THE EFFECT OF DISTRIBUTED GENERATION ON POWER SYSTEM PROTECTION A-REVIEW

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ABSTRACT

*Interconnecting a distributed generation (DG) to an existing distribution system provides various benefits to several entities such as the DG owner, utility and end users. DG provides an improved power quality, higher reliability of the distribution system and covering of peak shaves. Penetration of a DG into an existing distribution system has so many impacts on the system, despite the benefits a DG will provide; it has a negative impact on one of the most important aspects of the system which is the power system protection, and it is a main factor affecting both reliability and stability of the system. DG causes the system to lose its radial power flow, besides the increased fault level of the system caused by the DG. In this thesis, the effect of DG penetration on the short circuit level of the network is investigated through simulating the IEEE 13 bus test feeder using **ETAP.** The simulation is repeated for nine different cases at which the location of one large DG is changed in six of the cases to study the effect of the distance on the fault level, while the rest of the cases are performed using small decentralised DGs. The result of those three cases at which the DG is decentralised are used to investigate the effect of the generating capacity of the generation unit on the distribution network parameters and on the currents flowing through the laterals of the distribution network. Results are compared to that of the normal case to investigate the impact of the DG on the short circuit currents flowing through different branches of the network to deduce the effect on protective devices.*

I INTRODUCTION

Among the various energy forms, electrical power plays the major role due to the fact of its ease to generate and utilise. As a result of the increasing awareness and economic concern of the consumers in the past few decades, one of their main concerns is to receive a more reliable electrical power supply with fewer expenses which caused a higher challenge to the electric utilities, as they are expected to deliver higher quality service through the reliability of the supply with less cost. In order to achieve less cost, utilities are targeting a system with less operation and maintenance costs, reduction of resources cost and reducing the system losses.For electric utilities to deliver electric power to consumers there are several stages to be passed through, the first stage is the generation, at which electricity is generated in large sized generation stations that are located in non-populated areas away from all loads to overcome the economics of size and environmental issues. Second stage is the transmission; this is done with the aid of several equipments such as transformers, overhead transmission lines and underground cables. Transmission is an important part of the system that consumes a lot of money to transmit the generated electricity to reach the last stage which is the distribution.Distribution system is the link between the end user and the utility system, it is the most crucial part of the power system and it is facing a lot of threats that cause a power interruption to customers, it can be stated that a great percentage of end users' power outages are due to distribution networks, it can also occur due to mal functioning of the networks protection equipment as a result of adding a Distributed Generation (DG) to increase the network's reliability. DG is an alternative small rated power generation unit added to the distribution network to cover the supply of some loads. There are different types and technologies of DG's used nowadays such as photovoltaic (PV) systems, wind turbine, micro-turbines, fuel cells and rotating machines. PV and wind turbines are examples of renewable energy consumables as they need no fossil fuel to operate, PV utilises the sun and wind turbines operate by the aid of wind.

Distributed Generation (DG) is one of the new trends that attracted attention for the past years and its penetration in distribution networks is increasing in an enormous rate. DG is presented in the form of solar (PV), wind (wind farms) and many other forms with small scale ratings up to 10MW. DG refers to electric generators that are built to generate electricity and supplying it to customers close to their locations, it can also be interconnected to the utility grids. There are so many privileges a DG delivers to the customer, which encourages their choice to install a DG rather than constructing new distribution lines, doing so might be cost effective to some customers. DG can be used to provide electricity supply to customers during peak times, it can provide a consumer full demand allowing them to operate apart from the grid, thus it can support intentional islanding.

One of the most important issues that has to be considered to achieve a safe and effective use of DG is the interconnection of the DG to the utility grid, which is discussed later in this chapter. There are different DG technologies and impacts of distributed generations that are introduced in this chapter, besides the impact of DG on protection and the coordination of protective devices.

II TYPES OF DISTRIBUTED GENERATION

DG can be classified into two major groups, inverter based DG and rotating machine DG. Usually inverters are used in DG systems after the generation process, as the generated voltage may be in DC form or AC but it is required to be changed to the nominal voltage and frequency so it has to be converted first to DC then back to AC with the nominal parameters through the rectifier.

2.1 Photo voltaic

PV system is an environment friendly system as it has no emissions what so ever. PV systems utilise the sun as its fuel to generate DC voltage with a range of few megawatts then transferred to AC with the aid of inverters. A PV system consists of cells placed in an array that is either fixed or moving through motors to keep tracking the sun for maximising the power generated. PV systems occupy large spaces to be able to generate sufficient power and this is one of its disadvantages besides the high initial cost.

2.2 Wind Turbines

Wind turbines utilise the wind as its input to be converted to useful electricity as the output of the system. It acts as a turbine with the wind as its prime mover to rotate the turbine that is connected to the shaft of a generator. The generator gives an AC output voltage that is dependent on the wind speed. As wind speed is variable so the voltage generated has to be transferred to DC and back again to AC with the aid of inverters. The range of power generated by wind turbines could be a few megawatts for each turbine.

2.3 Fuel Cells

Operation of fuel cells is similar to that of a battery but it is continuously charged with hydrogen which can be extracted from any hydro-carbon source, this is the charge of the fuel cell along with air (oxygen). The fuel cell utilises the reaction of hydrogen and oxygen with the aid of an ion-conducting electrolyte to produce an induced DC voltage which is proportional to the number of fuel cells. The generated DC voltage is converted to AC using an inverter. A fuel cell also produces heat and water along with electricity but it has a high running cost which is its major disadvantage. The major advantage of a fuel cell is that there are no moving parts which increases the reliability of this technology and no noise is generated; besides no fuel is consumed except for electricity generation.

2.4 Micro-Turbines

The technology of micro-turbines is based on very high speed rotating turbines along with a generator to produce a high frequency output voltage. Micro-turbines are usually operated by natural gas. The main advantage of micro-turbines is the clean operation with low emissions produced, but on the other hand its disadvantage is the high level of noise produced and the low efficiency.

The output voltage from micro-turbines cannot be utilised or connected to the utility, it has to be transferred to the nominal voltage with the nominal frequency, thus it has to be first converted to DC and then converted back again to AC with the nominal voltageand frequency by the aid of inverters. Micro-turbines can operate in both stand alone and parallel modes, but in the case of parallel operation with the utility grid they have to be designed to supply a fixed power output. Many benefits can be obtained from operating micro-turbines in the stand-alone mode such as the use of micro-turbines to regulate both the voltage and frequency besides the supply of active power.

2.5 Rotating Machines

Rotating machine types are the DGs that include induction or synchronous machines such as induction and synchronous generators. Synchronous types operate with fuel as its input to generate electricity, and can be of different ratings starting from kW range up to few MW ratings. Rotating machines are mainly used as standalone systems or as backup generation systems.

2.6 Impact of Distributed Generation on Power System Grids

Penetration of DG in Distribution networks has an impact on various fields. These impacts could be positive or negative and are considered as the benefits and drawbacks of the distributed generation. This part is addressing the impacts of DG on different aspects of the network.

2.7 Impact of DG on Voltage Regulation

The main regulating method used in radial distribution systems is by the aid of load tap changing transformers at substations [6], additional line regulators on distribution feeders and switched capacitors on feeders. Through the performance of the mentioned devices voltages are usually maintained within the required ranges. The criteria of voltage regulation is based on radial power flow from the substation down to all loads, DG penetration changes the radial characteristics and the system loses its radiality and power flows in different directions and a new power flow scheme is introduced. Losing radiality of the system impacts the effectiveness of standard voltage regulation technique, regulation controls will not properly measure the feeder demand [6].One of the major impacts of Distributed generation is on the losses in a feeder. Locating the DG units is an important criterion that has to be considered to be able to reach a better performance of the system with reduced losses, and this is used to reach an optimal performance of the network. According to [6], Locating DG units to minimise losses is similar to locating capacitor banks to reduce losses; the major difference between both cases is that DG may contribute to both active and reactive power flow (P and Q) of the system while capacitor banks will only contribute to the reactive power flow (Q) of the system. Most generators in the system will operate at a power factor range between 0.85 lagging and unity, but the presence of inverters is able to provide a contribution to reactive power compensation (leading current).The optimum location for placing the DG can be obtained with the aid of load flow analysis software that is able to investigate the location of DG to reduce the losses in the system. Considering feeders with high losses, adding a number of small capacity DGswith a total output of 10–20% of the feeder demand will show a significant positive effect on losses and it will be reduced which is a great benefit to the system, but when deciding optimum DG location this is a theoretical decision as most of the DGs are owned by individuals, and the electric authorities or utilities do not have any influence on the locations at which the DG is required to be embedded [6]. If the analysis shows that larger DG units are required other factors have to be considered in the study, such as feeder capacity due to the thermal capacity of overhead lines and underground cables because these elements of the network may not withstand the injected currents from the DG and will result in a poor or weak distribution system with a lot of weak points and the possibility of consequent undesirable consequences might take place [6].

2.8 Impact of DG on Harmonics

DG can be a source of harmonics to the network; harmonics produced can be either from the generation unit itself (generator) or from the power electronics equipment such as inverters used to transfer the generated form of electricity (DC) to AC to be injected to the network. The old inverter technologies that were based on SCR produced high levels of harmonics, while the new inverter technology is based on IGBT's (Insulated Gate Bipolar Transistor) operating with the pulse width modulation technique in producing the generated "sine" wave [6]. This new technology produces a cleaner output with less harmonics produced that should satisfy the IEEE 1547-2003 standards [7] as expressed in Table 2.1 below. Rotating machines such as synchronous generators are another source of harmonics; this depends on the design of the windings of the generator (pitch of the coils), non-linearity of the coil, grounding and other factors that may result in significant harmonics propagation [6]. The best or the most specified synchronous generators are that with a winding pitch of 2/3 as they are the least third harmonic producers when compared with other generators with different pitches, but on the other hand the 2/3 winding pitch generators may cause more harmonic currents to flow through it from other parallel connected sources due to its low impedance [6].

III CONCLUSION

The main objective of this thesis is to analyse the different types of faults occurring in distribution systems and investigating the effect of penetrating DG into the distribution system. The model used in this thesis is the IEEE 13 bus system and it was simulated using software named **ETAP.** The output of the software i**s** in the form of tables listing the fault currents of four different types of faults which are single line to ground, three phase, line to line and line to line to ground faults. The main type of fault that is focused on in this thesis is the common type of fault which is the single line to ground fault. Simulation was repeated nine times with different configurations of the DG, six out of the nine cases were simulated with one large DG placed at different locations in the network, while the other three cases were simulated with smaller DGs but distributed in the network.

REFERENCES

[1] Peter A. Daly and Jay Morrison "Understanding he Potential Benefits of Distributed Generation on Power Delivery Systems" in Proc. 2001 Rural sElectric Power Conference, pp A2/ 1-13.

[2] H.H.Zeineldin "Distributed Generation Micro -grid Operation: Control, Protection and Electricity Market Operation" Ph.D. dissertation, Dept. Electrical and Computer Eng., Univ. Waterloo, Canada, 2006.

[3] R. Lasseter, A. Akhil, C. Marney, J. Stephens, J. Dagle, R. Guttromson, A. SakisMeliopoulous, R. Yinger and J. Eto, "Integration of Distributed Energy Resources- The CERTS MicroGrid Concept", Tech. Rep. LNBL-50829, April 2002.

[4] S. Abu-Sharkh, R. Li, T. Markvart, N. Ross, P. Wilson, R. Yoo, K. Steemer, J. Kohler and R. Arnold,

"Microgrids: distributed on -site generation", Tyndall center for climate changes, March 2005.

[5] CIGRE TF38.01.10 "Modeling New Forms of Generation and Storage", November 2000.

[6] Philip P. Barker and Robert W. de Mello, "Determinin g the Impact of Distributed Generation on Power Systems: Part -1 radial DG systems", Power Engineering Society Summer Meeting, 2000.

[7] IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Standard 1547-2003.

[8] Recommended Practice for Utility Interface of PV (PV) Systems, IEEE Std. 929-2000. Published by IEEE, 2000.

[9] Philip Barker, Jim Feltes and David Smith, "Determining the Impact of Distributed Generation on Power Systems: Part 2 - Low Voltage Network Systems and DG Dynamics", Power Engineering Society Summer Meeting, 2000.

[10] Onan Liquid-Cooled Generator Set Application Manual (T -030), Onan Corporation, November 1993.

[11] Static Power Converters of 500 kW or Less Serving as the Relay Interface Package for Non-Conventional Generators, IEEE 93THO 597 -5 PWR, Published by IEEE, 1993.

[12] Juan A. Martinez and Jacinto Martin-Arnedo "Impacts of Distributed Generation on Protection and Power Quality" Power & Energy Society General Meeting, Oct 2009. Pp. 1-6.

[13] C.J. Mozina, "Interconnection protection of IPP generators at commercial /industrial facilities," IEEE Trans. on Industry Applications, vol. 37, no. 3, pp. 681-688, May/June 2001.

[14] C.J. Mozina, "Interconnect protection of dispersed generators," 2001 IEEE PES T&D Conf., pp. 707-723.

[15] C.J. Mozina, "Distributed generator interconnect protection practices", 2006 IEEE PES T&D Conf., pp. 1164-1170.

[16] D. Tholomier, T. Yip and G. Lloyd "Protection of Distributed Generation (DG) Interconnection", Power Systems Conference 2009, pp.1-17.

[17] M. A. Redfern, and O. Usta, "A new microprocessor based islanding protection algorithm for dispersed storage and generation units ", IEEE Transaction on Power Delivery, vol.10, pp. 1249-1254, July 1995.

[18] M. E. Ropp, M. Begovic, A. Rohatgi, g. A. Kern, R. H. Bonn, and S.Gonzalez, "Determining the relative effectiveness of islanding detection methods using phase criteria and non-detection zones", IEEE Transaction on Energy Conversion, vol.15, pp. 290-296, Sept. 2000.

[19] A. Woyte, R. Belmans, and J. Nijs, "Testing the islanding protection function of PV inverters", IEEE Transaction on Energy Conversion, vol.18, pp. 157-162, March 2003.

[20] M.E. Ropp, M. Begovic and A. Rohatgi, "Analysis and performance assessment of the active frequency drift method of islanding prevention", IEEE Transaction on Energy Conversion, vol.14, pp. 810-816, Sept. 1999.

[21] Fu-Sheng Pai and Shyh-Jier Huang, "A detection algorithm for islanding prevention of dispersed consumer owned storage and generating units ", IEEE Transaction on Energy Conversion, vol.16, pp. 346-351, Dec. 2001

[22] Juan A. Martinez and Jacinto Martin-Arnedo, “Investigation of Impacts of Distributed Generation on Feeder Protection”, PES 2009, Oct. 2009 pp.1-6.

[23] YahiaBaghzouz, "Voltage Regulation and Overcurrent Protection Issues in Distribution Feeders with Distributed Generation - A Case Study," Proceedings of the 38th Annual Hawaii International Conference on System Sciences (HICSS'05), vol. 2, pp.66b, 2005.

[24] AdlyGirgis and Sukumar Brahma “Effect of Distributed Generation on Protective device Co -ordination in Distribution Systems”, Large Engineering System Conference on Power Engineering, 2001, Aug.2002, pp.115-119.

[25] Surachai Chaitusaney and Akihiko Yokoyama, “Prevention of Reliability Degradation from Recloser–Fuse Miscoordination Due To Distributed Generation”, September 2008, TPWRD-00722-2006

[26] WWW.IEEE.ORG, IEEE Test Feeders.

[27] Kersting, W.H. “Radial Distribution Test Feeders”, Transaction on Power System, August 1991, pp. 975-985.