Voltage Stability, Loadability and Contingency Analysis with Optimal Integration of Renewable Distributed Generation

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Abstract - This study focuses on Voltage Stability, Loadability And Contingency Analysis of Renewable Distributed Generators (RDGs) using Continuation Power Flow (CPF) analysis. Also, the optimal mix of different types of RDG units (wind turbines, fuel cells, and solar photovoltaics) is selected. Power systems are operated so that overloads do not occur either in real-time or under any statistically likely contingency. – This is often called maintaining system "security".

The motivation of the work is to carry out the contingency selection by calculating the reactive power performance index (PIv) for single transmission line outage. The proposed method is applied on a IEEE 9-bus system, using Power System Analysis Toolbox (PSAT), which is a MATLAB environment. The results showed that the optimal location and optimal mix of different types of RDGs enhanced the voltage stability and increased the maximum loadability point.

Key Words: **Renewable Distributed Generators (RDGs), Power System Analysis Toolbox (PSAT), Power System Analysis Toolbox (PSAT).**

1. INTRODUCTION

Power system security is the probability of system's operating conditions which should remain within the tolerable ranges. This characteristic plays an important role in point of view its operations and planning. Following are few points which make the power reliability and safety over a long run. Firstly, power system should be properly designed with taking security as main concern. Secondly, regular monitoring during operation, maintaining with adequate ranges is second most concern. Thirdly, good engineering is required to achieve these goals which mainly rely on the usage of tools used for power system analysis. The changes that are occurring in the environment have finely tuned the requirement of power system security analysis and its assessments and has also changed the analysis tools of power system.

The control of active and reactive power flows is essential for running power systems. An imbalance in the reactive power will cause voltage instability of the system. Due to the increase in demand for electric power and inability to install new lines because of boundaries, transmission systems are becoming complex. To solve this problem, the most sensitive nodes in the distribution system must be determined to maintain the stability of the system. Many studies have presented different distributed generator (DG) placement algorithms using analytic and heuristic methods. Reference [1] presents a study of the impact of integrated renewable energy sources on the voltage stability by using the Continuation Power Flow (CPF) method for different levels of wind penetration. Various types of voltage stabilities have been studied to make the voltage instability problem more limited and conception [2]. Reference [3] proposed using a generalized pattern search method to calculate the placement and DGs in the distribution network.

1.1 RENEWABLE DISTRIBUTED GENERATION

Renewable Distributed Generation (RDGs) is the generation of electricity from many small energy sources, e.g., solar, wind, Fuel cell etc. The Distributed Generation power integration have some effect into the power system grids as power system issues transmission congestion, optimal power flow, system stability, power quality, system economics and load dispatch. In the future RDG penetration is expected to rise to about i10% of total installed capacity in the next decade. Distributed Generation can be defined as an electrical power source connected directly to the distribution network or ion the consumer side of the meter. It may be understood in simple term as small-scale electricity market. There are a number of DG technologies available in the market today and few are still in research and development stage.

Some currently available technologies are reciprocating engines, micro turbines, combustion gas turbines, fuel cells, photovoltaic and wind turbines.

2. OBJECTIVE OF LOAD FLOW STUDY

Power flow analysis is very important in planning stages of new networks or addition to existing ones like adding new generator sites, meeting increase load demand and locating new transmission sites. The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines. It determines the voltage of the buses. The voltage level at the certain buses must be kept within the closed tolerances. System transmission loss minimizes Economic system operation with respect to fuel cost to generate all the power needed The line flows can be known. The line should not be overloaded, it means, we should not operate the close to their stability or thermal limits.

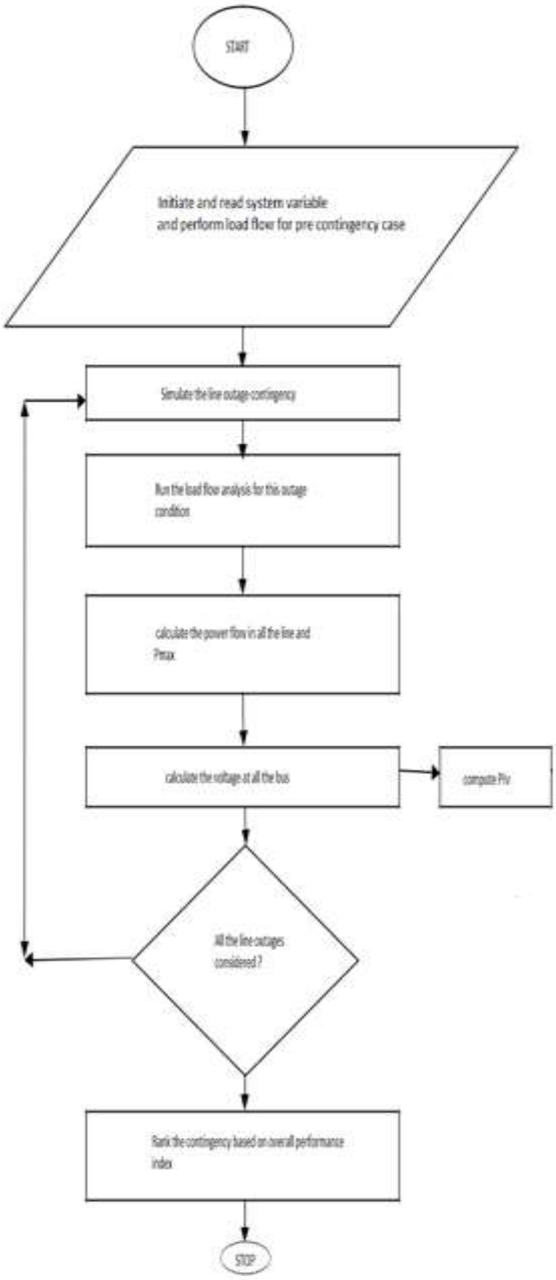
2.1 LOAD FLOW ANALYSIS USING POWER SYSTEM ANALYSIS TOOLBOX (PSAT)

The power system analysis toolbox (PSAT), an open source Matlab and GNU/Octave-based software package for analysis and design of small to medium size electric power systems. PSAT includes power flow, continuation power flow, optimal power flow, small signal stability analysis and time domain simulation. PSAT are Simulink library models for elements (wind turbines – WTs, fuel cells –FCs, solar photovoltaic generators – SPVGs, transformers, transmission lines, FACT device, and load models). PSAT provides many numerical methods such as the Newton-Raphson (NR) method, fast decoupled methods (both BX and XB), and Runge-Kutta methods to conduct PF analysis.

3. CONTINGENCY ANALYSIS WITH OPTIMAL PLACEMENT AND OPTIMAL MIX OF RDGS

There are many power systems where voltage magnitudes are the critical factor in assessing contingencies. The method gives rapid analysis of the MW flows in the system, but cannot give information about MVAR flows and bus voltages. In systems where VAR flows predominate, such as underground cables, an analysis of only the MW flows will not be adequate to indicate overloads. Hence the method of contingency analysis using AC power flow is preferred as it gives the information about MVAR flows and bus voltages in the system. When AC power flow is to be used to study each contingency case, the speed of solution for estimating the MW and MVAR flows for the contingency cases are important, if the solution of post contingency state comes late, the purpose of contingency analysis fails. The method using AC power flow will determine the overloads and voltage limit violations accurately. It does suffer a drawback, that the time such a program takes to execute might be too long. If the list of outages has several thousand entries, then the total time to test for all of the outages can be too long.

3.1 FLOW CHART OF ALGORITHM FOR CONTINGENCY ANALYSIS



3.2 REACTIVE POWER PERFORMANCE INDEX (PI_V)

This is the index which helps in determining bus voltages limit violation.

$$PI_v = \sum_{i=1}^{Nb} \left(\frac{W}{2n}\right) \{(|V_i| - |V_i^{sp}|)/\Delta V_i^{lim}\}^{2n}$$

Where,

$|V_i|$ is the voltage magnitude at i^{th} bus

$|V_i^{sp}|$ is the specified (rated) voltage magnitude at i^{th} bus
ΔV_i^{lim} is the deviation limit of the voltage
n is the exponent of penalty function and value is (=1)
N_b is the number of buses in the system taken.

W the real non-negative weighting factor and the value is (= 1)

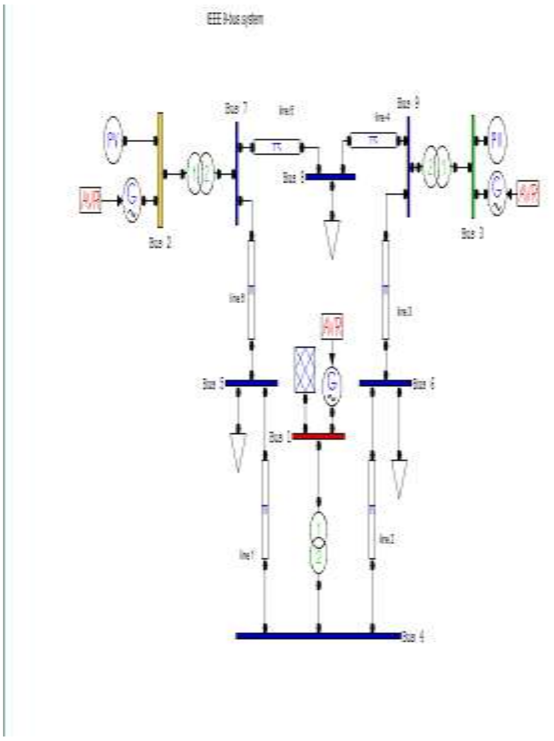
3.3 APPROACH TO SELECTING OPTIMAL PLACEMENT AND OPTIMAL MIX OF RDGS

- Run the load flow and CPF by using PSAT to determine the voltage stability and maximum loadability point.
- Simulating a line outage or line contingency, i.e. removing a line and proceeding to the next step.
- The Reactive Power performance index (PI_V) is being calculated which indicates the voltage limit violation at all the load buses due to the line contingencies.
- The optimal placement of RDGs to be installed in the distribution system is assessed by using Performance Index analysis.
- The Bus has a maximum value of the (PI_V) that represents the more critical Bus with respect to that bus (selected from critical buses only).
- Place the RDG at the selected bus.
- Run CPF and print the results.
- Save the optimal placement and optimal mix of RDGs that gives the maximum loadability point.
- Change the type of RDG in all cases.
- Print the final results and end.

4. TEST SYSTEM (SIMULATION AND RESULTS)

The main aim here is to obtain contingency analysis using calculated value of reactive performance indices PI_V. The contingency ranking is done in the order of their severities which uses the performance index(PI). The computation of performance indices are calculated based on the load flow analysis carried out using conventional methodNewton Raphson method under MATALB environment. The most severe contingent is chosen from the contingency list and the corresponding power flows and line flows are analyzed for the considered power system. The study has been carried out for the following standard systems.

4.1 IEEE 9 Bus System General Model Without Integration of RDG



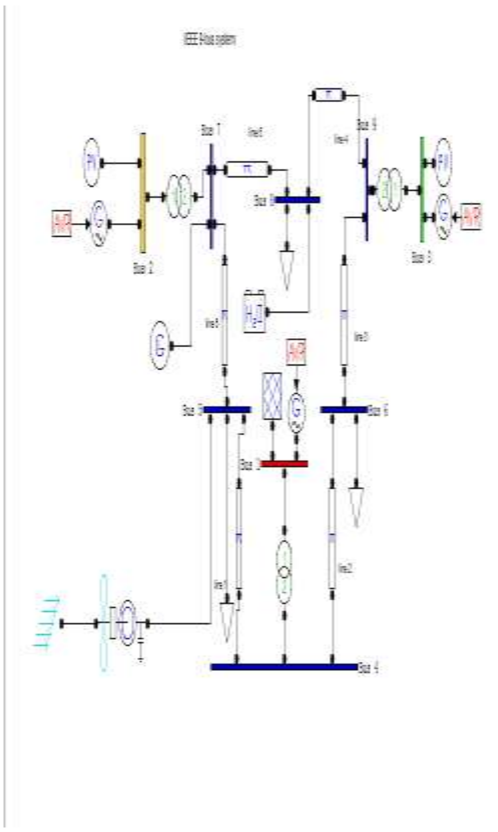
NETWORK STATISTICS

Buses:	9
Lines:	6
Transformers:	3
Generators:	3
Loads:	3

The bus data and line for the 9 bus test system has been given in Table Below. The following conventions were used for all the test bus systems; Base MVA = 100.

Bus No.	Voltage Mag.(pu)	Phase(Radian)
1	1.0262	0
2	0.83908	0.49518
3	0.93685	0.21344
4	1.0421	-0.05882
5	0.89304	-0.10294
6	0.95526	-0.09595
7	0.84506	0.24554
8	0.8374	0.06595
9	0.92104	0.11401

4.2 IEEE 9 Bus System Line 1 out Contingency Model With Integration of RDG(SPVG+FC+WT)



The bus data and line for the 9 bus test system Line 1 contingency Model with integration of RDG has been given in Table Below. The following conventions were used for all the test bus systems; Base MVA = 100.

From Bus	To Bus	P flow(pu)	Q flow(pu)
9	8	0.69724	0.21592
8	7	-0.30919	0.03391
9	6	0.15276	-0.68915
7	5	1.3195	0.51142
5	4	0	-0.06732
6	4	-0.75661	-0.60598
2	7	1.63	0.44657
3	9	0.85	-0.42295
1	4	0.76778	0.36305

TOTAL GENERATION
REAL POWER [p.u.] 3.2478
REACTIVE POWER [p.u.] 0.38667

TOTAL LOAD
REAL POWER [p.u.] 3.15
REACTIVE POWER [p.u.] 1.15

4.3 REACTIVE POWER PERFORMANCE INDEX CALCULATION (PIv)

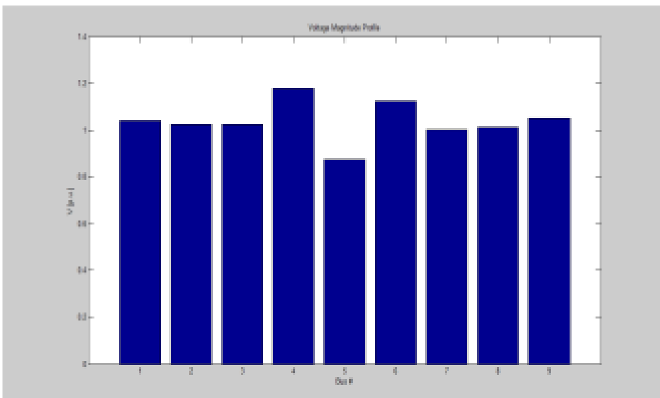
BUS NUMBER	REACTIVE POWER PERFORMANCE INDEX
1	8.688 * 10^-4
2	828*10^-4
3	1.0905*10^-4
4	176*10^-4
5	157*10^-4
6	8.218*10^-4
7	466*10^-4
8	149*10^-4
9	3.141*10^-3

4.4 LOADABILITY PARAMETER (LAMBDA ƛMAX)UNDER CONTINGENCY CONDITION LINE 1 OUTAGE AND DIFFERENT RDG UNITS

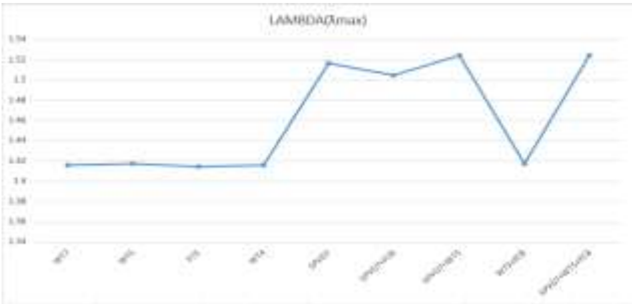
Bus No.	Voltage Mag.(pu)	Phase(Radian)
1	1.04	0
2	1.025	0.03006
3	1.025	0.00713
4	1.1791	-0.03137
5	0.87481	-0.2889
6	1.125	-0.07737
7	1.0027	-0.06922
8	1.0126	-0.10158
9	1.0503	-0.03916

4.5 GRAPHICAL REPRESENTATION OF RESULT

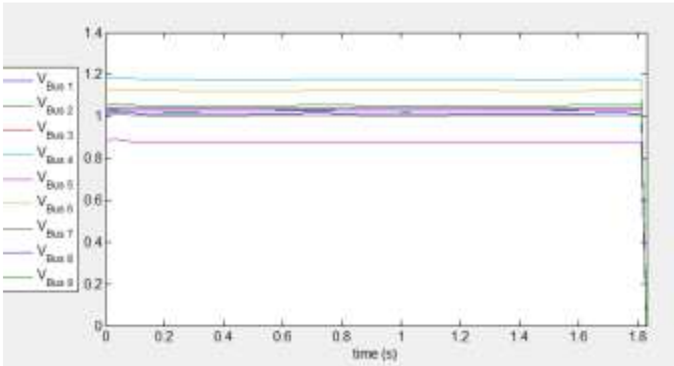
(a)BUS VOLTAGE PROFILE IEEE 9 BUS SYSTEM LINE 1 OUT CONTINGENCY MODEL WITH INTEGRATION OF RDG(SPVG+FC+WT)



(b) GRAPHICAL REPRESENTATION OF LOADABILITY PARAMETER UNDER CONTINGENCY CONDITION LINE 1 OUTAND DIFFERENT RDG UNIT



(C) VOLTAGE TIME GRAPH IEEE 9 BUS SYSTEM LINE 1 OUT CONTINGENCY MODEL WITH INTEGRATION OF RDG(SPVG+FC+WT)



RDG CASE	LAMBDA(λmax)
WT7	1.4157
WT5	1.4176
FC5	1.4149
WT4	1.4157
SPVG7	1.5166
SPVG7+FC8	1.5051
SPVG7+WT5	1.5244
WT5+FC8	1.4176
SPVG7+WT5+FC8	1.5248

5. CONCLUSIONS

- This Dissertation discusses use of the optimization method to determine the optimal placement and optimal mix of RDGs in an electric grid.
- The Performance Index method and CPF were proposed for selecting the optimum position and optimal mix of RDGs in the distribution system.
- This study aims to increase the maximum loadability and improve the voltage stability.
- The proposed method was tested on an IEEE 9 bus system for nine cases, with and without including the optimal mix of different types of RDG units (FC, WT, and SPVG).
- The contingency selection and ranking which are important for contingency analysis have been done by evaluating reactive power performance index (PI_V).
- However, the maximum loadability point and voltage stability of the test system in case ninth are better than in the base case.

FUTURE SCOPE

- The training for large systems like 118-Bus system and the structure of RBF-ANN like, neurons in hidden layer need to be investigated further.
- To perform the contingency analysis and the contingency selection consider a multiple line or equipment failures. .
- Implement a hardware model so that it can be used for online applications in power system contingency analysis.

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