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FINDING OPTIMAL LOCATION OF DISTRIBUTED GENERATOR BY USING A LOAD FLOW ANALYSIS

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Abstract

Distributed Generator when connected to power system, Voltage stability in power system is a major problem that receives international attention. Before connecting Distributed Generator to power system optimal location is necessary to find out. For increase of current and voltage stability as well to achieve power quality, optimal location is must. An open and free source piece of software, Power System Analysis Toolbox (PSAT) is used in this study to create a model of modified IEEE 14 bus system. This paper primarily addressed to find optimal location of distributed generator by using a load flow analysis with the help of MATLAB.

This Research work is depending on a load flow analysis made initially for an IEEE14-bus system before connecting the DG into the power system to find optimal location. It is observed that bus 14 is the weakest node which is best place to connect DG. More total real & reactive power losses are noticed.

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Keywords: PSAT, power quality, voltage stability, load flow, optimal location, weakest node

Introduction

Power is growing and meeting a constantly growing portion of the energy needs in several nations throughout the world. That need is satisfied today by using renewable energy sources. There are certain technical issues that need to be resolved, from an environmental perspective. This is a positive step in perspective of nonconventional energy sources. The power systems that receive power from wind turbines are impacted by the growth of wind power. When wind energy is used more frequently, conventional power plants that typically regulate and stabilise the electricity system are replaced with wind turbines.

Wind power plants must delivers the power quality necessary to ensure the dependability of the power system to which they are linked and to satisfy the needs of customers who are also connected to same grid. It is crucial to comprehend the causes of disturbances that have an impact on power quality [6]. Wind power generation currently uses induction generators with fixed and variable speeds. Issues with voltage stability and transient stability are brought on by their integration into the grid. The stability of the power system depends on turbine, generator, and governor factors. They have an impact on both transient stability and tiny signal stability.

In a power system, a transient short circuit failure is a highly frequent disruption [1]. The rotating machinery close to the fault is disturbed, which leads to oscillations in both the network's power flows and machine

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speeds. The generators which have accelerated will decelerate and re-synchronize with the rest of the system once the short circuit has been resolved by cutting off the faulty line. Widespread blackouts and mechanical harm to generators are possible if they don't and the system becomes unstable. [2, 3].

According to the authors of [10], modelling and a transient stability analysis of the wind integrated IEEE 14 test bus system are investigated. In a wind integrated power system with storage, the investigation's goal is to increase transient stability by using a central area controller. In [11], a comparison of the steady and transient characteristics of three different types of the wind turbines is made. The Power System Analysis Toolbox-implemented Nordic grid model was also validated by time-domain simulation by using small and large disturbances [12].

Operation of PSAT based on MATLAB

Here the simulation results were obtained using the PSAT (Power System Analysis Toolbox) which is a tool for the analysis of the power system. PSAT is based on MATLAB and in this method one need not solve long and complex mathematical equations that means this method is easy to understand and use.

Steps involved in the operation of PSAT are as follows:

1. Start the MATLAB software.
2. Run PSAT.m file.
3. Open the Simulink library from PSAT window.
4. Select the components which are required to draw the network.
5. Draw the network and save it.
6. In the PSAT window load the saved network and run the continuous power flow.
7. Click on the static report tab. It will generate the report of the continuous power flow.
8. From the static report one can also get the graphs showing the variation in voltage profile, active and reactive power profile of the network.

Besides continuous power flow, PSAT also performs the optimal power flow, time domain analysis, frequency domain analysis etc.

An overview of distributed generation along with the problem identification has been presented in the previous chapters. This chapter focuses on the methodology implemented in our work, starting with a mention of the basic criteria to be fulfilled for a system to be under stable operation and the PSAT/MATLAB Simulink demonstration of the entire methodology.

Iterative Solution Method

The digital load flow solution algorithms appeared in the mid-1950s; a seemingly infinite collection of iterative schemes has been developed and reported. Many of these are variations of one or the other of two basic techniques that are in extensive use by the industry today the Gauss-Seidel technique and the Newton-Raphson technique. The common techniques used by commercial load flow software are variations of the Newton technique. All of these techniques solve bus equations in admittance form, as described in the previous section. This system of equations has gained widespread application because of the simplicity of data preparation and the ease with which the bus admittance matrix can be formed and changed in

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subsequent cases. In a load flow study, the primary parameters are as follows:

P is the real power into the network
Q is the reactive power into the network
|*V*| is the magnitude of bus voltage
θ is the angle of bus voltage referred to a common location

In order to define the load flow problem to be solved, it is necessary to specify two of the four quantities at each bus. For generating units, it is reasonable to specify *P* and |*V*| because these quantities are controllable through governor and excitation controls, respectively. For loads, one generally specifies the real power demand *P* and the reactive power *Q*. Since there are losses in the transmission system and these losses are not known before the load flow solution is obtained, it is necessary to keep one bus where *P* is not specified this bus is called a swing bus, |*V*| as well as θ are specified. Since θ is specified (that is, held constant during the load flow solution), it is the reference angle for the system. The swing bus is therefore also called the reference bus. Since the real power, *P*, and reactive power, *Q*, are not specified at the swing bus, they are free to adjust to "cover" transmission losses in the system. The classifications of "generator bus" and "load bus" should not be taken as absolute.
There will, for example, be occasions where a pure load bus may be specified by *P* and |*V* |. Bus specification is the tool with which the engineer manipulates the load flow solution to obtain the desired information. The objective of the load flow solution is to determine the two quantities at each bus that are not specified. The generator specification of holding the bus voltage constant and calculating the reactive power output will be overridden in the load flow solution if the generator reactive output reaches its maximum or minimum var limit. In this case, the generator reactive power will be held at the respective limit, and the bus voltage will be allowed to vary.

Newton-Raphson Iterative Method

All load flow problems cannot be solved efficiently using the Gauss-Seidel technique. For some problems, this scheme converges rather slowly. For others, it does not converge at all. Problems that cannot be solved using the Gauss-Seidel technique may often be solved using the Newton-Raphson Technique.

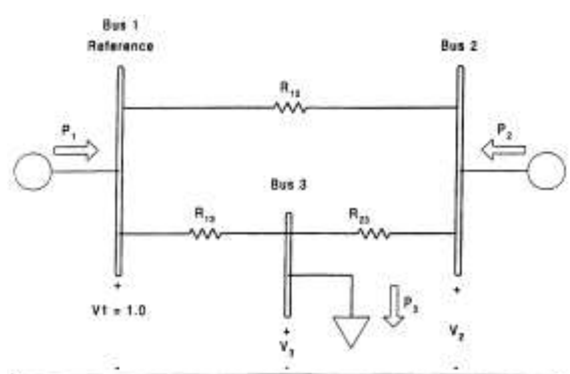

Figure 1 Bus Network

This approach utilizes the partial derivatives of the load flow relationships to estimate the Changes in the

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independent variables required finding the solution. In general, the Newton-Raphson technique achieves convergence using less iteration than the Gauss-Seidel technique. However, the computational effort per iteration is somewhat greater. By applying the Newton-Raphson technique to the three-bus example as shown in Figure 1, the bus Powers are expressed as nonlinear functions of the bus voltage.

However, the decoupled technique does not work well for systems with high branch resistance to reactance ratios, such as often found in industrial systems.

Another method may also use to solve load flow problems efficiently known as fast decoupled power flow but in our work we are only used Newton-Raphson method for load flow analysis.

Fast Decoupled Power Flow Method

This method was first developed by Stott and Alsac in 1974 and has been further established and generalized in some dissimilarities. PSAT used fast decoupled and BX methods presented by van Amerogen in 1989. Decoupled power flow permanently starts with the decoupling of the linearized power flow equations. The two conditions are very important and must be satisfied for coupling, first the resistances of the branches are small with respect to their reactance and second the angle differences are small.

In this work we are used Newton - Raphson Method for load flow analysis.

1. **Load flow of IEEE-14 bus without Distributed Generation**

Here considered 14 bus systems for the analysis as shown in figure 2. It is standard IEEE bus system.

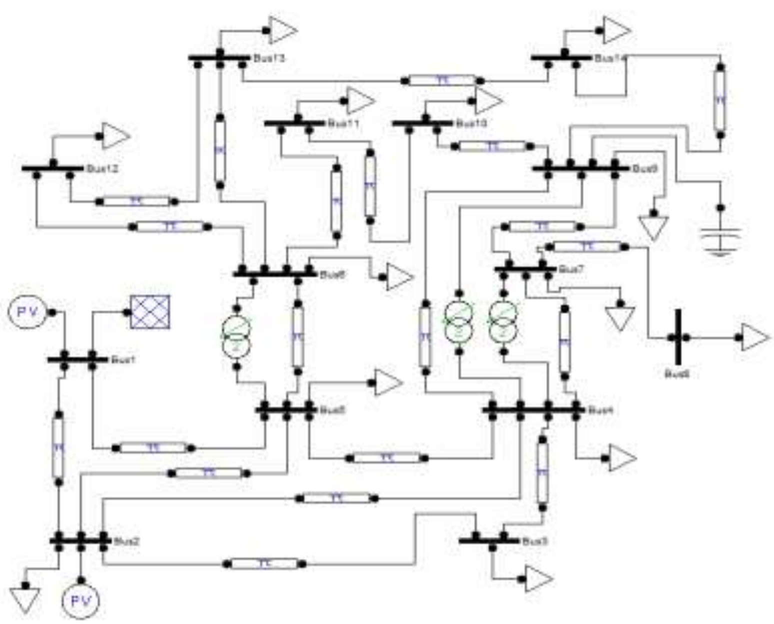

Figure 2 load flow diagram of IEEE-14 bus without DG

CONTINUATION POWER FLOW REPORT

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NETWORK STATISTICS

Buses:	14
Lines:	20
Transformers:	03
Generators:	03
Loads:	13

SOLUTION STATISTICS

Number of Iterations:	19
Maximum P mismatch [p.u.]:	00
Maximum Q mismatch [p.u.]:	00
Power rate [MVA]:	100

Table 1 Power Flow Results without DG

Bus	V (p.u)	Phase (rad)	P. gen (p.u)	Q. gen (p.u)	P.load (p.u)	Q. load (p.u)
Bus 1	1	0	5.8174	0.3894	0	0
Bus 2	0.51611	- 0.76315	0	0	0.12221	0.03206
Bus 3	0.54466	- 0.71821	0	0	0.07012	0.03606
Bus 4	0.53720	- 0.75392	0	0	0.18032	0.11620
Bus 5	0.49604	- 0.77454	0	0	0.27047	0.11620
Bus 6	0.44386	- 0.91063	0	0	0.29852	0.10018
Bus 7	1	- 0.26843	0.8014	6.5577	0.43476	0.25444
Bus 8	0.65532	- 0.69231	0	0	1.88730	0.38267
Bus 9	0.67750	- 0.51698	0	0	0.95767	0.07814
Bus 10	0.71529	- 0.41975	0	0	0.15227	0.03206
Bus 11	0.58035	- 0.65053	0	0	0.22439	0.15026
Bus 12	0.61492	- 0.60867	0	0	0	0
Bus 13	0.61497	- 0.60867	0	0	0	0
Bus 14	0.56355	- 0.73091	0	0	0.59103	0.27224

Table 2 Forward Line Flows without DG

From Bus	To Bus	Line	P. flow (p.u)	Q. flow (p.u)	P. loss (p.u)	Q. loss (p.u)
Bus 1	Bus 2	1	4.2271	- 0.77977	0.35806	1.0922
Bus 2	Bus 3	2	1.7459	1.6191	0.26649	1.1220
Bus 9	Bus 4	3	- 0.14574	- 0.09997	0	0.05426
Bus 7	Bus 9	4	0.38411	0.31046	0	0.07065

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Bus 10	Bus 9	5	- 0.12713	- 0.11888	0.00334	0.00856
Bus 11	Bus 6	6	- 0.12411	- 0.03498	0.00532	0.01082
Bus 12	Bus 6	7	- 0.15461	- 0.04803	0.01209	0.02486
Bus 13	Bus 6	8	- 0.34006	- 0.1315	0.03573	0.07007
Bus 14	Bus 9	9	- 0.20535	- 0.08514	0.03187	0.06754
Bus 11	Bus 10	10	0.05399	- 0.00108	0.00081	0.0016
Bus 13	Bus 14	11	0.10089	0.03054	0.00772	0.01551
Bus 12	Bus 13	12	0.03239	0.01597	0.00109	0.00073
Bus 2	Bus 4	13	1.4315	1.4749	0.24556	0.74437
Bus 2	Bus 5	14	1.0583	1.3373	0.16571	0.50518
Bus 1	Bus 5	15	1.5903	1.1692	0.21057	0.86847
Bus 4	Bus 3	16	0.4359	- 0.04336	0.02801	0.07105
Bus 5	Bus 4	17	1.2157	0.31052	0.04108	0.12911
Bus 6	Bus 5	18	- 0.37676	- 0.26724	0	0.15916
Bus 7	Bus 4	19	- 0.1824	- 0.17585	0	0.03505
Bus 7	Bus 8	20	0	- 0.00038	0	- 0.00038
Bus 9	Bus 4	21	- 0.42888	- 0.21258	0.00677	0.13548
Bus 7	Bus 4	22	- 0.20172	- 0.13423	0.00148	0.0297
Bus 6	Bus 5	23	- 0.51955	- 0.20328	0.00803	0.16055

Table 3 Reverse Line Flows without DG

From Bus	To Bus	Line	P. flow (p.u)	Q. flow (p.u)	P. loss (p.u)	Q. loss (p.u)
Bus 2	Bus 1	1	- 3.869	1.872	0.35806	1.0922
Bus 3	Bus 2	2	- 1.4794	- 0.49707	0.26649	1.122
Bus 4	Bus 9	3	0.14574	0.15423	0	0.05426
Bus 9	Bus 7	4	- 0.38411	- 0.2398	0	0.07065
Bus 9	Bus 10	5	0.13047	0.12744	0.00334	0.00856
Bus 6	Bus 11	6	0.12943	0.0458	0.00532	0.01082
Bus 6	Bus 12	7	0.16669	0.07289	0.01209	0.02486
Bus 6	Bus 13	8	0.37579	0.20157	0.03573	0.07007
Bus 9	Bus 14	9	0.23723	0.15268	0.03187	0.06754

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Bus 10	Bus 11	10	- 0.05318	0.00268	0.00081	0.0016
Bus 14	Bus 13	11	- 0.09317	- 0.01504	0.00772	0.01551
Bus 13	Bus 12	12	- 0.03131	- 0.01525	0.00109	0.00073
Bus 4	Bus 2	13	- 1.1859	- 0.73048	0.24556	0.74437
Bus 5	Bus 2	14	- 0.89258	- 0.83212	0.16571	0.50518
Bus 5	Bus 1	15	- 1.3797	- 0.30069	0.21057	0.86847
Bus 3	Bus 4	16	- 0.40789	0.1144	0.02801	0.07105
Bus 4	Bus 5	17	- 1.1746	- 0.18142	0.04108	0.12911
Bus 5	Bus 6	18	0.37676	0.4264	0	0.15916
Bus 4	Bus 7	19	0.1824	0.21089	0	0.03505
Bus 8	Bus 7	20	0	0	0	- 0.00038
Bus 4	Bus 9	21	0.43565	0.34807	0.00677	0.13548
Bus 4	Bus 7	22	0.2032	0.16393	0.00148	0.0297
Bus 5	Bus 6	23	0.52758	0.36383	0.00803	0.16055

GLOBAL SUMMARY REPORT
TOTAL GENERATION
REAL POWER [p.u]: 6.6188
REACTIVE POWER [p.u]: 6.9471

TOTAL LOAD
REAL POWER [p.u]: 5.1891
REACTIVE POWER [p.u]: 1.5705

TOTAL LOSSES
REAL POWER [p.u]: 1.4297
REACTIVE POWER [p.u]: 5.3766

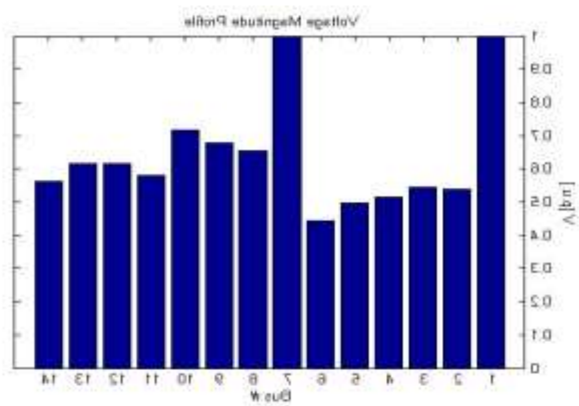

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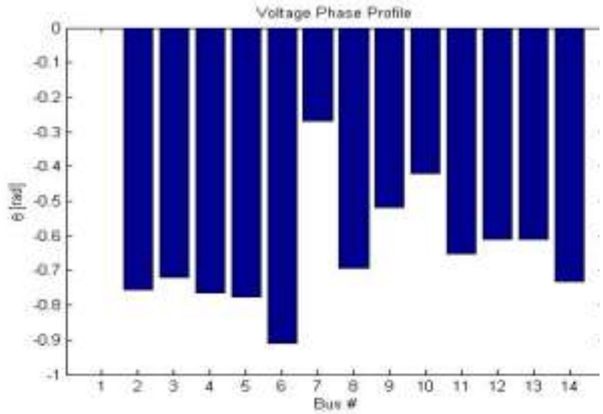
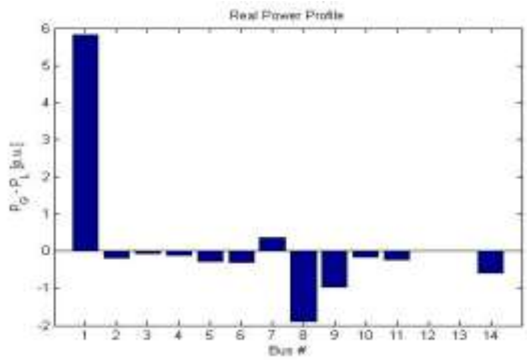
Figure 3 Voltage Profile without DG **Figure 4 Phase Profile without DG**





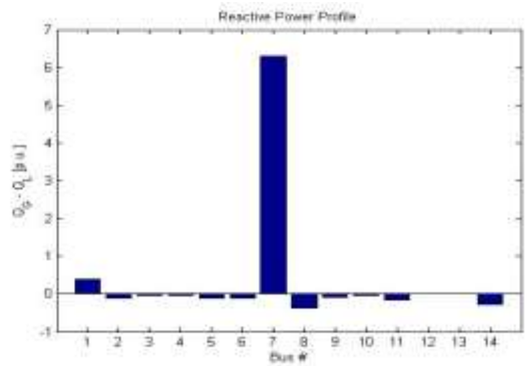


Figure 5 Real Power Profile without DG **Figure 6 Reactive Power Profile without DG**

The results show that bus 14 is the weakest node which is best place to connect DG. More total real & reactive power losses are noticed.

In summary

This paper primarily addressed to find optimal location of distributed generator by using a load flow analysis with the help of MATLAB.

This Research work is concluded as follows

A load flow analysis made initially for an IEEE14-bus system before connecting the DG into the power system to find optimal location. It is observed that bus 14 is the weakest node which is best place to connect DG. Thus optimal location of DG found. More total real & reactive power losses are noticed.

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