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Acceleration of Interfacing Distributed Generation in Power System through Reactive Power Compensation

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Abstract

The past method of power generation involves utilizing the non renewable energy sources such as coal for the production of electricity. This paper focuses on the development of decentralized energy generation units for the fulfillment of power requirement. Distributed Generation (DG) makes the use of renewable energy sources (like wind, solar, hydropower generation, biomass, etc.) which are non-polluting, economical and/or does not exhaust. A DG is defined as combined utilization of energy management and storage system during installation and operation of small modular power generating technologies. It improves the electricity generation and delivery to the end customers. Interfacing of DG with the distribution grid network produces various effects on the grid network such as voltage imbalance and current disturbances, reactive and active power imbalance, phase disturbances, etc. The research work in this paper presents an approach for the insertion of Distributed Generation in order to handle the reactive power imbalances in the grid network. The proposed methodology deals with the finding of an optimal location for integrating a compensating device to obtain the simulation results through the interfacing of Distributed Generation under normal operating condition of a grid network. The results obtained after simulation were recorded as per IEEE-14 bus network.

Keywords: *reactive power, distributed generation, power system, power generation, etc.*

1. Introduction

The steady growth of renewable energy source has opened up new opportunities in developing technologies for the effective consumption of renewable energy sources looking to the global increase in the environmental concern and the day by day increased demand for energy[1]. It was believed that the world's one year energy requirement can be overcome by the sun's energy in one hour if we are able to consume all the radiations entering to the earth surface. Solar energy can be converted into other form of energy by deploying the following two methods: [3]

1. Solar energy can be utilized to produce hot water or air by utilizing the effect of thermal heating.
2. Solar energy can be converted into electrical energy through the use of photovoltaic (PV) cell.

Energy generation using photovoltaic cell has many advantages and disadvantages. More commonly disadvantages are high initial cost, intermittent power output due to variations in environmental conditions like available intensity of sunlight during day and night, low efficiency, etc[6][7].

The radial behavior of the traditional power systems

in India allows the power flow from the source station with the capacity of generating several thousand of Mega Watts (MW) to the customer ends (like household applications, industry, private and govt. organizations etc.). A great deal of power wastage faced during transmission as well as environmental impacts due to the far off location of power station and/or substation[8][11]. Nowadays, the demand for power requirement is increasing continuously and it will not be possible to afford such losses. A good deal of work to minimize these losses has already been done in the past by various researchers and academicians [2] [12].

In the present research study, a new technology was developed for installing small generation unit termed as Distributed Generation. The DG unit possessed the capacity varying from kW (Kilo Watt) to MW (Mega Watt) which helps to utilize renewable energy sources [5]. The major advantage of using Distributed Generation is to be stationed at nearby places to customers and thereby reducing the transmission losses due to long transmission lines. Besides, the other advantage of DG unit is to provide the users, a low budget electricity and can be installed on roof top for generating their income by connection to the grid (i.e. solar panel generation unit) [4].

DG is a very helpful technology in the single ended system. However, DG unit connected to grid network, create disturbances in the power system like voltage disturbance and flow of current balance [4] [5]. As a result, imbalances in the active and reactive power flow may be noticed and may cause the failure of connected devices and devices. The research under study, proposed a method to identify the bus with great deal of reactive power disturbance and also suggest the optimal position for installing compensating device. In the present study, the 14 bus IEEE network has been designed and simulated with and without DG connection. STATCOM has been utilized as a compensating device to minimize the reactive power imbalances[7][9].

2. Literature Review

Here the authors had used an IEEE-14 bus test network to analyze the power flow in the network. The test network of IEEE-14 bus network was simulated using MATLAB and observed that the voltage profile in an existing grid network gets disturbed when the DG is connected to it. Optimal location for the connection of DG have been found out in order to minimize the losses from the study of the weakest bus i.e. the bus with the maximum voltage drop [1].

Here the author discusses about the self sufficient characteristics of hybrid power system in terms of frequency and voltage control. Also it suggest the control strategy for combined operation of wind and diesel generation along with battery storage system. It divides the control strategy into two parts and tested on hybrid power system.[2]

In this paper, a hybrid power system comprising of wind and solar energy is proposed. The proposed system is connected to a fuel based energy storage system along with the battery system. Proposed model is simulated and concluded that the power generation from wind and PV is not predictable hence a battery storage system is connected to smoothen the large power fluctuations.[3]

The authors in this paper designed a solar- wind based hybrid power system and battery energy storage system is connected to smoothen the intermittency of the solar and wind. The model is simulated using MATLAB to test the consistency. A PI controller based control scheme is implemented for this purpose and MPPT is connected to wind turbines to extract the maximum power.[4]

This paper presented a genetic algorithm based approach for integration of distributed generation in radial distribution network. The uncertainties of load are modeled using fuzzy logic. The study shows that the location and size of DG is different as calculated using fuzzy logic and deterministic approach.[5]

In this paper, a method is proposed for optimal operation of distribution network with distributed generation. A special attention is paid towards the reliability assessment wherein a reliability index is considered as an objective function. It turns the proposed problem into a multiojective energy management (MOEM) and particle swarm optimization algorithm is proposed to solve the MOEM.[6]

In this paper the author had demonstrated the effect of introducing distributed generation (DG) on a 38kV distribution system (DS) which is a part of Brazil and had demonstrated that the voltage profile

of the DS get disturbed with DG connected. The model that was used by the author for study consist of three 38kV feeders connected between the two 110kV substation, and the author has used two methods- overhead line conductor and shunt reactance connected in parallel to compensate the disturbances in the voltage profile caused by the integration of the distributed generation[16]. The simulation was done using the ERAC power flow analysis software. Simulation results for the voltage profile with and without DG are compared and the simulation results for the compensation technique are also shown and comparison is done.[7]

3. Problem Identification

In the developing countries around the world, a large percentage of population lacks the accessibility of electricity to their places of installing power station because of un-approachable costly affair for them to install other sources of power supply [15]. With an increasing power requirement, it is necessary to modify the pre-existing electrical network to meet the ever increasing demand of power. A DG technology was based on the renewable sources and may be served for an increased power demand [12]. The distributed generation offers several advantages such as it is environmental friendly i.e. it does not produces any harmful toxic by- products which can directly or indirectly affect the living beings, economical technology, varied production capability, less area of installation, etc.[13], [14], [15] [17].

The integration of DG into the power system posed too many problems like voltage flicker, harmonic distortion, voltage profile disturbances, degradation in power quality, instability, etc.[7], [8], [10]. In order to minimize these effects, the utilization of power electronic devices plays a very vital role for efficient and continuous supply of electricity. With the help of the flexible AC transmission devices (FACT) the power system can be made stable and reliable. The objective of study undertaken is to measure the performance of the power system when DG is interfaced into it. However, the work under study mainly focuses on the analysis of the disturbances in the reactive power and its methods for its compensation[13].

1. To analyze the imbalances in the reactive power when the distributed generation (DG) is interfaced to the grid network.
2. To suggest the suitable method for the compensation of the reactive power imbalance.

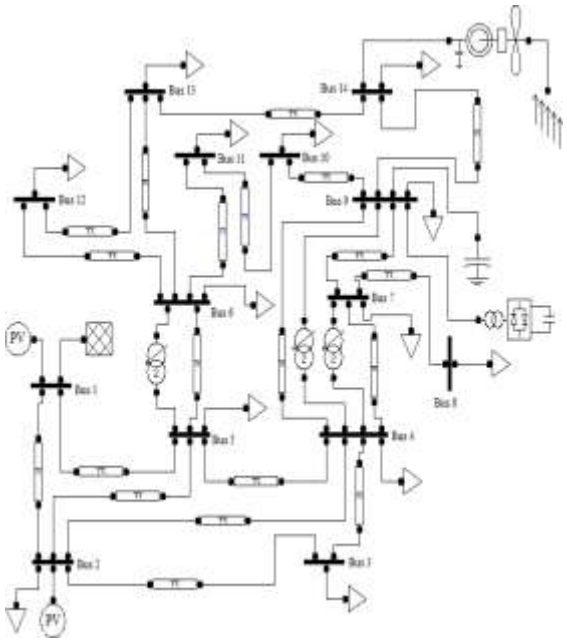
The compensation technique is tested in an IEEE-14 bus network and simulation results were compared to identify the optimal location of DG.

4. Methodology

The 14 bus IEEE network under study was designed and parameter values were chosen according to an IEEE-14 bus standard (Fig.1 and Fig.2). The IEEE-14 network was simulated with the help of Power System Analysis Tool (PSAT) software [1][10].

The objective of a power flow simulation is to record the voltage magnitude and phase angle for each and every bus in a power system for the specified load rating, generation end real power and voltage magnitudes. After obtaining the results of simulation, it is possible to determine real and reactive power flow in each branch as well as reactive power at the generator output. [7] [9].The solution of the power flow problem begins with the known and unknown variables in the system generally depend on the type of bus. A bus connected without any generators is called a load bus. With the exception that a bus with at least one generator connected to it is called a generator bus which is arbitrarily selected and referred as the slack bus [5].

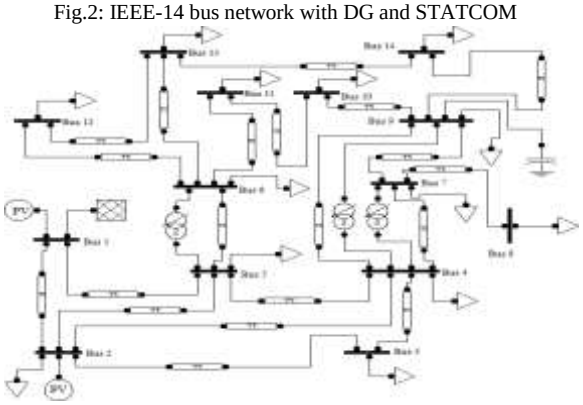
Fig.1: IEEE-14 bus network



An IEEE-14 bus system architecture without Distributed Generation connection, IEEE-14 bus system architecture with Distributed Generation and STATCOM connected has been shown in (Fig.1, and Fig.2) respectively. It consists of two generators of 100MVA rating. Three transformers having tap rating of 0.978, 0.969 and 0.932 p.u. are connected between bus no.4 and 7, bus no. 4 and 9 and bus no. 5 and 6 respectively. IEEE-14 bus network statistics is shown in Table.1

Under the study test network, a wind based distributed generation of 50 MVA and 11kV is connected at bus 14, since it is the weakest bus having maximum amount of power drop, indicating the increasing trend in the power utility [1]. After connecting DG an imbalance

Fig.2: IEEE-14 bus network with DG and STATCOM



was observed in reactive power and to overcome it, a STATCOM device of 100MVA and 11kV is connected at bus 9 (Fig.2).

5. Result/Findings

The simulation results obtained from IEEE-14 bus system architecture shows that the total reactive power loss occurring in the network is 5.3766 p.u (Fig.3). The simulation result of an IEEE-14 bus network with DG and STATCOM connection shows that the total loss of reactive power occurring in the network has been reduced to 0.12023 p.u. (Fig.5).

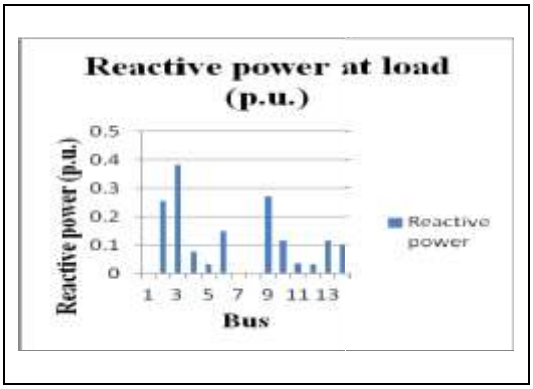


Fig.3: Reactive power at load

Table.1: IEEE-14 bus network Statistics

Network Elements	No. of Elements
Buses	14
Lines	20
Transformer	3
Generators	3
Loads	13

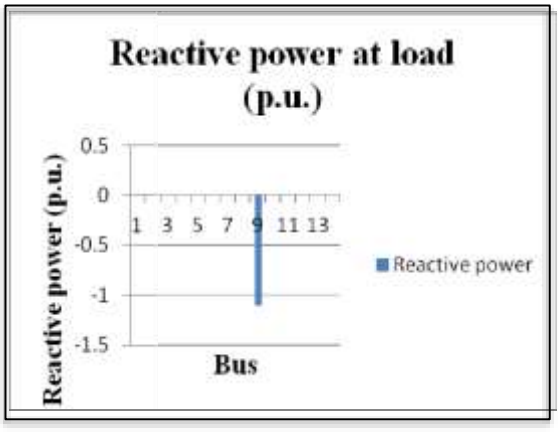


Fig.4: Reactive power at load with DG connection

: Reactive power at load with DG and STATCOM

The disturbances in the voltage profile, active power and reactive power was observed and the simulation result without DG was obtained on IEEE-14 bus

6. Discussion and Implication

The disturbances in the voltage profile, active power and reactive power was observed and the simulation result without DG was obtained on IEEE-14 bus architecture. The optimal location for DG connection was found from the study of weakest bus in order to minimize losses [1]. Similar findings were obtained under this research work with DG connection. The optimal location of DG was found out in order to minimize the losses and compensation method has also been suggested through the use of STATCOM device.

After obtaining the simulation results from power flow analysis of IEEE-14 bus network, it was found that there was a need to connect DG as per the power requirement at particular bus and STATCOM was connected to minimize the reactive power imbalances within the test network.

7.Conclusion

The present findings conclude that the distributed generation is a helpful technology near to the location of costumers to fulfill their need of power utilization. DG utilizes renewable energy and may be installed at reasonable cost. Although, it is beneficial if operated as a single utility. However, if it is connected to an electrical network may lead to various losses like disturbances in the voltage and current flow, active power and reactive power imbalances, etc. These losses were studied and compensated by the integration of STATCOM.

Under this research work, the effect of DG on the reactive power balance of the network has been studied and compensation method was study. An IEEE-14 bus network was designed under 11kV, 100MVA transmission line and three generators are connected to the bus no. 6, 7 and 9 respectively. A wind based distributed generation of 11kV, 50MVA is connected to bus no. 14 wherein a STATCOM device of 11kV, 100MVA was connected to bus no. 9 which is being the most sensitive bus. This research study is useful in the analysis of the power system to reduce losses. The exact location of connecting DG was identified and the compensation method was suggested to overcome the disturbances in the reactive power balance. It has been concluded that the present method reducing the reactive power loss from 5.3766 p.u. to 0.12023 p.u. (Fig.3 and Fig.5).

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