

Comparative Analysis of General Power Flow and Optimal Power flow using Linear Programming Method

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ABSTRACT: In power system, power flow is very essential. Power is generated at the generating station and then it flows through transmission lines. General power flow does not need any limits of bus voltage or generator voltage or any other limits. In this paper, a practical method is used by which we can solve the problem of power flow by using control variables. The control variables are real power, reactive power and transformer ratios with automatic adjustment to minimize instantaneous costs or losses. Minimization of the costs and losses are needed to transform a general power flow to an optimal power flow. Here linear programming method which can deal with constraints of inequality and converge easily, has been applied simulation by using matpower 4.1 and matlab 2010 for solving the power flow problem and comparing it with optimal power flow solutions.

KEYWORDS: Optimal power flow, Linear Programming method, Mat power, Inequality constraints, LPOPF.

I. INTRODUCTION

Now a days Energy requirements is increasing gradually. So, Grid system is very known system to provide a huge amount of power. It is used to interconnect the generation, transmission and distribution system and can provide synchronised power. So it plays a great role now-a-days. To run the grid system economically, generation cost has to be minimum. A power flow analysis means that a steady-state analysis by which voltage, current, real power, and reactive power can be found under loaded conditions.

Power flow studies is used for planning of system operation. For example, if a transmission line is to be taken off line for maintenance, can the remaining lines in the system handle the required loads without exceeding their rated values. [1] The objective of this project is to transform MATPOWER program which is used in MATLAB. Considering the hurdle occurs in solving Power flow problem due to nonlinear constraints, OPF is modeled in a linear way by linear programming method. The first person who solved an exact optimization problem with the use of linear programming taking into consideration system equality and inequality constraints was Carpentier.

The main aim goal is to minimize the generation cost in time of maintaining the security of the system. To maintain the system security all devices should be in desired operation range in steady state condition [2]

System security depends on the maximum output and input of generator, mva flow of transmission line and transformer and also system bus voltages. System bus voltage should be kept within specified limit. OPF is performed under steady state condition. OPF can be determined the marginal cost data of the system. In the pricing of MW transactions, system marginal cost data plays a great role.

II. LINEAR PROGRAMMING METHOD

Linear programming method lpopf is a mathematical technique. From this method we can get optimized data. Inequality constraints which are the hurdles in the other methods can be handled easily in this method by linearization. lpopf method is fully developed now a days. Given a set of m linear inequalities or equations in r variables, we wish to find non-negative values of these variables. It will satisfy the constraints and maximize or minimize some linear function of the variables. Mathematically,

$$p_1x_1 + p_2x_2 + \dots + p_r x_r \{>=, =, <=\} q_i \quad i=1, \dots, m, \dots \quad (1)$$

where for each constraint one and only one of the signs \leq , $=$, \geq holds, but the sign may vary from one constraint to another. Now we need the values of x_j which satisfy equation (1) and

$$x_j \geq 0, \quad j= 1, \dots, r \tag{2}$$

which maximize or minimize a linear function

$$z = h_1x_1 + \dots + h_r x_r \tag{3}$$

Here p_{ij} , q_i , h_j are known constants.

A programming problem is linear if, in the constraints and function to be optimized, the variables appear only as linear forms. Linear Programming is a generalized form of Linear Algebra. [3]

It can handle a variety of problems. It is a mathematical method which can do a best outcome of a mathematical model. It can perform the optimization technique of linear objective function.

This method helps to maximize or minimize a linear function which is made of a bunch of constraints which are linear in nature. It consists of

- a set of decision variables - The values of the variables of the problem are unknown. The variables represent the things which can be controlled or adjusted. The objective is to find out the values of the variable that provide the best result of the objective function.
- an objective function - It is a mathematical expression. It combines with variable to reveal the goal. It can be maximized or minimized.
- a set of constraints - These are the mathematical interpretation which merge the variables to limits for getting the feasible solutions.
- Variable bounds - rarely some variables in an optimization problem allowed to take any value from minus infinity to plus infinity. Instead the variables usually have bounds.

III. BLOCK DIAGRAM OF THE WHOLE PROCESS

The strategy for solution of LPOPF is as follows:-

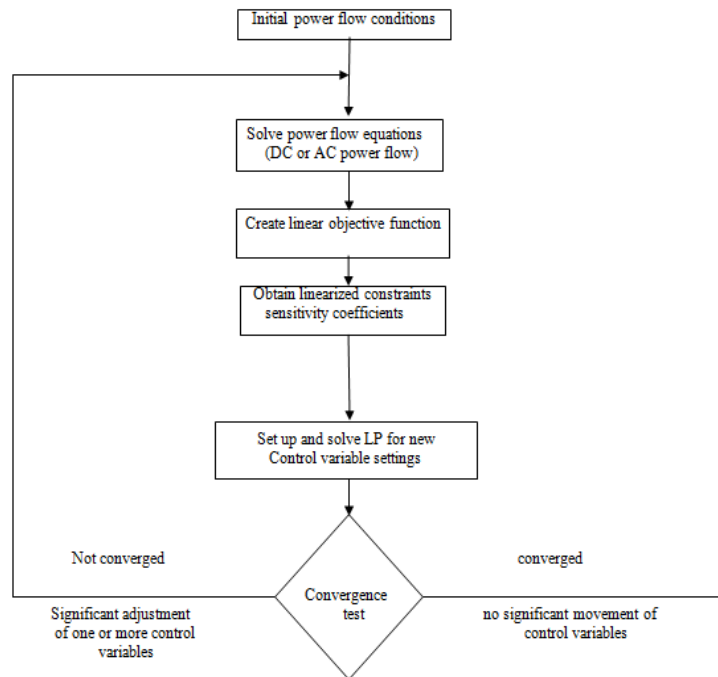


Fig. 1 Block Diagram

IV. RESULTS

Newton's method power flow converged in 3 iterations.

System summary

TABLE I

Elements	No. of Elements	P (MW)	Q (MVAR)
buses	5	300	30.0 to 140.0
generators	3	300	30.0 to 140.0
Committed generators	3	153.1	73.2
loads	4	150	95
Fixed	4	150	95
Dispatchable	0	0	0
Shunt	0	0	0
braches	7	3.05	9.16
transformers		-	30.9
Inter-ties		0	0
areas	1		

TABLE II

Parameters	Minimum	Maximum
Voltage Magnitude	0.990 p.u. @ bus 5	1.060 p.u. @ bus 1
Voltage Angle	-4.41 deg @ bus 5	0.00 deg @ bus 1
P Losses ($I^2 \cdot R$)		1.30 MW @ line 2-5
Q Losses ($I^2 \cdot X$)		3.89 MVAR @ line 2-5

Bus Data

TABLE III

Bus #	Voltage		Generation		Load	
	Mag(pu)	Ang(deg)	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)
1	1.06	0	83.05	7.27	-	-
2	1.045	-1.782	40	41.81	20	10
3	1.03	-2.664	30	24.15	20	15
4	1.019	-3.243	-	-	50	30
5	0.99	-4.405	-	-	60	40
Total			153.05	73.23	150	95

Branch Data

TABLE IV

Branch #	From bus	To bus	From bus injection		To bus injection		Loss($I^2 \cdot Z$)	
			P(MW)	Q(MVAR)	P(MW)	Q(MVAR)	P(MW)	Q(MVAR)
1	1	2	59.9	4.06	-59.25	-8.76	0.648	1.95
2	1	3	23.15	3.22	-22.74	-7.45	0.407	1.22
3	2	3	10.91	2.96	-10.83	-7.02	0.08	0.24
4	2	4	18.22	7.24	-17.99	-10.81	0.231	0.69
5	2	5	50.12	30.37	-48.83	-29.59	1.295	3.89
6	3	4	43.58	23.63	-43.33	-25.02	0.236	0.71
7	4	5	43.58	23.63	-43.33	-25.02	0.236	0.71
total							3.053	9.16

Result of optimal power flow

Converged in 2.33 seconds

Objective Function Value = 5296.69 \$/hr

System summary

TABLE V

Elements	No. of elements	P(MW)	Q(MVAR)
Buses	9	820	-900.0 to 900.0
Generators	3	820	-900.0 to 900.0
Committed gens	3	318.3	-9.6
loads	3	315	115
fixed	3	315	115
dispatchable	0	-0.0 of -0.0	-0.0
shunts	0	-0.0	0.0
branches	9	3.31	36.46
transformers	0	-	161.1
Inter-ties	0	0.0	0.0
areas	1		

TABLE VI

Parameters	Minimum	Maximum
Voltage magnitude	1.072 p.u @ bus 9	1.100 p.u. @ bus 8
Voltage angle	-4.62 deg @ bus 9	4.89 deg @ bus 2
P losses	-	1.39 MW @ line 8-9
Q losses	-	9.36 MVA @ line 8-2
Lambda P	24.03 \$/MWh @ bus 2	25.00 \$/MWh @ bus 9
Lambda Q	-0.00 \$/MWh @ bus 3	0.11 \$/MWh @ bus 9

Bus data

TABLE VII

Bus #	Voltage		Generation				Load	
	Mag(p.u)	Ang(p.u)	Lambda P(MW)	Lambda Q(MVAR)	P(MW)	Q(MVAR)	P(MW)	Q(MVAR)
1	1.1	0	89.8	12.94	-	-	24.756	-
2	1.097	4.893	134.32	0.05	-	-	24.035	-
3	1.087	3.249	94.19	-22.62	-	-	24.076	-
4	1.094	-2.463	-	-	-	-	24.756	0.004
5	1.084	-3.982	-	-	90	30	24.998	0.027
6	1.1	0.602	-	-	-	-	24.076	-
7	1.089	-1.197	-	-	100	35	24.254	0.036
8	1.1	0.905	-	-	-	-	24.035	-
9	1.072	-4.616	-	-	125	50	24.999	0.112
total					318.31	-9.63	315	115

Branch data

TABLE VIII

Branch #	From bus	To bus	From bus injection		To bus injection		Loss(I^2R)	
			P(MW)	Q(MVAR)	P(MW)	Q(MVAR)	P(MW)	Q(MVAR)
1	1	4	89.8	12.94	-89.8	-9.02	0	3.92
2	4	5	35.22	-3.9	-35.04	-13.87	0.181	0.98
3	5	6	-54.96	-16.13	55.97	-22.18	1.01	4.4
4	3	6	94.19	-22.62	-94.19	27.28	0	4.66
5	6	7	38.22	-5.1	-38.07	-18.68	0.149	1.26
6	7	8	-61.93	-16.32	62.21	0.82	0.279	2.36
7	8	2	-134.32	9.32	134.32	0.05	0	9.36
8	8	9	72.11	-10.14	-70.72	-18.94	1.394	7.01
9	9	4	-54.28	-31.06	54.58	12.92	0.295	2.51
total							3.307	36.46

Voltage constraints

TABLE IX

Bus #	Vmin mu	Vmin	V	Vmax	Vmax mu
1	-	0.9	1.1	1.1	8.384
6	-	0.9	1.1	1.1	75.329
8	-	0.9	1.1	1.1	77.457

V. CONCLUSION

In general power flow problem the loads are specified in megawatts and megavars and are to be provided at definite nodes or bus bars of transmission system. The generated powers and the voltage magnitudes are identified at the remaining nodes of this system jointly with an entire description of the system including its impedances. Power flows, currents and losses can be expressed by considering nodal voltages which are complex in nature. In mathematical terms, the problem can be diminished to a set of nonlinear equations. In that case the variables are the real and imaginary

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components of the busbar voltages. The nonlinearities have quadratic nature. By Gradient and relaxation methods, the problems can be solved.

The power flow problem is one of the basic problems. Here, load powers and generator powers both are given. On the contrary, optimal power flow problem some adjustments are made according to some specified criteria for generated power bus voltage etc. In this case, generating cost should be the minimum. It can be determined that the voltages at nodes where the loads are supplied along with the input power. Mathematics is more needed in optimal power flow problem. Here we have some limits of voltage, power beyond which we cannot let the output go because violation of those limits, fault will be occurred and the system will become damaged.

Now a more realistic definition is wanted for practical requirement, adding the statement of constraints. In reality any variable in the system will be limited because it changes the mathematical nature of the problem excessively. Whenever a variable reaches its upper or lower limit, it becomes a fixed quantity and the method of solution has to recognize it as such and be sure that the fixed quantity is optimal. [4]

The problems of ordinary power flow can be easily handled by using optimal power flow. So this method is more superior to ordinary power flow method. In this project we use linear programming method for solving any OPF problem.

REFERENCES

- [1] <http://www.egr.unlv.edu/~eebag/Power%20Flow%20Analysis.pdf>
- [2] C.L. Wadhwa, "Electrical Power Systems", 6th edition, pp. no.820-830, 2010
- [3] http://web.williams.edu/Mathematics/sjmiller/public_html/416/currentnotes/LinearProgramming.pdf
- [4] <http://rajanandpec.hubpages.com/hub/Optimal-power-flow-algorithm>
- [5] http://www.arpapress.com/volumes/vol12issue2/ijrras_12_2_20.pdf
- [6] icceexplore.ieee.org
- [7] Matpower manual