IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-7, Issue-6, June 2019 E-ISSN: 2347-2693

Optimized Power Flow Analysis of IEEE 14 Bus System Using Matlab

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DOI: https://doi.org/10.26438/ijcse/v7i6.12001203 | Available online at: www.ijcseonline.org

Accepted: 24/Jun/2019, Published: 30/Jun/2019

***Abstract*:** For proper planning and operation of power system and economic scheduling of generating units, power flow analysis plays a vital role. It is performed to have clear knowledge regarding bus voltage magnitude and angle and line flows. A number of methods are being used all over the world for power flow analysis. Newton Raphson method, Gauss Seidal method, fast decoupled load flow methods are a few to name. Now days, various soft computing techniques are adopted by researchers as well as practicing engineers for load flow analysis to cater various needs of the research institutes and the utilities. Every method has got advantages as well as disadvantages.
The objective of this paper is to develop an user friendly software to perform load flow analysis for IEEE 14 bus system. Optimization of IEEE 14 bus sytem has been performed using Particle Swarm Optimization Technique. The software will be helpful for researchers, practicing engineers, students of power system of various levels to carry out power flow quickly and efficiently as per their requirement. The software is developed using MATLAB programming.

Keywords: 14 bus system, power flow, optimization

I. INTRODUCTION

Line flow analysis (LFA) is used to make sure that electrical power transfer from generator stations to consumers end through the grid system in reliable and economical form. Conventional techniques for line flow analysis problem are iterative mathematical method like the Newton-Raphson (NR) or the Gauss-Seidel (GS) methods. An engineer is always concerned about economic condition of the system operation. For the mighty interconnected grid system, the power shortage results continuous hike in prices. Thus, it is the priority of engineer to control this continuous hike. Another major problem is economic load dispatch in an optimized manner as it is directly related with load demands.

For economically optimized operation of interconnected grid system modern system theory and optimization techniques are being applied with the optimized generation cost function. Through the line flow study, the voltage magnitude and angle at each bus under the steady state can be obtained. Load flow studies are undertaken to determine the following parameters.

i) The bus voltage magnitude and system voltage profile.
ii) The line flows.
iii) The effect of change in circuit configurations and inclusion of new circuit elements on system loading.
iv) The effect of temporary loss of transmission capacity and generations on supplied load and accompanied effects.
v) The effect of in-phase and quadrature boost voltages on system loading data obtained from
load flow can be further useful for economic system operation and system transmission loss minimization.

1.1. Power flow analysis

A bus is a node at which one or many lines, one or many loads and generators are connected. In a power system each node or bus is associated with 4 quantities, such as magnitude of voltage, phage angle of voltage, active or true 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. Depending on the quantities that have been specified, the buses are classified into 3 categories. Buses are classified according to which two out of the four variables are specified

1.2. Classification of Buses

In an electrical power system all the buses constitutes of four variables, which are voltage magnitude, voltage phase angle, active power and reactive power in line flow. For power flow solution out of these four variables, two are made constant and two are treated as variable. All the buses are categorised on the basis of the constant parameters.

1) **Load bus**: At this bus, the real and reactive powers are specified. Voltage and phase angles are not defined. No generators are attached with this bus.
2) **Generator bus**: This bus is also called as voltage controlled bus. Here the voltage magnitude corresponding to the generator voltage and real power (Pg) are specified. Reactive power generation (Qg) and voltage phase angle are the unknown parameter for line flow calculations.

3) **Slack Bus**: It is also known as Swing Bus. In this bus it is assumed that voltage magnitude and phase angle is known parameters. The real power generated (Pg) and the reactive power generated (Qg) are considered as unknown parameter.

1.3. Newton Raphson Method

Newton Raphson method is the best opted method for solving non-linear load flow equations as it gives better convergence speed as compare to other load flow methods. The number of iterations involved in Newton Raphson method is independent of number of buses considered, hence power flow equations can be solved just in few iterations. Newton Raphson method transforms the set of non-linear equations into a set of linear equations which approach to the original solution efficiently.

The Newton Raphson method is the most robust power flow algorithm used in practice. However, drawback of this method lies in the fact that the terms of the Jacobian matrix must be recalculated and then the entire set of linear equations must also be solved in each iteration.

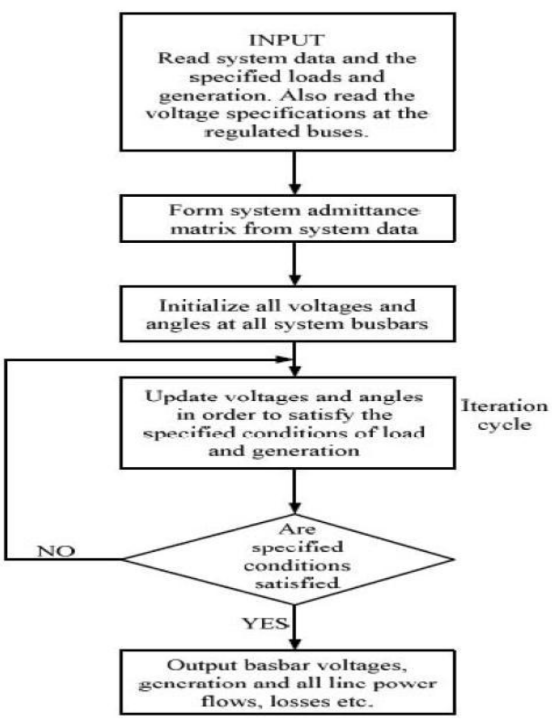

Fig 1: Flowchart of Newton-Raphson Method

1.4. Objectives of the paper

This paper aims to investigate the effect of applying Newton Raphson method in calculation of power flow in a IEEE 14 bus system. The aim is to investigate the real power loss and reactive power loss and to plot for different branches.

Addition to that, the paper also aims to investigate the voltage profile at different nodes by calculating voltage magnitude and angle for different nodes. It Aims to analyse the scenario of real power loss and reactive power loss for all the mentioned cases.

II. RESULTS AND ANALYSIS

A IEEE 14 bus system with 11 loads and 3 transformers have been chosen for analysis. The detail description of the system is given below.

System Details	
Buses	14
Generators	5
Loads	11
Shunts	1
Branches	20
Transformers	3

Table 1: System Configuration

The Bus data of the IEEE 14 bus system with Power generation and load details are given in Table 2.

Table 2: Bus data of 14 bus system

Bus Data of IEEE 14 Bus System						
Bus	Volt	Angle	Generation		Load	
	pu	Deg	P(MW)	Q(MVAR)	P(MW)	Q(MVAR)
1	1	0.06	0.000*	232.39	-16.55	-
2	1.045	-4.983	40	43.56	21.7	12.7
3	1.01	-12.725	0	25.08	94.2	19
4	1.018	-10.313	-	-	47.8	-3.9
5	1.02	-8.774	-	-	7.6	1.6
6	1.07	-14.221	0	12.73	11.2	7.5
7	1.062	-13.36	-	-	-	-
8	1.09	-13.36	0	17.62	-	-
9	1.056	-14.939	-	-	29.5	16.6
10	1.051	-15.097	-	-	9	5.8
11	1.057	-14.791	-	-	3.5	1.8
12	1.055	-15.076	-	-	6.1	1.6
13	1.05	-15.156	-	-	13.5	5.8
14	1.036	-16.034	-	-	14.9	5
		Total:	272.39	82.44	259	73.5

Table 3: Power Injection of 14 bus system

Power Injection Details						
Branch	From	To	Injection from bus		Injection to bus	
	Bus	Bus	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)
1	1	2	156.88	-20.4	-152.59	27.68
2	1	5	75.51	3.85	-72.75	2.23
3	2	3	73.24	3.56	-70.91	1.6
4	2	4	56.13	-1.55	-54.45	3.02
5	2	5	41.52	1.17	-40.61	-2.1
6	3	4	-23.29	4.47	23.66	-4.84
7	4	5	-61.16	15.82	61.67	-14.2
8	4	7	28.07	-9.68	-28.07	11.38
9	4	9	16.08	-0.43	-16.08	1.73
10	5	6	44.09	12.47	-44.09	-8.05
11	6	11	7.35	3.56	-7.3	-3.44
12	6	12	7.79	2.5	-7.71	-2.35
13	6	13	17.75	7.22	-17.54	-6.8
14	7	8	0	-17.16	0	17.62
15	7	9	28.07	5.78	-28.07	-4.98
16	9	10	5.23	4.22	-5.21	-4.18
17	9	14	9.43	3.61	-9.31	-3.36
18	10	11	-3.79	-1.62	3.8	1.64
19	12	13	1.61	0.75	-1.61	-0.75
20	13	14	5.64	1.75	-5.59	-1.64

With this existing system load flow analysis has been carried out and voltage magnitude and angles at different points have been calculated. The real and reactive power injections to different nodes have been calculated using Newton-Raphson method and are summarised in Table 3.

The real power loss have been calculated and it is found that the real power loss is highest at branch1 (line 1-2). The scenario of real power loss and reactive power have been forecasted with the help of the following Fig2 & Fig 3.

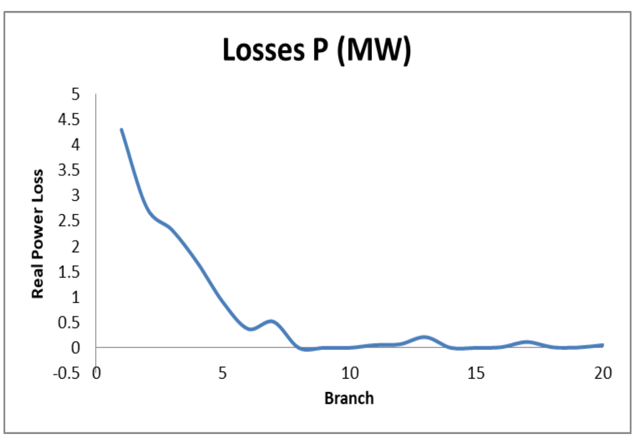

Fig 2: Real power loss (MW)

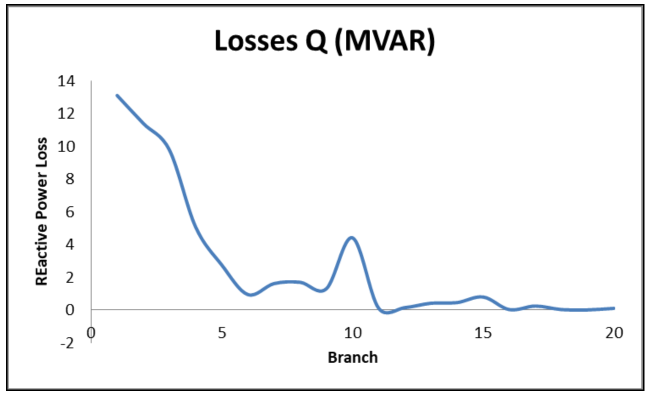

Fig 3: Reactive power loss (MVAR)

The real and reactive power losses at different buses have been calculated and are summerised in table 4. It is seen from the investigation that, the real power loss will be highest in line 1-2 and reactive power loss is also highest in line 1-2. Optimization is required to minimize the losses i.e. real power loss and reactive power loss.

Table 4: Power flow solution of 14 bus system

Loss Analysis				
Branch	From	To	Losses	
	Bus	Bus	P (MW)	Q (MVAR)
1	1	2	4.298	13.12
2	1	5	2.763	11.41
3	2	3	2.323	9.79
4	2	4	1.677	5.09
5	2	5	0.904	2.76
6	3	4	0.373	0.95
7	4	5	0.514	1.62
8	4	7	0	1.7
9	4	9	0	1.3
10	5	6	0	4.42
11	6	11	0.055	0.12
12	6	12	0.072	0.15
13	6	13	0.212	0.42
14	7	8	0	0.46
15	7	9	0	0.8
16	9	10	0.013	0.03
17	9	14	0.116	0.25
18	10	11	0.013	0.03
19	12	13	0.006	0.01
20	13	14	0.054	0.11
Total			**13.39**	**54.54**

The above investigation shows the real and reactive power loss in all the branches. Now optimization technique is used to find out the optimum real and reactive power loss in IEEE 14 bus system.

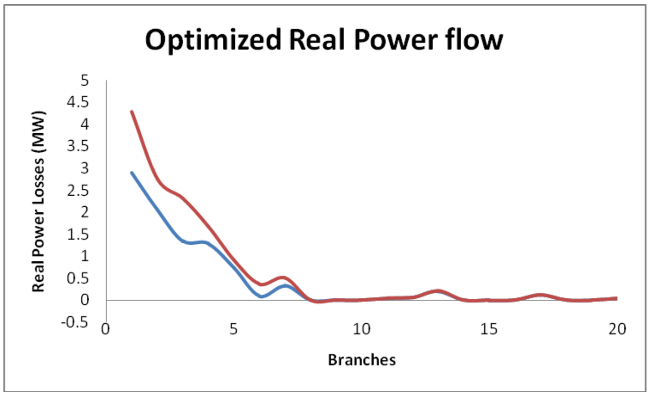

Fig4 : Optimized real power flow solution

Table 5: Optimized Power flow solution of IEEE 14 Bus system

Optimized Loss Analysis				
Branch	From Bus	To Bus	Losses P (MW)	Losses Q (MVAR)
1	1	2	2.902	8.86
2	1	5	2.051	8.47
3	2	3	1.344	5.66
4	2	4	1.285	3.9
5	2	5	0.737	2.25
6	3	4	0.099	0.25
7	4	5	0.331	1.04
8	4	7	0	1.05
9	4	9	0	1.12
10	5	6	0	4.23
11	6	11	0.049	0.1
12	6	12	0.072	0.15
13	6	13	0.208	0.41
14	7	8	0	0.22
15	7	9	0	1
16	9	10	0.015	0.04
17	9	14	0.131	0.28
18	10	11	0.01	0.02
19	12	13	0.006	0.01
20	13	14	0.047	0.1
Total			**9.287**	**39.16**

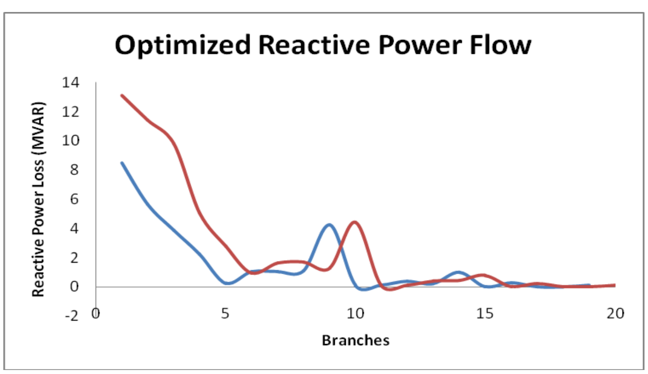

Fig4 : Optimized reactive power flow solution

III. CONCLUSION

The real power variations and voltage profile can indicate the need of improving in respect to voltage and load requirement. Loss optimization has been performed using optimization technique and it is seen that a good amount of los can be minimized with the help of this technique. In this investigation, 4.103 MW of real power and 15.38 MVAR reactive power loss can be minimized with the help of optimized technique. The real power loss and reactive power loss in maximum in line 1-2. Similarly the voltage magnitude became highest in Bus 8.

Author's Profile

Sanjib Hazarika received B.E Degree from Guwahati University, Assam, in 2007, M.Tech from Tezpur University, Assam, India, in 2010 and pursuing Ph.D in Guwahati University, Assam, India. Currently, he is an Assistant Professor in Electrical Engineering Department of GIMT, Azara, Guwahati, Assam.

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