Placement of D-FACTs in Distribution Network with the Accommodation of DER

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Abstract: This paper proposes the placement of D-facts in Distribution network at optimal location in the presence of Distributed energy resources. With increasing capacity of DGs in power system, the operation of power system disturbed. As in existing power system configuration power flow allowed only in one direction (i.e. vertically integrated manner), but with the accommodation of distributed energy resources (DERs) in distribution network the power flow will not be in conventional manner results voltage profile get disturbed. In order to have increased DGs capacity and to maintain the voltage profile in permissible limits D-FACTs devices have been placed optimally, according to the ranking of the nodes depends upon the voltage profile.

The problem has been formulated and simulated in MATLAB environment. The 33 node generic distribution network with the injection of various DERs capacity has been considered.

Keywords: Distributed generators, D-FACTs, Distribution network, voltage profile etc.

1. INTRODUCTION

Electricity has become essential for the development of a nation. With the increase in population and changing life style, energy demand is continuously growing. It is necessary to meet the increased energy demand without affecting the reliability and quality of supply at less cost. In the present scenario the demand-supply gap is widening. For minimizing the energy demand & supply gap the power generation capacity has to be increased, with the consideration of environmental constraints i.e. green energy sources or reduce the energy demand considerably at consumer ends by using solar powered lighting equipments and solar energy operated home appliances. In order to meet the increased energy demand new generating plants and additional power system infrastructure may not be required if load at the consumer end is managed properly or more solar panels and small wind turbines are installed on their premises to fulfill the energy demand [1,2]. The additional generated power may be transferred to the grid directly or generated energy may be stored (during off-peak load hours) and transferred to the grid (during peak load hours). The existing power system is based on large and centralized power stations connected to high and extra-high voltage networks, which transfer power to medium and then low voltage distribution systems (i.e. vertically integrated manner). The electric grid having more constrained and it is expected to perform better and also greener [3,4]. That can be only achieved with accommodation of new technological advances, such as distributed generation. DG applications in the distribution network show great operational and power-quality advantages, in addition to transmission and distribution network losses reduction. DGs are very suitable for site-specific applications, as they have short period of construction and low investment. When DGs are penetrated into the distribution network, the power flow pattern gets affected [5,7]. This paper proposes the placement of D-Facts at optimal location. In this paper, a scheme is proposed to relax the restriction on the location and capacity of DGs by the optimal placement of D-FACTs devices.

2. DISTRIBUTED GENERATION

Distributed Generators are small capacity generation units connected to the distribution network or connected directly to the costumer site The aiming of distribution generation is to increase the uses of renewable energy i.e. wind energy, solar energy. It brought attention from the power sector, that sometime location and capacity of DGs has adverse impact on distribution system, D-FACTs devices with capability of power flow control and maintain the voltage profile in permissible limit, be a possible solution to this issue. DG produces electricity at or near the place where it's use [6, 12]. DG technologies can further categorize as renewable and non-renewable. Renewable technologies are:

- Solar, photovoltaic or thermal
- Wind
- Geothermal
- Ocean

Nonrenewable technologies are:

- Internal combustion engine (IC engine)
- Combined cycle
- Combustion turbine
- Micro-turbines
- Fuel cell

Distribution Network

Generating plants, transmission lines and the distribution systems are the main components of an electric power system. Generating stations and a distribution system are connected through transmissions lines, which also connect one power system to another. A distribution system connects all the loads in a particular area to the transmission lines. Electric power is generated at a voltage of 11 to 33 kV which then is stepped up to the transmission levels. The first step down of voltage from transmission level is at the bulk power sub-station. This step down is from the transmission and grid level to sub-transmission level. The next step-down in voltage is at the distribution substation. The distribution system fed from the distribution transformer stations, supplies power to the large number of domestic or industrial and commercial consumers [7,11].

Distribution Network and Impacts of DGs

The main function of distribution networks is to transfer electricity to consumers after receiving electric energy from interconnected high voltage transmission networks. The electric energy is being transported from remotely located centralized power plants to the consumers. Distribution networks are designed to supply power to meet out the load demands at a specified voltage level, if load increased on distribution line the voltage at the node may not be in the specified limit as in fig.(2).The existing distribution network having distributed generators as in fig.(1), the voltage rise problem has been observed as in fig.(4).

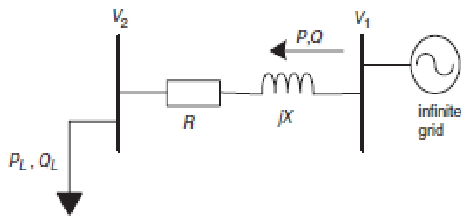

Fig.1: Basic two bus-bar (Radial) network

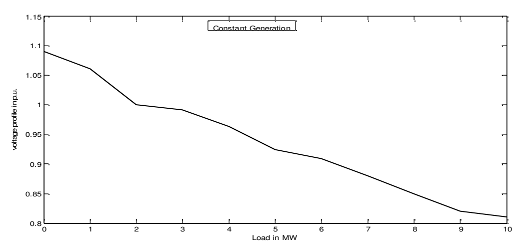

Fig.2: Voltage profile at Load bus of the radial network for constant generation

Distribution feeders are typically operated in a radial fashion. Feeders consist in a tree-like topology rooted at the secondary of a transformer, typically with on-load tap-changing for voltage regulation.

The voltage at bus-bar 2 calculated as:

$$V_2 \approx V_1 + R(P_G - P_L) + X(Q_G - Q_L)$$

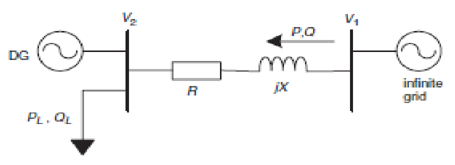

Fig.3: Voltage profile of the radial network with distributed generators

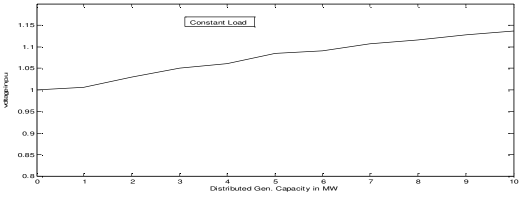

Fig. 4: Load bus Voltage profile of the radial network with injected generator power and constant load

The voltage profile at bus(2) varying with the capacity of distributed generators at the end of radial feeders as shown in fig.(3). When DG capacity is higher than the connected load at that particular node the direction of power flow be in opposite direction, The distributed generators inject power in to the distribution networks but the power quality of supply gets affected as in fig. (4). The benefits which we can get from distributed generators in relation to T&D networks could include reduction in additional power system infrastructure; T&D network losses, improved reliability and quality, improved voltage regulation, T&D system congestion. The integration of distributed generators with distribution network could worsen the performance of the power system. The integration of distributed generators can have a serious impact on the operation and integrity of the electric power [4, 8].

D-FACTs

The FACTS devices are used for maintaining i.e. either supporting or the preventing from rising the voltage means supplying or absorbing the reactive power but not exclusively for the improvement of quality of the supply. The D-FACTs devices are exclusively for the improvement of the quality of the supply. Widespread use of conventional FACTS controllers has not extensively occurred due in part to size, expense, and installation effort. The use of D-FACTs devices may facilitate the realization of a comprehensively controllable power system. Large-scale power flow control may finally be achievable. A D-FACTs device changes the effective line impedance actively by producing a voltage drop across the line which is in quadrature with the line current. Thus, a D-FACTs device provides either purely reactive or purely capacitive compensation. D-FACTs devices do not change the line's resistance at all since doing so would imply the ability of the device to create real power. The impact on the system caused by D-Facts devices on different lines working together can be coordinated to achieve some desired control objective. D-FACTs devices may be configured to operate autonomously in certain situations such as during transients, faults etc. [5, 10].

- Distributed FACTs Devices:
- Capacitive or inductive
- Distributed Static Series Compensator (DSSC)
- Distributed Series Reactor (DSR)
- Synchronous Voltage Source Improved operation of distribution networks with the use of D-FACTs device.
- Determine the best location

Integration of DGs with Distribution Networks

The electricity is being generated primarily from fossil fuel (coal, gas and oil etc.) based centralized power plants. The fossil fuel reserves are needed to preserve for longer period. For energy security and climate change abatement, renewable energy sources are only the way.

In the present scenario, there is need to generate more electricity from renewable energy sources i.e. small combustion turbines and micro turbines, small steam turbines, fuel cells, mini / micro hydroelectric power, photovoltaic, solar energy, wind turbines, energy storage technologies etc. With the increasing efforts towards electricity generation from green energy sources, there is need to integrate the distributed energy resources with the power system, which may be integrated with the placement of DGs and D-Facts devices at the suitable locations [9, 13].

Problem formulation

The objective of placement of D-Facts in the distribution system is to maintain the voltage profile in the permissible limit and reduction of distribution network losses, subjected to certain operating constraints and load pattern. The three-phase system is considered as balanced and loads are assumed as time invariant.

Thus objective function is considering the following constraints.

- Branch current constraint
- Node voltage constraint
- Load connectivity.
- Radial network structure

In order to maintain the voltage profile and to reduce the distribution network power losses, D-Facts devices are placed in the distribution systems.

The variation in voltage profile has two sub problems, that of optimal placement and optimal parameters of D-Facts components. To obtain the optimal location for D-Facts devices that maintains the voltages within the permissible limits of the distribution system, the grading of nodes has been done. The system is a 33–bus, 12.66-kV, radial distribution system. The initial power loss of 33 node distribution network system is 201.588 kW. The node voltage is considered as 1pu. The algorithm was developed in MATLAB, and the simulations were done on a computer.

Results: P_L=3715 Kw, Q_L=2300kVAR

S. No.	% penentration of DGs	P_G kW	Q_G kVAR	P_{loss} kW	Q_{loss} kVAR	P_{DG} kW	Q_{DG} kVAR	Before D-facts Voltage Profile	After D-facts Voltage Profile
1	No DGs	3916	2470	201	170	0	0	V_{min}: .90509 at node-18 V_{max}:1.094at node-1	V_{min}: .90509 at node-18 V_{max}: 1 at node-1
2	10%	3527	2274	182	158	370	167	V_{min}: .94201at node-18 V_{max}:1.0103at node-1	V_{min}: .94021at node-18 V_{max}: 1.0107at node-1
3	20%	3139	2081	167	149	743	322	V_{min}:.96053at node-10 V_{max}:1.0712 at node-26	V_{min}: .98206at node-14 V_{max}: 1.05361at node-25
4	30%	2810	1844	187	142	1092	697	V_{min}:.99130 at node-31 V_{max}:1.04360 at node-22	V_{min}: .99703at node-17 V_{max}: 1.05361at node-33
5	40%	2493	1593	212	121	1434	848	V_{min}:1.04360at node-14 V_{max}:1.12059at node-25	V_{min}: 1.0215 at node-17 V_{max}: 1.05531 at node-03

3. CONCLUSION

In radial distribution systems it is necessary to maintain voltage levels within limits at various buses. This paper aims at discussing for maintaining the voltage levels by using voltage regulators in order to improve the voltage profile. The proposed method deals with initial selection of VR by using power loss indices (PLI) and grading of node voltage has been used for optimal location and number along with setting of the D-FACTs to maintain voltage profile within the desired limits and reduces the network losses. The proposed algorithm is tested with 33 bus. From the simulation results it has been observed that with placement of D-Facts in the distribution network, the increased capacity of DGs may be accommodated.

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