Power Flow Analysis for Four Buses System by NR Method

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ABSTRACT

Power flow studies provide a systematic mathematical approach for determination of various bus voltages, there phase angle, active and reactive power flows through different branches, generators and loads under steady state condition. In this paper, the purpose of power flow analysis is to determine four bus system power flows. Case studies have been performed on Lawpita - Taungoo - Kamarnat - Hlawga (230kV) Line (Myanmar). This paper presents a reliable method to meet the requirements by developing a Newton-Raphson based load flow calculation program through which control setting of Shunt Compensator can be determined directly. This program computes the voltage magnitude and angle at each bus in a power system under balanced steady state conditions. Real and reactive power flows for all buses, as well as line flow and line losses, are also computed. And then the compensation of shunt capacitor is proposed for load flow analysis and also for overall loss minimization and improvement in system voltage profile.

KEYWORDS: - Load Flow, Newton-Raphson Method, MATLAB, Shunt Compensator.

I. INTRODUCTION

The power flow analysis (also known as the load flow problem) is a very important and fundamental tool involving numerical analysis applied to a power system. The analysis is also employed during power system design procedures, planning expansion and development of control strategies. The purpose of any load flow analysis is to compute precise steady-state voltages and voltage angles of all buses in the network, for specified load, generator real power and voltage conditions. Once this information is known, the real and reactive power flows into every line and transformer, as well as generator reactive power output can be analytically determined. Due to the nonlinear nature of this problem, numerical methods are employed to obtain a solution that is within an acceptable tolerance. A power flow analysis for a system operating under actual or projected normal operation conditions (base case) give the results which constitute a benchmark for comparison of changes in the network flows and voltages under abnormal conditions. It is helpful in determining the best location as well as

optimal capacity of proposed generating station, substation and new lines. Power flow analysis is an efficient mean that uses numerical analysis technique for developing a power system. To carry out these analyses, iterative techniques are used due to existence of no known analytical method to solve the problem.

II. CLASSIFICATION OF BUS

A bus is a node at which one or many lines, one or various loads and generators are connected. In a power system each node or bus is associated with 4 quantities, such as magnitude of voltage, phase angle of voltage, active or real power and reactive power. In load flow problem two out of these 4 quantities are specified and remaining 2 are required to be determined through the solution of equation. However in power flow analysis, they are classified into three types based on their known as

1. Slack Bus or Swing Bus
2. Generator Bus or Voltage Controlled Bus
3. Load Bus

TABLE I VARIABLES IN POWER FLOW ANALYSIS

Sr. No.	Type of Bus	Variable (Known)	Variable (Unknown)
1	Slack or Swing Bus	l V l, δ	P, Q
2	Load Bus	P, Q	l V l, δ
3	Voltage Controlled Bus	P, l V l	Q, δ

III. PROBLEM FORMULATION

A. Power Flow Model Based Newton-Raphson Iteration Method

Power flow analysis based on Newton-Raphson method is an iterative method which approximates a set of non-linear simultaneous equations to a set of simultaneous linear equations using Taylor's series expansion while limiting the term to first order approximation. The Newton-Rsphson method has quadrature convergence characteristics and therefore has less iteration. The Newton Raphson load flow method calculation is shown below. The injected current in term of admittance matrix,

$$I_i = \sum_{j=1}^{n} |Y_{ij}| \, |V_j| \qquad (1)$$

$$P_i = \sum_{j=1}^{n} |V_i||V_j| \, |Y_{ij}| \cos (\theta_{ij} - \delta_i + \delta_j) \qquad (2)$$

$$Q_i = \sum_{j=1}^{n} |V_i||V_j| \, |Y_{ij}| \sin (\theta_{ij} - \delta_i + \delta_j) \qquad (3)$$

Jacobian Matrix is

$$J = \begin{bmatrix} \dfrac{\partial \Delta P}{\partial \delta} & \dfrac{\partial \Delta P}{\partial |V|} \\ \dfrac{\partial \Delta Q}{\partial \delta} & \dfrac{\partial \Delta Q}{\partial |V|} \end{bmatrix} \qquad (4)$$

$$\begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} = J^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \qquad (5)$$

The new voltage magnitude and phase angle,

$$\left| V_i^{(k+1)} \right| = \left| V_i^{(k)} \right| + \Delta \left| V_i^{(k)} \right| \qquad (6)$$

$$= \delta_i^{(k)} \, \delta_i^{(k)} \qquad (7)$$

The line flow and line losses,

$$S_{ij} = P_{ij} + Q_{ij} \qquad (8)$$

$$S_{ji} = P_{ji} + Q_{ji} \qquad (9)$$

$$S_L = S_{ij} + S_{ji} \qquad (10)$$

B. Flow Chart For Newton-Raphson Power Flow Solution

In context to various steps involved in carrying out load flow analysis with Newton Raphson method, following flow chart has been designed:
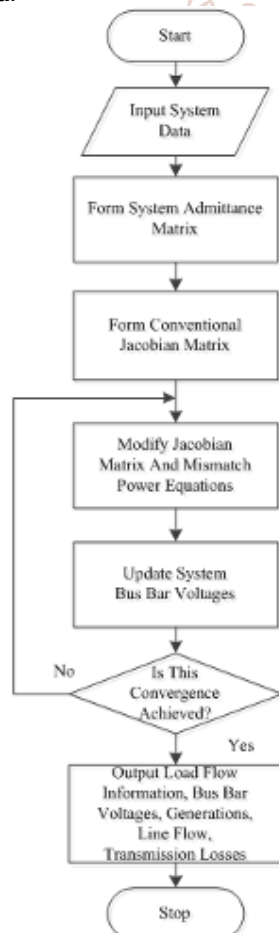

Figure 1.Flow Chart for Newton Raphson Method

c. Reactive Power Compensation

Reactive power compensation played benefiting roles in power system such as improving steady-state and dynamic stability, improving voltage profiles of the system and reduction of network loss if correctly placed. Injecting reactive power correctly into the system reduces transmission losses, improves voltage profile of the system and as well decreases line loading. Reactive power can be injected at the specified buses via shunt capacitor to reduce transmission loss, increase system voltage profile and reduce cost of generation.

IV. CASE STUDY

For the analysis of power flow problems, a sample transmission system is applied. To analyze the transmission line flow and line losses, the application of Shunt Compensator is executed at Lawpita-Taungoo-Kamarnat-Hlawga line which is the longest transmission line in Myanmar. The system block diagram of this line is shown in Figure 2. For this system, the load flow equations are modified correspondingly at four buses. The load flow solution for the modified network is obtained by using Newton-Raphson Method.
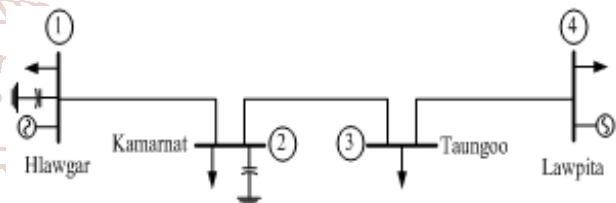

Figure 2.Sample Transmission System

TABLE II DATA OF BUS IN THE SYSTEM

Bus No.	Assumed Bus Voltage	Generation		Load	
		MW	Mvar	MW	Mvar
1	1.0+j0.0	0	0	80	60
2	1.0+j0.0	0	0	64	48
3	1.0+j0.0	0	0	64	48
4	1.04+j0.0	190	47.6	32	24

TABLE III TRANSMISSION LINE PARAMETERS

Sr. No.	Name of "FROM" System	Name of "TO" System	FROM → TO Loss Factor {R(p.u)}	FROM → TO Reactance {X(pu)}
1	Lawpita	Taungoo	0.052519	0.13893
2	Taungoo	Kamarnat	0.004893	0.02698
3	Kamarnat	Hlawga	0.005743	0.03167

V. RESULTS

In this paper, the 4 bus system is analyzed by using Newton Raphson method. The main work of this paper is to develop a MATLAB program to calculate voltages, active and reactive power and losses at each bus for 4 bus systems.

TABLE III RESULTS OF VOLTAGE MAGNITUDE AND ANGLE

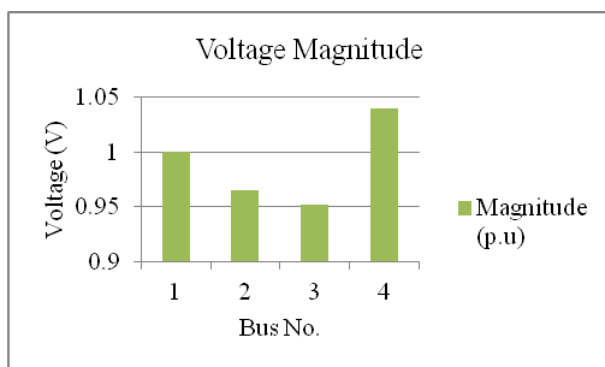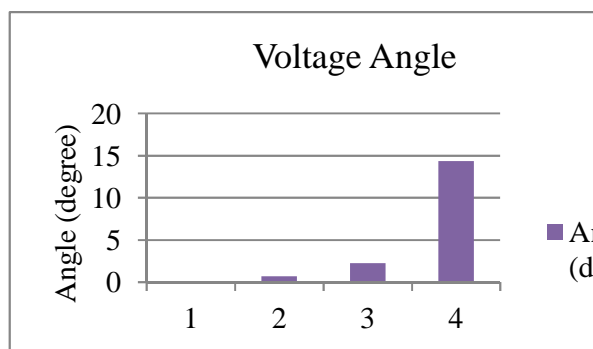| Bus No.	Bus Voltage	
	Magnitude (p.u)	Angle (degree)
1	1	0
2	0.965	0.696
3	0.952	2.249
4	1.04	14.373

Figure 3.Voltage Magnitude versus Buses

Figure 4.Voltage Angle versus Buses

TABLE III RESULTS OF REAL AND REACTIVE POWER

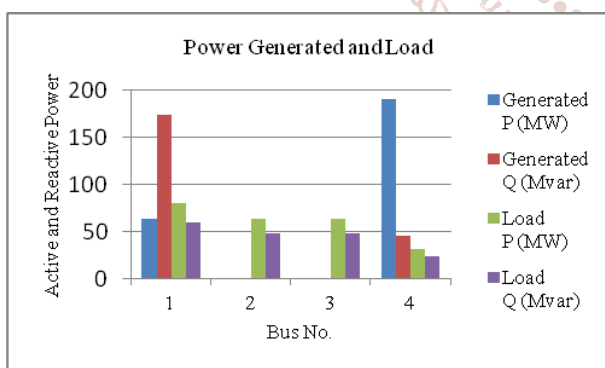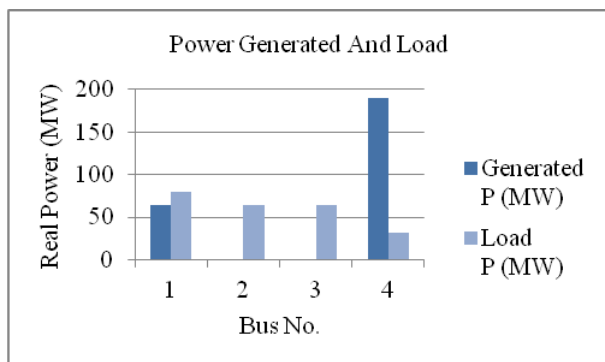| Bus No.	Power Generated		Load	
	Real Power (MW)	Reactive Power (Mvar)	Real Power (MW)	Reactive Power (Mvar)
1	63.663	173.938	80	60
2	0	0	64	48
3	0	0	64	48
4	190	45.953	32	24

Figure 5.Power Generated and Load

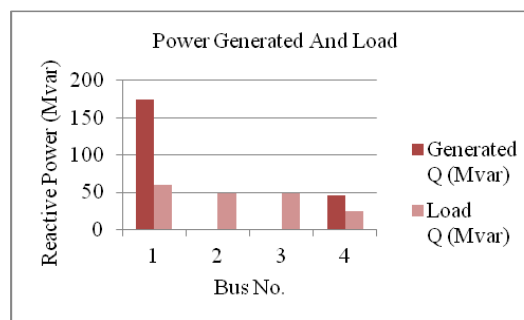Figure 6.Real Power Generated and Load

Figure 7.Reactive Power Generated and Load

TABLE III LINE FLOW AND LINE LOSS FOR REAL POWER

From Bus	To Bus	Line Flow (MW)	Line Loss (MW)
1	2	-16.337	0.761
2	1	17.098	
2	3	-81.098	0.546
3	2	81.644	
3	4	-145.644	12.356
4	3	158	
Total Loss			13.663

TABLE III LINE FLOW AND LINE LOSS FOR REACTIVE POWER

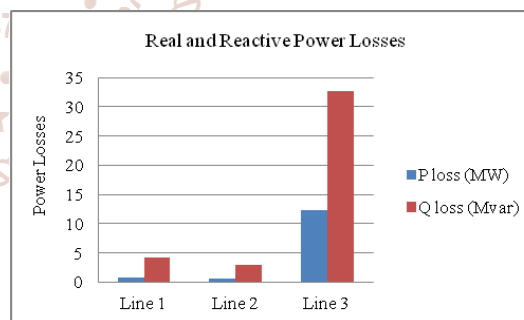| From Bus	To Bus	Line Flow (Mvar)	Line Loss (Mvar)
1	2	113.938	4.196
2	1	-109.742	
2	3	61.742	3.01
3	2	-58.732	
3	4	10.732	32.685
4	3	21.953	
Total Loss			39.891

Figure 8.Real and Reactive Power Line Losses

According to TABLE III and IV, the power losses can be observed in Line 1, 2 and 3. Figure 8 shows the line loss at line 1, 2 and 3. Among these, loss at line 3 is more compared to others. Here it can be analyzed that by the use of shunt compensator loss can be minimized in a better way when it will install at the optimal location of the four bus system. In some cases loss is more but generation is also more. Shunt compensation via optimal capacitor placement for the real and reactive power losses reduction and improvement in system voltage profile. If the minimum value of 5 Mvar, Shunt Compensator is set at bus 3, the system power losses are 13.556 MW and 39 399 Mvar. If the maximum value of 80 Mvar, Shunt Compensator is set at bus 3, the total power losses are 12.645 MW and 34.943 Mvar. From the comparison results, the system performs better when various sizes of Shunt Compensators are connected to a bus 3 as shown in figures 9 and 10.
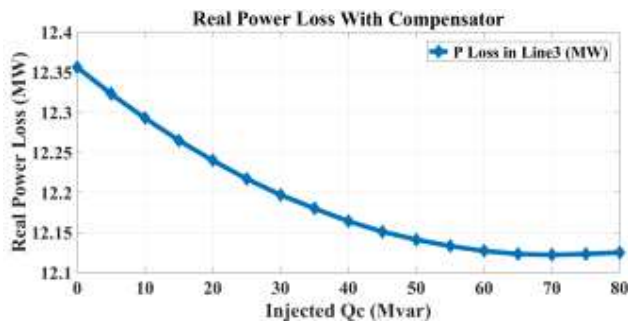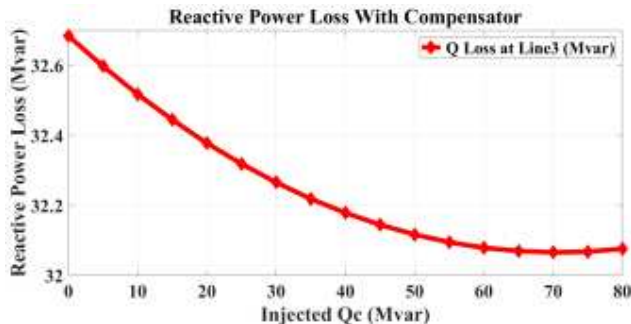
Figure 9.Real Power Losses at Line3

Figure 10.Reactive Power Losses at Line3

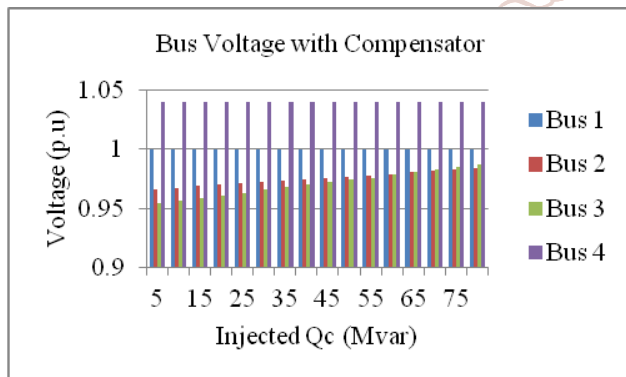

Figure 11.Bus Voltage with Compensator

Figure 11 it can be seen that the variation of voltage magnitude at different buses according to the compensation of various sizes of shunt compensator. It determines the voltage of the buses. The voltage level at the certain buses must be kept within the closed tolerances. It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines.

VI. CONCLUSIONS

The power flow analysis for the four bus electrical system has been conducted by using MATLAB program. Here firstly the analysis was done for a normal uncompensated system and its load flow study was investigated in terms of voltage magnitude at all four buses, overall power generation and overall power losses. It was found that by the compensation of shunt capacitor in to the four buses system the voltage stability enhances in terms of magnitude and angle variation and here it is found to be at bus 3. Similarly overall losses (real & reactive power) also reduced and can be analyzed by means of loss minimization. The study reveals that the injected Mvar brings about reduction in the total cost of generation, the total system losses and a significant improvement in the system voltage profile. Therefore 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.

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