored is a transient fault. Power line outages often only last for a short period of time. When a problem arises, the protective devices activate to cut power to the affected region. The power-line is back up after the transitory issue was fixed. Some such types of temporary defects are:

- brief tree contact
- bird or other animal contact
- lightning strike
- clashing of conductors

In the case of a transient failure, transmission and distribution systems employ an automated re-close mechanism, which is also often used on overhead lines. However, this is not the case with subterranean networks. Whenever a transient fault occurs, it may create problems both at the fault location and elsewhere in the network due to the flow of fault current.

4. Persistent fault

There is a defect that remains regardless of whether or not electricity is supplied. Underground electrical lines often suffer from this sort of flaw because of mechanical degradation.

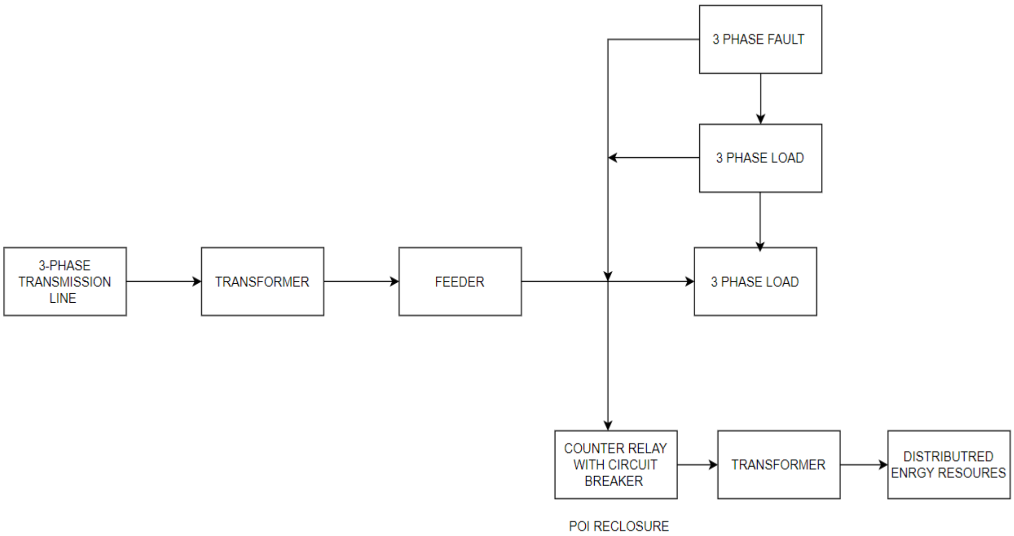

Fig. 3 Proposed system of Fault Characteristic of DER System

III. Literature Review

This chapter presents the literature review of various types of faults in distributed solar generation, protection gaps of conventional solutions, as well as existing approaches of fault detection, classification and protection solutions. The benefits and limitations of these existing approaches are also explored and compared.

H. Hooshyar and M. E. Baran [4] The fault current profile of a distribution feeder in which PV is preponderant is distinct from that of a traditional feeder. This research provides a novel approach that augments the capacity of traditional short-circuit analysis technique to estimate the fault current profile on such a feeder. Overcurrent relays and similar devices make it harder to predict how long a fault current will continue to flow, as this paper demonstrates.

Alsfasfeh et.al. [6] provides a framework for solving capacity maximisation issues for PV power sources subject to voltage variations, based on IEEE standard node system and power system analysis theory. The suggested work's performance is analysed and evaluated using a simulator built in MATLAB R2017B. Through modelling the IEEE 33-node system, we examine the spectrum of PV power integration capacity and determine the maximum PV power integration capacity at each node.

Mohamed-M-H et.al.[7] It's becoming more common for utilities to include renewable energy from wind power facilities in their distribution networks. To harness the power of the wind, it uses a DFIG (Doubly Fed Induction Generator). The study focuses on problems that arise from both short and long transmission lines, as well as the existence of faults and the Static Synchronous Compensator (STATCOM). This study mostly focuses on determining how to regulate voltage and current in electrical circuits. This study suggests a Distribution Static Synchronous Compensator (DSTATCOM). DSTATCOM is linked to the distribution network through a DFIG-based wind farm, which serves as the power supply.

D. Kim and N. Cho et.al. [8] The goal of this research is to provide a technique for steady-state short-circuit analysis in power networks that make use of decentralized energy sources (DERs). Therefore, we propose a method for fault analysis that accounts for the influence of currently-managed DERs. The large filter inductance of a DER and the limit effects of its output current and voltage are two features of the current-controlled DER that need special attention. We should also take into account the characteristics of loads requiring continuous power in the network for the fault investigation. Therefore, we offer a power-flow based fault analysis method to address these issues.

Lucian loan Dulau [10] The impact dispersed generation has on the electrical power grid is discussed in this study. Distributed generation, in this context, means generating power close to where it will be used. Power quality and reliability may be compromised, and the network may fail to operate as intended, as a result of distributed generation's impact on short circuit level, load losses, voltage profile along the network, voltage transients, and congestions in system branches.

Namhun Cho [11] From this study, it has become clear that the integration of DERs reduces power grid dependability. In order to address this issue, KEPCO has been working on creating a fault analysis technique for DERs that can be used in a distribution management system (DMS). This research introduces a unique way for assessing the effects of different DERs during shunt failures. The foundational ideas of the suggested approach are presented first. To then identify the roles played by balanced and unbalanced DERs during shunt faults, the fault analysis approach is presented.

Madeleine and han slootweg et.al.[12] This research investigate the maximum of profits from distributed energy resources operating in a local day-ahead and balancing market. Competition among dispersed energy resources may flourish in the local market, but market dominance is also a risk. Bi-level optimization is used to represent the strategic maximizing of distributed energy resources' revenues in the day-ahead market. Within the framework of a bi-level optimization, the upper-level issue is framed from the standpoint of the strategic distributed energy resource, while the lower-level problem is framed from the viewpoint of the local market operator. The contracting rolling horizon model is used to simulate the equilibrating market (when perfect competition exists).

Dong-Eok Kimand Namhun Cho et.al. [13] This work presents a technique for fault analysis applicable to a power distribution system including PCS-based DERs. We begin by defining a PCS-based DER and outlining its key features. Given its qualities, a DER may be thought of as a current-controlled voltage source that generates voltages that change within a range that allows currents that are constant relative to certain reference values to flow from the DER into the grid. As a result, we provide the symmetrical equivalent models in the shape of a variable voltage source for fault analysis, and we design a convex optimization problem to address the fault issue inherent in the equivalent models and the grid's constraints. The suggested technique allows for accurate fault analysis to be performed while taking into account the DER's unique properties of current control, voltage limitation, and power factor unity.

Mesut E. Baran and EI- Markaby [14] This research demonstrates that owing mostly to the quick responsiveness of its controller, the current that an inverter-interfaced distributed generator (IIDG) provides to a malfunction varies greatly. In order to quantify the contribution of IIDGs in fault analysis, this research presents a way to expand the standard fault analysis methodologies. The suggested technique provides root-mean-square (rms) profiles of relevant fault currents. The suggested method has been tested on a prototype feeder and shown to be capable of fault current contribution estimation in both balanced and unbalanced fault scenarios.

Haizhu Yang et.al.[15] This research proposes a fault location approach based on the ideas of minimal fault reactance and golden section to address the issue of fault location in distribution networks that include distributed energy resources (DERs). It is suggested to modify the trapezoidal iteration approach for load flow analysis and fault current computation in distribution networks to account for the impact of distributed energy resource supply on fault point current. By just requiring the measurement of the synchronous current of the distributed energy resource rather of the more expensive voltage information, this technique reduces the overall cost of the necessary measurement equipment. The IEEE 34-node test feeder is used for verification. The method's suitability for fault finding in distribution networks with many dispersed generators is shown by simulation results. The active distribution network's flaws may be discovered using this technology even in extreme environments.

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.

Any numerical models, i.e. mathematical simulation models have limitations. A mathematical simulation model will provide correct simulation results to the type of phenomena to be observed or examined by including appropriate individual model component (such as protections, controls and capabilities). Thus, the proper selection of the mathematical simulation model needs to be performed by power system engineers in academia as well as in industry. However, the proper selection of the mathematical simulation model is not an easy task. Distributed generation is expected to play a greater role in power generation over the coming decades, especially close to the end-use low voltage consumer side. There is a growing interest on the part of power consumers for installing their own generating capacity in order to take advantage of flexible DG technologies to produce power during favorable times, enhance power reliability and quality, or supply heating/cooling needs. The range of DG technologies and the variability in their size, performance, and suitable applications suggest that DG could provide power supply solutions in many different industrial, commercial, and residential settings. In this way, DG is contributing to improving the security of electricity supply. If DG does take a large share of the generation market, the role of distribution utilities will become vastly more important than currently. There will be a need to reform distribution system design requirements to accommodate DG. Undertaking further studies to identify the technical capabilities, the operating strategies, and the skill requirements of distribution network operators would help prepare electricity markets for a more decentralized electricity system.

Future Scope

In the given proposed system, the model can be updated with other renewable source like wind farm or fuel cell and can be protected with the proposed relay protection from faults. The relays can also be updated with directional over current relay or time inverse over current relay for better protection.

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