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Distributed Generation: Benefits, Issues and Challenges

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***Abstract*— Integrating of Distributed generation (DG) into power system is one of the emerging technological innovations in power sector that brings several benefits besides supporting power supply to the feeder. DG operates in parallel with distribution network meets base load, provides peak load, power quality improvement and generation backup stand-by supply. However, the connection of DG with the complexity of power system raises various issues. The inclusion of DG in distribution system changes the operating characteristics such as power losses, voltage profile, stability and reliability of distribution system. Moreover, the impact of DG in power system depends on various technical features, such as technology, size of the units, operation and control strategies and location in the power network. This paper listed few challenges related to integration of DG in distribution system.**

***Index Terms*— Distributed generation, Distributed generation benefits, Power quality, Reliability, Regulations.**

I. Introduction

Distributed generation (DG) is an emerging approach in electric power sector. It is seen that there is no consensus on a precise definition of DG due to its varying technology and wide applications. The best definition of DG is an electric power generation source within the distribution networks or on the customer side of the network [1-3]. These are also called dispersed generations, embedded generations and decentralized generations depending on purpose, location, power delivery, technology, ownership and penetration of distributed generation in the world [1]. DG includes both conventional and renewable energy resources. The renewable energy sources are environmentally friendly, that includes photo-voltaic system, wind turbines, small/micro hydro plants, fuel cells, micro-turbines, reciprocating engines etc. and storage technologies such as batteries, flywheels, ultra capacitors and superconducting magnetic energy storage. Being increasing interest on DG worldwide, it is expected to play a major role in power system in near future.

Integration of DG in distribution system has several benefits to utilities and customers [2-8]. A general approach has been proposed to assess the technical benefits of DG in a quantitative manner [5]. DG has the benefit to be used as a backup source and improve power system reliability [8, 9]. Nevertheless, the reliability of the power system reduces if DG is not properly coordinated, located and designed to work with existing network components [10, 11]. The impacts of DG on reliability indices and power quality are presented in [12]. The impact on power systems including intentional islanding on reliability are discussed [13]. The impact of DG on dynamics of power system and stability is investigated in [14-16]. Distributed

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resources impact on system voltage, capacitor operation, voltage regulator or load tap changing (LTC) transformer is presented in [17] in different operation mode of distribution system. Integration of DG in power system may impact positively or negatively depending on various technical features. Therefore, connection and increasing penetration of DG should be carefully evaluated and planned. Distribution system planning frameworks with DG in deregulated electricity market are proposed in [18, 19].

This paper presents a general discussion on integrating DG benefits, issues and challenges in sections II, III and IV respectively. Finally conclusion is given in section V.

II. DG Benefits

Placement of DG in suitable location in distribution system has several benefits. The benefits are categorized into three groups:

A. Technical benefits

1. Reduced line losses and voltage profile improvement

The power flow in the traditional distribution line is from the generating station to distribution systems. But placement of DG changes this scenario. Presence of DG converts the passive distribution network to active network and provides power locally to the loads which results in reduction of current flow in some part of the network. Consequently, there happens the reduction of line losses which are very much dependent on line currents. Similarly location and size of DG affects the voltage drop in the lines due to change scenario of flow of line current. DGs with power electronic converters are capable to deliver certain amount of reactive power, when it is necessary for the line. Hence DG integration impact positively on voltage profile and also minimizes line losses through avoiding the flow of reactive power over larger distances.

2. Increased overall energy efficiency

Reducing line losses, improving voltage profile and power factor correction increase overall energy efficiency.

3. Enhanced system reliability and security

Proper coordination between DG units and rest of the network results improvement of distribution system reliability. DG units can be used as a generation backup during interruption of main supply. For sensitive and critical loads, DG provides a standby power supply where the grid is not very reliable.

A DG can be modelled as constant active and reactive power injections independent of the system voltage at the unit terminal bus. Also it can be modelled as controlled voltage sources in which the terminal voltage is maintained at a constant value by reactive power injection. In both the cases the reliability of the system improves.

4. Improve power quality

Many distribution systems are operated radially and the distance customers experience low voltage at their terminals due to voltage drop in the lines. The locations of DG near the load, counter the poor voltage regulation. DG can also help to mitigate voltage sags during a fault. Thus DG improves power quality of both DG owners as well as nearby loads.

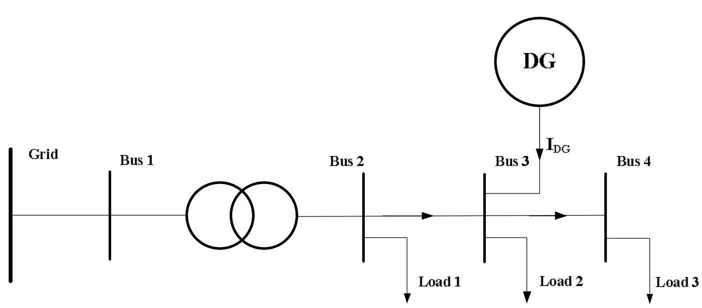

Fig. 1 A radial distribution system with DG

5. Relieved transmission and distribution (T&D) congestion

DG provides power locally to the load as shown in fig.1 and reduces power flow in some of the transmission network. It reliefs the transmission capacity and manages congestion in power system.

B. Economical benefits

1. Deferred investments for upgrades of facilities

DG provides power locally to the load. So these can reduce or avoid the need for building new T&D lines, upgrade the existing power systems and reduce T&D networks capacity during planning phase [20, 21].

2. Enhanced productivity

Increased energy efficiency and improved power quality enhance productivity. T&D lines capacity release increases the system equipment and transformers lifetime.

3. Reduced health care costs due to improved environment

Since most of the DG includes renewable energy sources, it has very little impact on environment. Thus it reduces health care costs.

4. Reduced fuel costs due to increased overall efficiency

Increased energy efficiency, improved power quality and increased productivity ultimately reduce fuel requirements and its associated costs.

5. Reduced reserve requirements and the associated costs

DG can be used as a generation backup during interruption from main supply and also cost effective source of peak power demand. So it ultimately reduces reserved requirements and the associated costs.

6. Lower operating costs due to peak shaving

DG is a cost effective source of peak power demand, or economic savings in energy consumed from utility and electricity demand charges [4].

C. Environmental benefits

Local atmospheric pollution, regional (acid rain) and global (greenhouse gases) environmental problems, mainly from the use of fossil fuels, are well established. Moreover, the still unsolved problem is of disposing of nuclear waste. Renewable energy sources provide a promising alternative and their deployment is thought of as an important energy policy priority for many countries. It is well known that renewable energy is environmentally friendlier than conventional fuels, it is indigenous, promoting national energy independence, and could actively contribute to local job creation. Renewable DG has several environmental benefits and could provide a promising alternative to conventional power generation if some economic, institutional, social and technical barriers could be overcome, and the appropriate planning instruments for their deployment be developed.

III. DG Integration Issues

There are various issues confronting the user of DG when integrating with distribution system and utility grid.

A. Voltage level

A rise in the voltage level above permissible limit in radial distribution systems is a key factor that limits the additional DG capacity. Drop of voltage may also occur due to improper location and coordination of DG with capacitor operation, voltage regulator or LTC transformer [13, 17]. So voltage control is an issue when DG is connected to the distribution grid as mention by IEA (2002) [22].

B. Reactive power

Most of the DG technologies use asynchronous generators. These machines derive excitation from the network and behave as reactive loads even if they generate active power. Hence voltage control is very difficult with these machines. Low power factor in induction machines draws more reactive power and low power factor results large fault current.

DGs with power electronic converters are capable to deliver certain amount of reactive power, when it is necessary for the line.

C. Reverse power flow

The power flow in the traditional distribution line is unidirectional from the generating station to distribution systems. But integration of DG in distribution system changes this scenario. An increased size of DG units may cause power flows from the low voltage distribution grid to the medium or high voltage grid. Thus, the system requires new protection schemes for this type of application.

D. System frequency

Imbalances between demand and supply of electricity cause the system frequency to deviate from the rated value. Increasing in the capacity of DG units affect the system frequency and have the potential to become free riders on the efforts of the transmission grid operator and the regulatory body and increases the complexity of control.

E. Protection scheme

The issues related to protection scheme are shown in fig. 2 to 4. As shown in fig.2, if any fault occurs at A, the fault current will flow from the grid and DG. The fault current increases depending on distributed generators types and characteristics. Relay located between bus 2 and bus 3 will only measure the current flowing from the grid. Means, the relay detects only a part of the real fault current and may therefore not trigger properly. With a fault at bus 2 as shown in fig. 3, fault current from DG passes the relay in reverse direction, which can cause problems if directional relays are used. Thus location of DG changes the magnitude, duration and direction of the fault current in a line.

The solution of the above problem is to use directional over current relays. But fault current contribution from relatively large DG may cause a nuisance trip of breaker A as the case shown in fig. 4 [12].

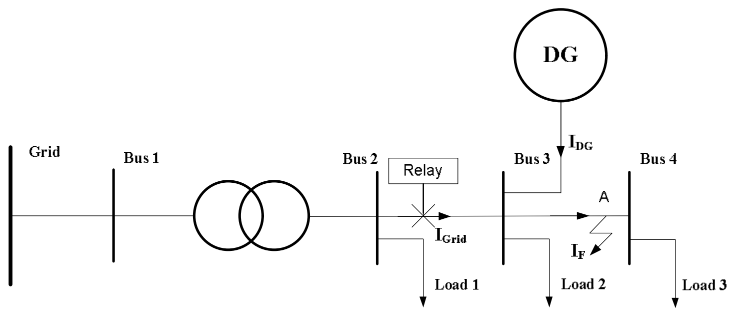

Fig. 2 A radial distribution system having DG and a fault at point A

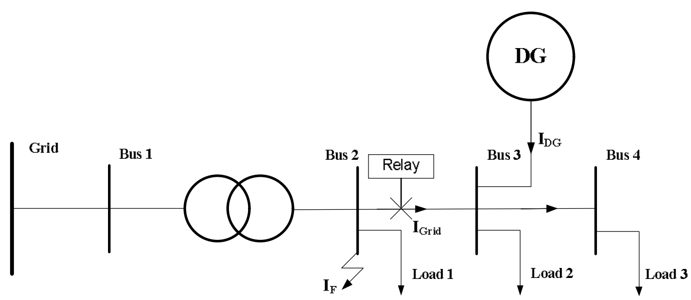

Fig. 3 A radial distribution system having DG and a fault in a line between buses 2 and 3

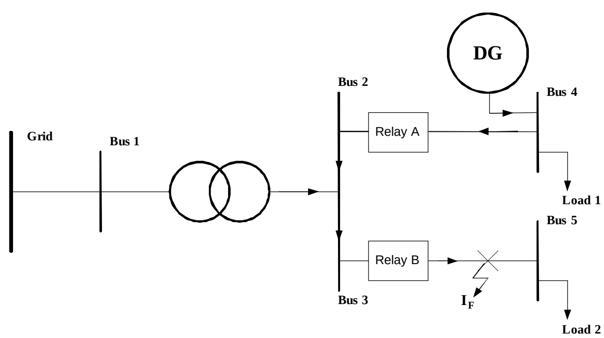

Fig. 4 A radial distribution system having DG and a fault near to bus 5

F. Islanding protection

Islanding is a condition which a portion of the utility system that contains distributed resources/group of distributed resources and some loads remains energized while isolating from main utility system. A DG may energize a certain segment of the network, which may cause risk to repairing personnel come into contact. Hence protective equipment must be placed to avoid such situation.

In most cases it is not desirable for a DG to island with any part of the utility system because this can lead to safety and power quality problems that will affect the utility system and loads [13]. Also reliability will reduce due to time elapsed for re-synchronizing with the main utility.

G. Power quality and reliability

Both electric utilities and end users are becoming increasingly concerned about the quality of electric power due to various reasons. Any power problem manifested in voltage, current or frequency deviations that result in failure or misoperation of customer equipment is called power quality problem. The benefit of DG to improve power quality of the DG owner and nearby loads is discussed in previous section. But connection of DG may also causes system frequency deviation due to demand supply mismatch, injection of harmonics by DG having power electronic converters and rise of voltage due to non-optimal placement and sizing of generation units etc. The introduction of DG in radial distribution system may cause reverse power flow. This reduces line voltage drops and it may increase the service voltage at customers end. If a voltage regulator or LTC transformer is present at substation for line drop compensation, then unsuitable location and coordination of DG causes interference of LTC transformer operation [12, 16] and results poor voltage regulation.

Investigation shows that DG may cause voltage flicker and introduce harmonics [12]. If DG starts or its output fluctuates frequently enough, flicker may be noticeable to customers lighting loads, and this is a well known phenomena of intermittent renewable DG sources. Some DG such as PV, fuel cells etc produce direct current. Hence, these are connected with the grid via DC-AC power electronics converter, which may contribute harmonics in power system. Also asynchronous DG sources which use power electronics converter for interconnection injects harmonics into the system. The harmonics type and severity will depend on the power converter technology and interconnection configuration.

DG can be used as a generation backup during outages of main supply [9]. If the DG is sized to support the critical load having very less starting time, then reliability for customer load improves considerably. But the improvement of reliability of system having number of customers by integration of DG cannot be realized.

IV. Challenges to Integrate DG

Challenges to integrate DG into distribution network are listed below.

A. Power quality

The aspects of integration of DG such as benefits and problem in view of power quality are presented in previous sections. DG may support the system or deteriorate power quality. So connecting DG is a challenging task and every possible ways need to be developed to counter power quality problems.

B. Protection scheme

An issue on failure of protection schemes due to introduction of DG in traditional distribution systems is discussed. Therefore, for each connection of DG in distribution system, the protection selectivity must be re-evaluated. Also research need are for finding the solution of nuisance tripping of breaker and issues related to fuse saving.

C. Stability

When the DG size is small, the impact on power system dynamic performance is negligible. Investigation shows that the effects of DG on the dynamics of a power system and stability strongly depend on the technology of the distributed generators [15, 16]. Large penetration of DG may lead to instability of the voltage profile due to the bidirectional power flows and complicated reactive power equilibrium arising when insufficient control is introduced. The voltage throughout the grid may fluctuate. The situation deteriorates if DG includes variable renewable energy resources. Therefore maintaining stability of power system is a challenging task after integration of DG and in increased penetration.

D. Regulatory

Most of the DGs are owned by customer. Some form of incentive schemes are in existence in many countries in the world for renewable DGs [6]. But surveys indicate that at present situation majority of the countries do not have well defined regulation and security standards [4, 6]. Many countries have no common guidelines for the connection of DG units to the utilities in their region. The rules for connection of DG are defined individually by the local utilities.

V. CONCLUSIONS

This paper has surveyed and presented DG benefits, key issues and challenges for DG integration to distribution networks. DG has the potential to improve distribution system performance. Also DG increases the complexities of controlling, protecting and maintaining the distribution systems. Therefore, DG connections are of most interest to power system planners, policy makers and regulators, DG owners and customers.

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