POWER FLOW ANALYSIS WITH DIFFERENT OPTIMAL INTEGRATION OF RENEWABLE DISTRIBUTED GENERATION USING PSAT

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Abstract : The present complexity of electrical power system engineering mainly includes the problems like blackout, power scarcity, incompetence of meeting the necessary demand of power, load shedding etc. As a result new power plants are designed or old ones are extended and upgraded. Load flow analysis plays a essential role in both the above mentioned cases. The power flow analysis provides the nodal voltages and phase angles and hence the power injected at all the buses and power flows through interconnecting power channels. The optimal power flow is used to optimize the load flow solutions of large scale power system. This is done by minimizing the selected objective functions while maintaining an acceptable limit in terms of generator capabilities and the output of the corresponding devices. Generally loads are taken as constant sink for both reactive and active power Where as in reality, the load power consumption depends magnitude of voltage and frequency deviations. Optimal Power Flow studies incorporating integration of (RDG) renewable distributed generation is a major tool for minimizing generation and transmission losses, generation costs and maximizing the system efficiency. This thesis focuses on inclusion of Renewable distributed generation in CPF analysis and comparing the results obtained with those obtained from CPF studies without inclusion of (RDG) Renewable distributed generation. An over-riding factor in the operation of the power system is the craving to maintain security and expectable reliability level in all the sectors- power generation, transmission and distribution. System security can be assessed using contingency analysis. The result of this analysis allows system to be operated defensively and steadily. In our thesis contingency analysis and reliability evaluation of power system network will be performed that will ensure safe, secure and reliable operation of the system.

***IndexTerms* – CPF –continous power flow, Load flow analysis,RDG.**

1.INTRODUCTION

Power flow analysis is the analysis of a network under steady state condition subjected to some inequality constraints under which the system operates. Load flow solution tells about the line flows of reactive and active power and voltage magnitude and phase difference at different bus bars. It is crucial for design of a new power system or for planning for the expansion of the existing one for augmented load demand. Electrical loads of a system comprises of various industrial, residential and municipal loads. the active and reactive power of loads of a distribution system are dependent on system voltage magnitude and phase angle. This effects, if taken into consideration would cause a major change in the results of load flow and CPF studies.

The optimal mix of different types of RDG units[1] (wind turbines, fuel cells, and solar photovoltaics) is selected. An example of the type of event sequence that can cause a blackout might start with a single line being opened due to an insulation failure; the remaining transmission circuits in the system will take up the flow that was flowing on the now-opened line. If one of the remaining lines is now heavily loaded, it may open due to relay action, thereby causing even more load on the remaining lines. This type of process is often termed a cascading outage. Most power systems are operated such that any single initial failure event will not leave other components heavily overloaded, specifically to avoid cascading failures.

1.1 PURPOSE OF POWER FLOW ANALYSIS

- To determine the magnitude of voltage and phase angles at all nodes of the feeder.
- To determine the line flow in each line section specified in Kilo Watt (KW) and KVAr, amperes and degrees or amperes and power factor.
- To determine the power loss.
- To determine the total input to the feeder Kilo Watt (KW) and KVAr.
- To determine the active and reactive power of load based on the defined model for the load.

1.2 RENEWABLE DISTRIBUTED GENERATION

Renewable Distributed Generation (RDGs)[3] 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 10% 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 on 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.

2. POWER SYSTEM ANALYSIS TOOLBOX (PSAT)

PSAT is a Matlab toolbox for electric power system analysis and control. The command line version of PSAT is also Octave compatible. PSAT[7] includes power flow, continuation power flow, optimal power flow, small signal stability analysis and time domain simulation. All operations can be assessed by means of graphical user interfaces (GUIs) and a Simulink-based library provides an user friendly tool for network design. The paper presents several Matlab toolboxes can be used in power system analysis. These toolboxes come with a variety of procedures for static and dynamic analysis that can be used with easiness in educational and research activities. One of the features of these Matlab toolboxes is the modularity of design, facilitating future revision and expansion of softwares. This is very important for researches who are interested in developing and testing new for various power system applications. PSAT are[2] Simulink library models for elements (wind turbines – WTs, fuel cells –FCs, solar photovoltaic generators – SPVGs, transformers, transmission lines, FACT device, and load models).

3. POWER FLOW ANALYSIS

Power flow analysis[5] is the analysis of a network under steady state condition subjected to some inequality constraints under which the system operates. Load flow solution tells about the line flows of reactive and active power and voltage magnitude and phase difference at different bus bars. It is essential for design of a new power system or for planning for the expansion of the existing one for increased load demand. Power flow analysis is probably the most important of all network calculations since it concerns the network performance in its normal operating conditions. It is performed to investigate the magnitude and phase angle of the voltage at each bus and the real and reactive power flows in the system components.

Power flow analysis has a great importance in future expansion planning, in stability studies and in determining the best economical operation for existing systems. Also load flow results are very valuable for setting the proper protection devices to insure the security of the system. In order to perform a load flow study, full data must be provided about the studied system, such as connection diagram, parameters of transformers and lines, rated values of each equipment, and the assumed values of real and reactive power for each load.

The steady state operation of power system as a topic for study is called “Power flow study”. The objective of any power flow program is to produce the following information:

- Voltage magnitude at each bus.
- Real and reactive power flowing in each line.
- Phase angle of voltage at each bus.
- Simply stated the power flow problem is as follows:
- At any bus there are four quantities of interest: $|V|$, θ, P, and Q.
- Ifany two of these quantities are specified, the other two must not be specified otherwise we end up with more unknowns than equations.
- Because records enable the real and reactive power to be accurately estimated at loads, P and Q are specified quantities at loads, which are called PQ buses.
- Likewise, the real power output of a generator is controlled by the prime mover and the magnitude of the voltage is controlled by the exciter, so and P and $|V|$ are specified at generators, which are called PV buses.
- This means that $|V|$ and θ are unknown at each load bus and θ and Q are unknown at each generator bus.
- Since the system losses are unknown until a solution to the load-flow problem has been found, it is necessary to specify one bus that will supply these losses. This is called the slack (or swing, or reference) bus and since P and Q are unknown, $|V|$ and θ must be specified. Usually, an angle of θ = 0 is used at the slack bus and all other bus angles are expressed with respect to slack.

3.1 NEWTON RAPHSON POWER FLOW(NRPF) IN POLAR CO-ORDINATES

For NRLF[6] techniques the starting equations are given below .

$$Pi = \sum_{j=1}^{n} Vi\ Vj\ Yij\ COS(\theta i - \theta j - \alpha ij)$$

$$Qi = \sum_{j=1}^{n} Vi\ Vj\ Yij\ COS(\theta i - \theta j - \alpha ij)$$

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \left[\begin{array}{c|c} \begin{pmatrix} \frac{\partial P_2^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial P_2^{(k)}}{\partial \delta_n^{(k)}} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial P_n^{(k)}}{\partial \delta_n^{(k)}} \end{pmatrix} & \begin{pmatrix} \frac{\partial P_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \end{pmatrix} \\ \hline \begin{pmatrix} \frac{\partial Q_2^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_2^{(k)}} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_n^{(k)}} \end{pmatrix} & \begin{pmatrix} \frac{\partial Q_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{pmatrix} \end{array}\right] \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix}$$

The Jacobian matrix gives the linearized relationship between small changes in $\Delta\delta_i^k$ and $\Delta[Vi^k]$ with small changes in real and reactive power $\Delta P_i{}^k$ and ΔQ_i^k

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J1 & J2 \\ J3 & J4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix}$$

The diagonal and off diagonal elements of $J_1$are

$$\frac{\partial Pi}{\partial \delta i} = \sum_{j\neq i} |Vi|\,|Vj|\,|Yij| \sin(\theta ij - \delta i - \delta j)$$

$$\frac{\partial Pi}{\partial \delta i} = -\,|Vi|\,|Vj|\,|Yij| \sin(\theta ij - \delta i - \delta j) \qquad j\neq i$$

Similarly we can find the diagonal and off diagonal elements for J2 ,J3,J4.

3.2 POWER FLOW ANALYSIS USING POWER SYSTEM ANALYSIS TOOLBOX (PSAT)

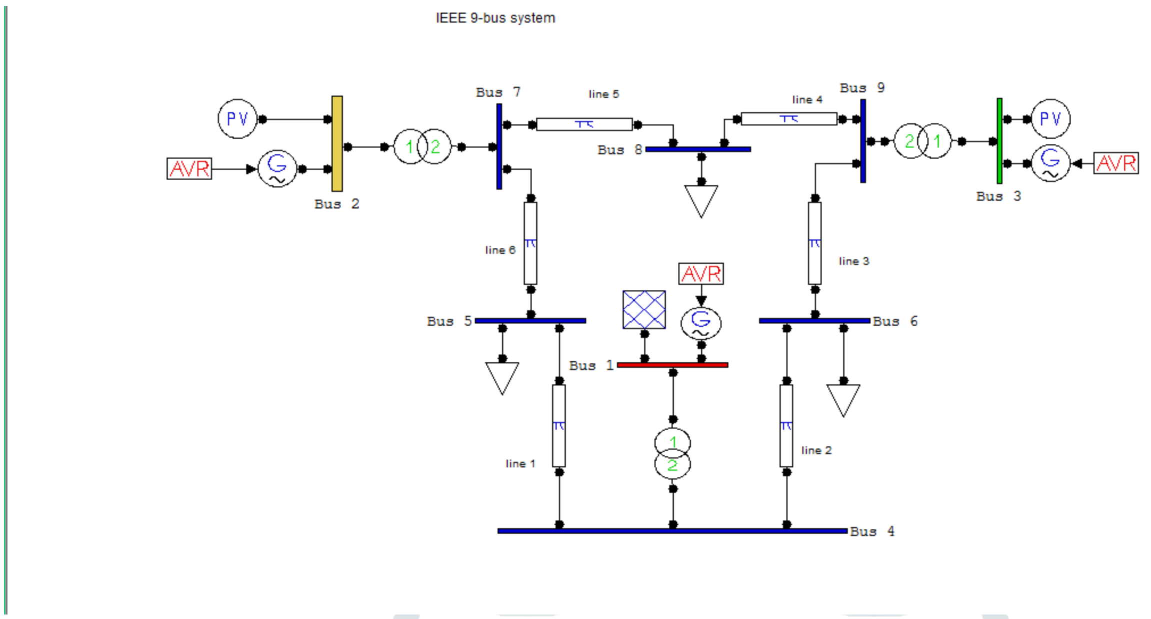
THE POWER SYSTEM ANALYSIS TOOLBOX (PSAT), AN OPEN SOURCE MATLAB AND GNU/OCTAVE-BASED SOFTWARE PACKAGE FOR ANALYSIS AND DESIGN OF SMALL TO MEDIUM SIZE ELECTRIC POWER SYSTEMS. PSAT INCLUDES POWER FLOW, CONTINUATION POWER FLOW, OPTIMAL POWER FLOW, SMALL SIGNAL STABILITY ANALYSIS AND TIME DOMAIN SIMULATION AS WELL AS SEVERAL STATIC AND DYNAMIC MODELS, INCLUDING NON-CONVENTIONAL LOADS, SYNCHRONOUS AND SYNCHRONOUS MACHINES, REGULATORS AND FACTS. PSAT IS ALSO PROVIDED WITH A COMPLETE SET OF USER-FRIENDLY GRAPHICAL INTERFACES AND A SIMULINK-BASED EDITOR OF ONE-LINE NETWORK DIAGRAMS. BASIC FEATURES, ALGORITHMS AND A VARIETY OF CASE STUDIES IS PROVIDED IN PSAT .POWER SYSTEM COURSES DEAL WITH COMPLEX PHYSICAL PHENOMENA AND DETAILED MATHEMATICAL MODELS .THE COMPLEXITY OF MATHEMATICAL MODELS OFTEN DEVIATE STUDENTS FOCUS FROM UNDERSTANDING THE UNDERLYING PHYSICAL PHENOMENA. FURTHERMORE, THE COMPUTATIONAL BURDEN OF POWER SYSTEM ANALYSIS IS CUMBERSOME EVEN FOR SMALL NETWORKS, ESPECIALLY IF DYNAMIC MODELS ARE INVOLVED. AS A RESULT, EDUCATIONAL POWER SYSTEM SOFTWARE HAS BECOME A FUNDAMENTAL TEACHING TOOL BECAUSE IT HELPS STUDENTS TO ASSIMILATE THEORETICAL ISSUES THROUGH GRAPHIC VISUALIZATION OF RESULTS AND USER-FRIENDLY INTERFACES.

POWER FLOW STUDY (PFS) IS THE MOST IMPORTANT PART OF SYSTEM-PLANNING STUDIES AND ALSO THE STARTING POINT FOR TRANSIENT AND DYNAMIC STABILITY STUDIES. THE LOAD FLOW PROBLEM MODELS THE NONLINEAR RELATIONSHIPS AMONG BUS POWER INJECTIONS, POWER DEMANDS, AND BUS VOLTAGES AND ANGLES, WITH THE NETWORK CONSTANTS PROVIDING THE CIRCUIT PARAMETERS. FORMULATIONS OF THE LOAD LFSS IN UNFORESEEN CONTINGENCY ENVIRONMENTS. LOAD FLOW ARE NECESSARY FOR PLANNING, OPERATION, ECONOMIC SCHEDULING AND EXCHANGE OF POWER BETWEEN UTILITIES. THE PRINCIPAL INFORMATION OF LFS IS TO FIND THE MAGNITUDE AND PHASE ANGLE OF VOLTAGE AT EACH BUS AND THE REAL AND REACTIVE LOAD FLOWING IN EACH TRANSMISSION LINES.ITERATIVE TECHNIQUES ARE SOLVED VIA POWER SYSTEM ANALYSIS TOOL. TO FINISH THIS STUDIES THERE ARE METHODS OF MATHEMATICAL CALCULATIONS WHICH CONSIST PLENTY OF STEP DEPEND ON THE SIZE OF SYSTEM. THIS PROCESS IS DIFFICULT AND TAKES A LOT OF TIMES TO PERFORM BY HAND. PFS SOFTWARE PACKAGE USE POWER SYSTEM ANALYSIS TOOLBOX (PSAT).

4. TEST SYSTEM (SIMULATION AND RESULTS)

A standard IEEE 9 bus system was considered for analysis both with conventional General Model Without Integration of RDG and With Integration of RDG. The simulations were made using Matlab Power system toolbox known as PSAT (Power System Analysis Toolbox). The results of the simulations were plotted and analyzed.

4.1 IEEE 9 Bus System General Model Without Integration of RDG



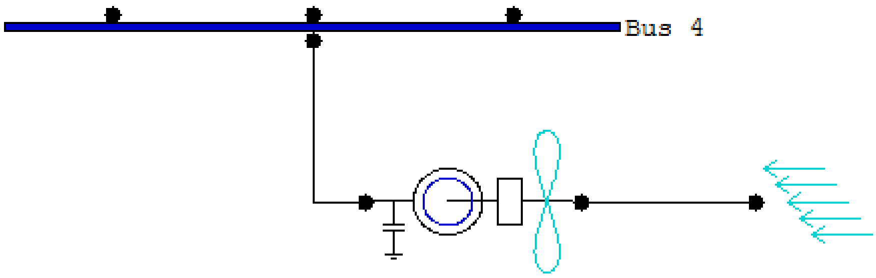
The bus data and line for the 9 bus test system has been given in Table Below. The following conventions were used for all the test bus systems; Base MVA = 100 .

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

ACTIVE(P) AND REACTIVE(Q) POWER LINE FLOWS

From Bus	To Bus	Line	P Flow (pu)	Q Flow(pu)	P Loss(pu)	Q Loss(pu)
9	8	1	0.45256	0.63099	0.01014	-0.07606
8	7	2	-1.2311	0.12133	0.02636	0.07538
9	6	3	1.0091	-0.45512	0.05104	-0.0927
7	5	4	1.5455	-0.38651	0.11048	0.32456
5	4	5	-0.65681	-1.5478	0.03279	0.11295
6	4	6	-0.54808	-0.86446	0.01729	-0.06429
2	7	7	2.8029	0.27149	0	0.70395
3	9	8	1.4616	0.32558	0	0.14972
1	4	9	1.255	2.8657	0	0.40479

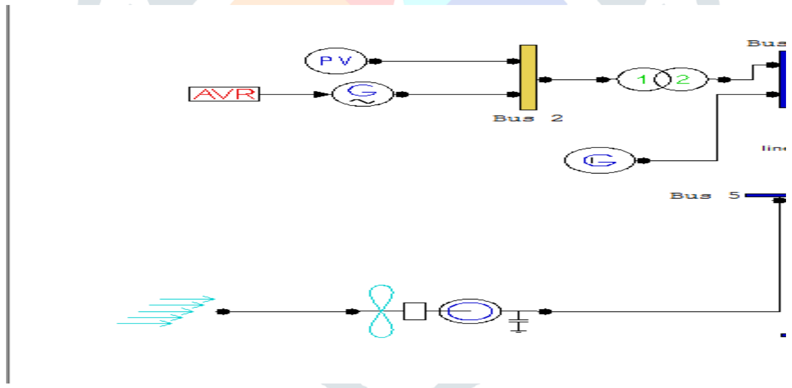
4.2 CONTINGENCY LINE 1 OUTAGE MODEL WITH INTEGRATION OF RDG WIND TURBINE AT BUS NO 4



ACTIVE(P) AND REACTIVE(Q) POWER LINE FLOWS

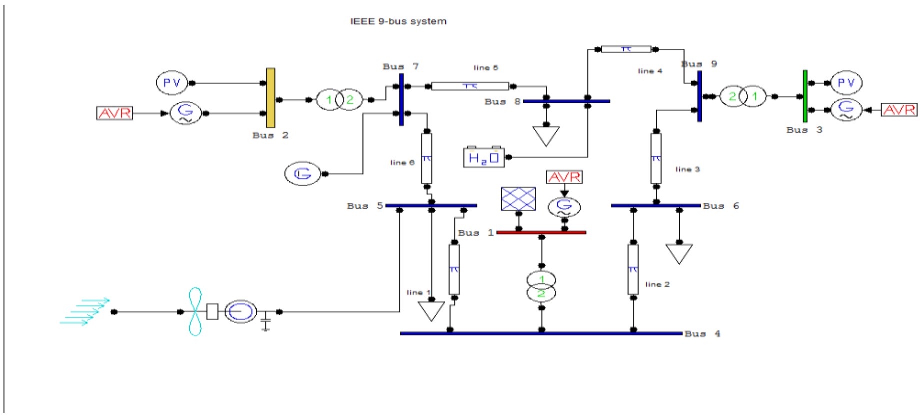
From Bus	To Bus	Line	P Flow (pu)	Q Flow(pu)	P Loss(pu)	Q Loss(pu)
9	8	1	0.98819	-1.1645	0.02123	-0.08356
8	7	2	-0.44141	-1.5739	0.01959	-0.15193
9	6	3	0.20927	-0.54347	0.00528	-0.4097
7	5	4	1.8353	0.49034	0.07484	-0.0921
5	4	5	1e-005	-0.12175	1e-005	-0.24405
6	4	6	-1.0636	-0.55628	0.01808	-0.11145
2	7	7	2.2963	2.2447	0	0.33241
3	9	8	1.1975	-1.4878	0	0.22025
1	4	9	1.0816	0.37535	0	0.05282

4.3 CONTINGENCY LINE 1 OUTAGE MODEL WITH INTEGRATION OF RDG WIND TURBINE AT BUS NO 5 AND SOLAR PHOTOVOLTAIC GENERATOR AT BUS NO 7



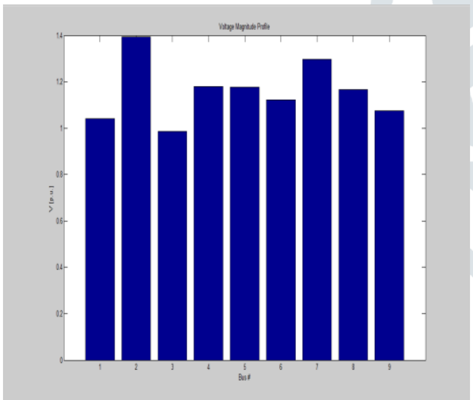
From Bus	To Bus	Line	P Flow (pu)	Q Flow(pu)	P Loss(pu)	Q Loss(pu)
9	8	1	1.0176	0.18837	0.01293	-0.09906
8	7	2	-0.5118	-0.24333	0.00349	-0.17593
9	6	3	0.25265	-0.65238	0.01064	-0.35026
7	5	4	2.3205	2.669	0.42499	1.9376
5	4	5	-2e-005	-0.02688	6e-005	-0.14611
6	4	6	-1.1228	-0.75706	0.02447	-0.06792
2	7	7	2.4358	0.02894	0	0.37633
3	9	8	1.2702	-0.36039	0	0.10362
1	4	9	1.1474	0.63969	0	0.0697

4.4 CONTINGENCY LINE 1 OUTAGE MODEL WITH INTEGRATION OF RDG WIND TURBINE AT BUS NO 5 SOLAR PHOTOVOLTAIC GENERATOR AT BUS NO 7 AND FUEL CELL AT BUS NO 8

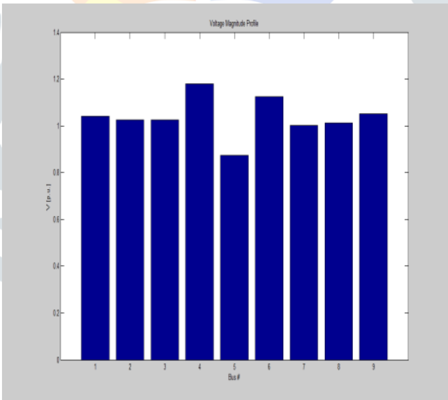


From Bus	To Bus	LINE	P flow(pu)	Q flow(pu)	P Loss (pu)	Q Loss(pu)
9	8	1	0.69724	0.21592	0.00643	-0.16798
8	7	2	-0.30919	0.03391	0.00134	-0.20086
9	6	3	0.15276	-0.68915	0.00937	-0.38317
7	5	4	1.3195	0.51142	0.0695	0.07874
5	4	5	0	-0.06732	2e-005	-0.18969
6	4	6	-0.75661	-0.60598	0.01113	-0.1496
2	7	7	1.63	0.44657	0	0.16992
3	9	8	0.85	-0.42295	0	0.05028
1	4	9	0.76778	0.36305	0	0.02905

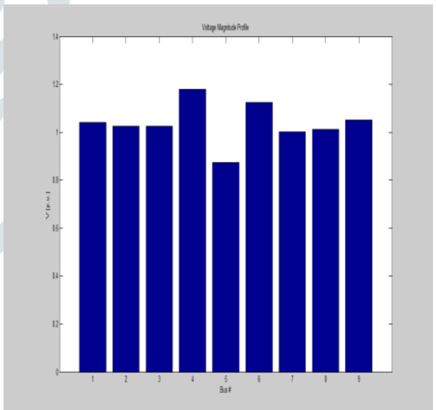
4.5 GRAPHICAL REPRESENTATION OF BUS VOLTAGES WITH DIFFERENT RDG WIND TURBINE(WT),SOLAR PHOTOVOLTAIC GEN(SPVG),FUEL CELL(FC)



WT at bus no 4



WT at bus no 5 & SPVG at bus no7



WT at bus 5,SPVG at bus 7,FC at bus 8

5. CONCLUSION

This dissertation introspects the effects of integration of renewable distributed generation i.e. the variation of active and reactive power demands with magnitude of voltage at different buses in load flow analysis. The simulation of a standard IEEE 9 bus bar system was conducted and the effects were also incorporated in the experiment. The proposed method was tested on an IEEE 9 bus system for different cases, with and without including the optimal mix of different types of RDG units (FC, WT, and SPVG).

Inclusion of RDG in a distribution system results in several benefits. One of the important one is the line loss reduction. This paper proposes an investigative algorithm to find the optimum location and size of a DG unit. The obtained location and size is the most optimum location and size in all of the possible optimum solutions because of analyzing all of the locations and sizes for each bus. Results for the test system can show the applicability of the method. In practice the choice of the best site and size may

not be always possible due to many constraint.The result has discussed in the different mode and describe one by one, in the weak distribution, the different voltage and power at various points. The voltage at bus 5 is about 1 pu and after disturbance line the voltage is 0.80 pu if any disturbance occur then the system may be shut down. When DG used to compensate the real and reactive power and the DG is integrated with the distribution network and all power generate from the DG is occupies in the weak distribution network. When the DG is applied then the voltage of the bus no.5 is also improved very fast, and the power supplied into the network that why the distribution network, improved and the DG is integrated in the system.

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