INTEGRATION IMPACTS OF DISTRIBUTED GENERATION ON DISTRIBUTION SYSTEM

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ABSTRACT: The main objective for design the Distribution network is to distribute electrical power to load at reasonable voltage and quality power. Therefore, in case of any fluctuation arise or a reverse power flow from generators connected with grid due to DG system, some effect may arise on the whole system like power quality or protection. Passive network is turn on active when DG system is installed in existing system, which leads to changes the normal characteristics of the existing distribution system. The design and manipulation of new distribution system (existing distribution with DG systems) is arranged in such a way that power flows from source to load. The DG System allocation in existing distribution system which affect the traditional characteristic of distribution system. In case of the distribution system power become higher than the downstream load then power flow become reversing to the main distribution system and at some point between the DG system and grid substation. Due to back flow of power from DG total real power flow in the whole system is zero.The impacts of DG on Distribution networks includes, but are not limited to; impact on voltage Regulation, Power losses, Power security, Harmonics, Power quality, and Environment.

Keywords: DG, SAIDI, SAIFI, CAIFI, CAIDI, ASAI

INTRODUCTION

In traditional distribution system, the load tap changers use to regulate the voltage between sources to load. To improve the voltage profile, real power and reactive power introduce DG system in traditional distribution system.The change in power flow makes the Distribution network active and non-unidirectional. The impact on voltage regulation may positive or negative depends on size, location and characteristics of DG system and existing distribution system as well. The effects of allocation of DG system in distribution systems are (i) stability (ii) power flow (iii) voltage regulation and (iv) reliability. By installation of DG system with distribution system, it changes all conventional characteristics of the distribution system. Most of the conventional distribution systems are designed in such a way that the power flows in one direction. The optimal allocation of DG system provides another source of power in the distribution system including existing power sources. In case of the distribution systempower become higher than the downstream load thenpower flowbecome reversingto the main distribution system and at some point between the DG system and grid substation. Due to back flow of power from DG total real power flow in the whole system is zero. The first rules are defined for reversal power flow from DG system to downstream load, optimal DG system allocation for reduction of losses and the impacts of interconnection of DG system with existing distribution system on over-current protection. The rules for design of modeling DG system interaction and its zero point analysis have been reported in the literatures survey so far.The 1547 series of IEEE standard parameters are set for interconnecting distributed system to thepower system is a set of standards containing of 6 parts.The standards parameters provide criteria and requirement for interconnecting distributed resources to the power system. The requirement for interconnecting equipment that connects the DG system to the conventional distribution system is define by IEEE 1547.1.The IEEE 1547.6 standard emphases on criteria, test and requirements for interconnection distribution system network of area electric power system with Distributed Resource generation.

The impacts of installing DGsystem on voltage, stability, losses and reliability indices of residential distribution systemsare studied based on following criteria.

(a)LOSSES

Power losses on the feeder are another impact of distributed generation on distribution network. Optimal DG system allocation is important factorsthat must be evaluate to achieve a bettersystem reliability of distribution network. Capacitor allocation on distribution network is similar to DG placement and sizing for losses reduction. Mainly, generators in the system operate with a power factor between 0.86 lagging and unity, but the presence of switching devices like inverters and synchronous generators provides a reactive power to compensate the reactivepower (Q).The optimal DG allocation can be achieved by using load flow analysis methods which is capable to find out the suitable location of DG system within existing system to reduce the losses. Suppose a feeders have high losses by introducing a number of small capacity DGs system but it increase feeder capacity limits but the feeder capacity limit may be restricted as overhead lines and cables have thermal characteristic they should not exceed over limit.Installation of DG impacts the losses and overall power factor of the total system. The reductions of transmission losses with DG using power summation method have been reported. The loss analysis at various penetration levels of DG and distributing were presented.

(b)RELIABILITY

Reliability is an important factor in Distribution system planning and operation. The reliability indices guided by IEEE is used to evaluate the system reliability. These reliability indices are:

- System Average Interruption Duration Index
- System Average Interruption Frequency Index
- Customer Average Interruption Frequency Index
- Customer Average Interruption Duration Index
- Average Service Availability Index
- Average Service Unavailability Index
- Energy Not Supplied

The methods of data collection to evaluate the reliability indices of system are very crucialmethod. It takes into account the power consumption pattern, selection of relevant index, outage data collection and actual consumer perceptions and hence would contribute towards improving the reliability.A general Distribution Reliability program can used to confirm the impact of DG system on system performance improvement as well as its reliability. It indicates that DG systems provide cost effective solution that could benefited for both utility and customers.The DG system modelling techniques for its application for radial network using commercial software tools like HOMER SOFTWARE shows improvement in the reliability indices.

(c) VOLTAGE IMPACTS

The overall voltage profile can be improve by introducing DG system with distribution system.In presence of DG can improve feeder voltage of distribution system in areas where voltage dip or blackouts are of apprehension for utilities.The DG has a greater impact on electric losses, voltage profile, flicker, harmonics, short circuit levels, islanding and reliability. The optimal location of DG allocation is an important aspect where system were analyzed.

(d) POWER QUALITY

Distributed Generation can also result in excess voltage. The voltage of substation distribution lines is controlled by a programmed timer or line drop compensator (LDC). Generally, a single distribution transformer has several feeder lines, and the voltage in these lines is adjusted in a block. Additionally, an SVR compensates the voltage midway along the line in heavy power-flow or long transmission lines. The load of each feeder should be balanced proportionally to utilize these voltage control systems. If large no of DG units are connected on a single line leads to increase the power flow gap between feeder line because of the back-flow from the DG systems.

(e)HARMONICS

A wave that does not follow a “pure” sinusoidal because harmonics are always present in power systems to some extent that why wave is considered as harmonically distorted. Harmonics can be caused by non-linearity in transformer impedance or nonlinear loads such as variable speed drives, all type of switching devices used in AC to DC conversion equipment, SMPS, and arc furnaces. Distribution system can be generate harmonics to the network due to DC to AC conversion process. Harmonics can be produced either from generation unit itself or from the switching devices such as inverters. Contribution to the harmonic currents by the inverters is in the part of SCR inverters which produce high level of harmonics currents components. But recently IGBT technology are used to design inverters that pulse width modulation technology used to generate pure sine wave. These inverters with new technology produces a cleaner output wave with fewer harmonic content in compare to SCRs inverter that contributes high levels on harmonic currents as per the IEEE 1547-2003 Standards. This problem of harmonics generally caused by the resonance with capacitor banks or in worst case the equipment powered by the DG sources need to be disconnected in case of the extra heating caused by the harmonic currents. Harmonics may increase due to fault current during normal condition at which no DG sources are installed in the networks. The contribution fault current by a single DG source is not large but in case of large no of small units or few large units, the short circuit fault current level can be altered enough to cause miss coordination between relays and protective devices such problem may affect the safety and reliability of whole distribution system. Figure 1 shows a typical distribution system where fuse on a feeder which is used to saving relaying system and DG systems are embedded with existing distribution system and this may lead to mall functioning of fuse and lead to decrease system reliability.

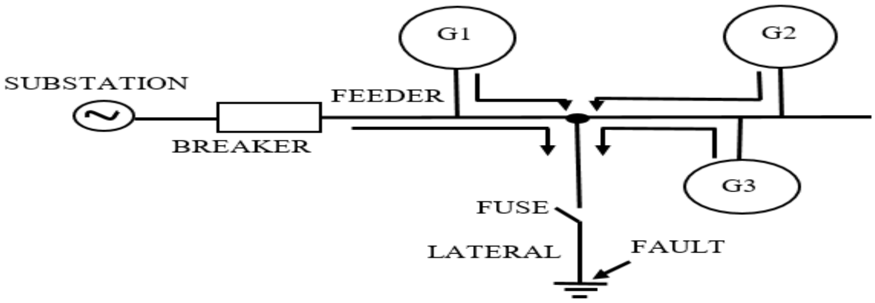

Figure 1.a typical distribution system with fused and relaying system

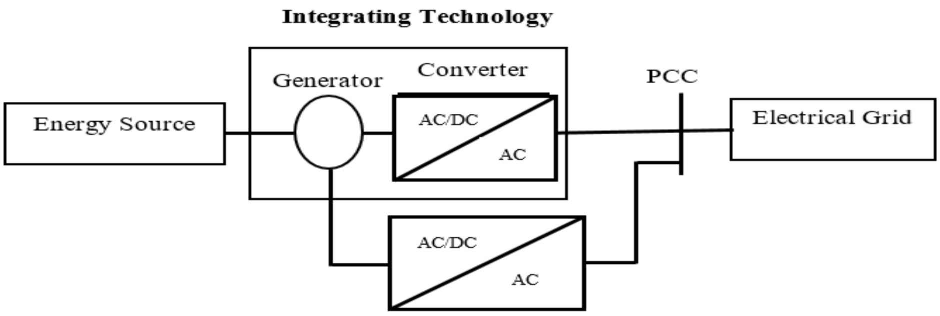

Figure 2: Fault contribution due to embedded DG with distribution system

COST ANALYSIS

If Distributed Generated sources are located between the existing distribution system then it decrease fault current from the existing distribution system. This fault current needs to be observed for minimum tripping or coordination problem. In other word, if combined DG sources are strong in compared to existing utility sources or distribution system , it may leads to increase or contribute fault current coming from utility substations. This fault current cause failure to trip, sequential tripping coordination between different protection units.

RELIABILITY

DG systems can improve the reliability of the whole distribution system if the all DG units are properly coordinated with the rest of distribution system otherwise they may leads to mall functioning in the system. Generally DGs uses are as power supply backup during interruption of main supply. DGs can improve network constraints like voltage drop or feeder over loading and also help to improve restoration capability of the whole distribution system. Because the DG systems are distributed, the "whole system" may be more reliable. In case of any damage one unit can be removed from the system for maintenance or service with only a moderate effect on the rest of the power distribution system. This is especially important for new technologies where the long-term reliability is not a big issue. Power is readily available for end users and the power has improved quality and reliability in compare to power generatedfrom central generating units.

ENVIRONMENT

Renewable DG such as wind, solar PV and other low carbon like Micro CHP system have a positive impact on the environment by effective reduction of emission and warming. Aside from the market attractiveness, environmental friendliness is one of the major criteria that support DG operation. Improvement in eco-friendly environment net emission from local and displaced emission should be minimum. The total emission tariff is included of seasonal, location and time so that the tariff would be more effective at worst pollutant location and location.

COST OF ENERGY BALANCE

To calculate the cost of energy before and after introducing DG systems in existing distribution system is Levelized Cost of Energy (LCOE) method. It is the most transparent metric method used to calculate electric power generating costs, and is extensively used as a tool to compare costs of differing generation sources. It is the average electricity price needed for a Net Present Value (NPV) of zero when performing a discounted cash flow (DCF) analysis. With the average electricity price equal to the LCOE, an investor would breakeven and so receive a return equal to the discount rate on the investment.

$$\sum_{t=0}^{m} \frac{Revenue}{(1+x)t} = \sum_{t=0}^{m} \frac{Price}{(1+x)t}$$

Where: m = Project lifetime (yrs.).
t = Year in which sale or cost is incurred.
x = Discount rate (%)
According to definition this point indicate the Net present value for a project is zero as follows –
NPV=summation of the *Present Values (PV)*of the cash flows

$$\mathrm{NPV} = \sum_{t=0}^{m} PV = 0$$

Where:

$$\text{Present V alue} = \frac{[\mathrm{EWI}\ (1-\mathrm{CT})\ + \mathrm{DEP} - \mathrm{CE}]}{(1+\mathrm{x})\ \mathrm{t}}$$

EWI = Earnings without Interest
DEP = Depreciation
CE = Capital Expenditure
CT = Corporate Tax rate (%)

GLOBAL ASSUMPTIONS

Tax: The corporate tax rate is assumed to be 30% for the purposes of all cash-flow analysis.
Depreciation: The electric utility industry typically uses the *straight-line* method, which was used in this analysis. For a 25 year lifetime, the annual depreciation is 4%, and for a 30 year lifetime, the annual depreciation is 3.33%.

ECONOMICAL LIFE CYCLE AND CONSTRUCTION TIME PERIOD OF VARIOUS DG'S

Economical life cycle and construction time period of various DG's play an important role on the Levelized cost of power generation. Economical life cycle and construction time period of various DG's are as shown in table.1.The IEA reports wind construction periods of 1 year (unlike AEMO), and the effects of this are explored.

TABLE 1: Construction Periodic and Economic Lifetimes

Technology	Construction Period	Economic Lifetime
Wind	2year	30years
Solar PV	1year	30years
Solar Thermal	2year	30years

THE CAPACITY FACTOR

In the case of renewable energy generators the assumed capacity factor of a facility has a significant impact on the LCOE. For renewable energy generators, the capacity factor is generally dependent on the quality of the renewable resource. In the interests of a consistent approach, constant capacity factors were used for each technology type. These capacities were based on reasonable resource qualities for Australian conditions, summarized below in Table 2, as used in the EPRI study.

TABLE 2. Capacity Factors

Technology	Resource Quality	Capacity Factor
Wind	6.8m/s	30%
Solar PV	2445 KWh/m2/yr	20%
Solar Thermal	2400 KWh/m2/yr	Varied by plant storage configuration

The economic problems resulting from the connection of distributed generation to the existing distribution network could be considered as the "disruptive threats of distributed generation". The current clamour for DG and by extension DER based on their benefits appears to overlook their financial implications to retail energy business (Onwunta and Kahn, 2013). According to IEA (2002) distributed generation is a "disruptive technology" that could fundamentally alter the organization of the electricity-supply industry.

For instance, energy-saving technologies like smart grids in North America are challenged by a traditional business model where the main driver is increasing energy sales (WEC, 2012). Adding the higher costs to integrate DER, increasing subsidies for DSM and direct metering of DER will result in the potential for a squeeze on profitability and, thus, credit metrics. While the regulatory process is expected to allow for recovery of lost revenues in future rate cases, tariff structures in most places call for non-DER customers to pay for (or absorb) lost revenues. According to Kind (2013) in a cost-of-service rate-regulated model, revenues are not directly correlated to customer levels or sales but to the cost of providing service. However, in most jurisdictions, customer rates are a function of usage/unit sales. In such a model, customer rate levels must increase via rate increase requests when usage declines, which from a financial perspective is intended to keep the company whole (i.e., earn its cost of capital). He posits that this may lead to a challenging cycle since an increase in customer rates over time to support investment spending in a declining sales environment (due to disruptive forces) will further enhance the competitive dynamics of competing technologies and supply/demand efficiency programs. His conclusion is that this set of dynamics can become a vicious cycle that, in the worst-case scenario, would leave few(er) customers remaining to support the costs of a large embedded infrastructure system, some of which may be stranded investment but most of the costs will continue to be incurred in order to manage the flows between supply and customers.

ADVANTAGES & DISADVANTAGES

Distributed generation reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building. This also reduces the size and number of power lines that must be constructed.

DISADVANTAGES OF DG

- Power Quality
- Cost of Operation and Maintenance
- Long Term Reliability of the Units
- Interconnection

CHALLENGES OF DISTRIBUTED GENERATION

- Intermittent in nature.
- Free but not always usable.
- Deteriorate system stability.
- Less efficiency.
- Voltage regulation problem.
- Less predictable load patterns – roof top solar, electric vehicles, and smart grid
- Changing revenue patterns – Decreasing marginal prices and changes in resource operational pattern

CONCLUSION

It has been concluded that distributed generation has a number of advantages over conventional central power generation, and is most suitable for tapping small power resources scattered over a large area, yet it still can-not replace the grid. Grid based central power system is still preferred for most of the cases except in situations when the cost of installation of transmission system is too high. The distributed generation help us to reduce the cost of the transmission line and the transmission losses. DG's play an important role in the field of the electricity generation whereas so many different issues related to reliability, power quality, protection and so on. Therefore DG's units can be accommodate into the grid along with central power system units so that surplus power generated by the DG's can easily sent to regions., an ideal power system ,which have a shortage. In the Indian context, distributed generation through small, mini, micro and pico-hydel projects do hold the solution to power crisis. Moreover distributed generation also aids in promoting economic development and social welfare. Moreover community distribution projects by ensuring greater participation of people helps to create a civic conscience in the society.

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