Optimal Power Flow and Load Flow Analysis with Considering Different DG Integration Rates

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Abstract- Lately, there is an increasing need for Optimal Power Flow (OPF) to solve problems of today's regulated and deregulated power systems and the unsolved problems in the vertically integrated power systems. The objective of an optimal power flow is to determine the best way to instantaneously operate a power system. OPF is considered with the goal of limiting either the power circulation misfortunes or the cost of influence drawn from the substation and provided by distributed generation (DG) units. The most important aspects related to OPF are the solution methodologies and the application areas. This paper presents OPF and load flow analysis of IEEE 30 bus system with DG. PV plant is determined as DG plant. According to different PV integration rates, system parameters are analysed. Especially active and reactive losses are investigated. More than 30% PV contribution in transmission and distribution systems can affect the system adversely. Because of this reason, the PV contribution limit is set at 30%. Newton-Raphson method is used as the load flow analysis method.

Indexed Terms- Optimal Power Flow (OPF), Regulated and Deregulated Power Systems.

I. INTRODUCTION

Optimal Power Flow was first introduced in the 1960s [1] and still remains to be a fundamental optimization problem in electrical power systems analysis. There are two challenges in the solution of OPF. First, it is an operational level problem solved every few minutes, hence the computational budget is limited. Second, it is a non-convex optimization problem on a large-scale power network of thousands of buses, generators, and loads. The importance of the problem and the aforementioned difficulties have produced a rich literature. Commonly used analysis model in power system is load flow analysis. The calculation of the load flow in the transmission lines and the transformers is called load flow analysis. It is necessary that not overloading of transmission lines and transformers in power systems, the voltages remain within certain limits for all buses and generator's reactive production to remain within acceptable limits.

Most commonly used iterative methods in solving power flow and load flow problems are the Newton-Raphson (N-R), the Gauss-Seidel, and the Fast - Decoupled method [2]. N-R method is used in this work because it is more reliable and converges faster with minimum iterations [3]. But these techniques are not suitable for systems having complex non-convex, non-smooth, and non-differentiable objective functions and constraints. Many heuristic algorithms have been projected to address the problem for solving load flow and non-linear optimal power flow problems, such as evolutionary programming (EP)[4], genetic algorithm (GA) [5], hybrid evolutionary programming (HEP) [6], particle swarm optimization (PSO) [7], differential evolution (DE) [8], tabu search [9], chaotic ant swarm optimization (CASO) [10], biogeography-based optimization (BBO) [11], bacteria foraging optimization (BFO) [12], harmony search algorithm (HSA) [13], gravitational search algorithm (GSA) [14], teaching learning based algorithm (TLBO) [16], etc. and their effectiveness have been established.

II. PROBLEM FORMULATION

Mathematically, an OPF problem can be formulated as follows:

min
$f(x, u)$ (The objective function) (1)
subject to $g(x, u) = 0$ (Equality constraints)   (2)
$h(x, u) \leq 0$ (Inequality constraints) (3)
Where;
x the vector of dependent variables consisting of slack bus power P_{g1}, load bus voltage vector V_L, generator reactive power output Q_g, and transmission line loading vector S_l.

u the vector of independent variables consisting of generators voltage magnitude vector V_g, generator real power output vector P_g except slack bus real power output P_{g1}, transformer tap settings vector T, and settings of the shuntVAR compensation vector Q_c.

Hence;
$$x^T = [P_{g1} \quad V_L \quad Q_g \quad S_l] \text{ and } u^T = [V_g \quad P_g \quad T \quad Q_c] \quad (4)$$

The equality constraints $h(x, u)$ represent typical load flow equations [17, 18]. The inequality constraints $g(x, u)$ represent the system operating constraints which can be arranged as follows:

- Generator maximum and minimum real and reactive powers:
- Maximum and minimum tap ratio of under-load tap changing transformers:
- Maximum and minimum limits of shunt VAR compensators
- Maximum and minimum of bus voltage magnitudes and line flows to maintain the quality of electricalservice and system security:

III.   APPLICATION

FIGURE 1 SHOWS THE IEEE-30 BUS TEST SYSTEM. IN ADDITION, INPUT DATA OF THE TEST SYSTEM WHICH AREGIVEN IN TABLE 3, TABLE 4 AND TABLE 5 DEFINED IN APPENDIX
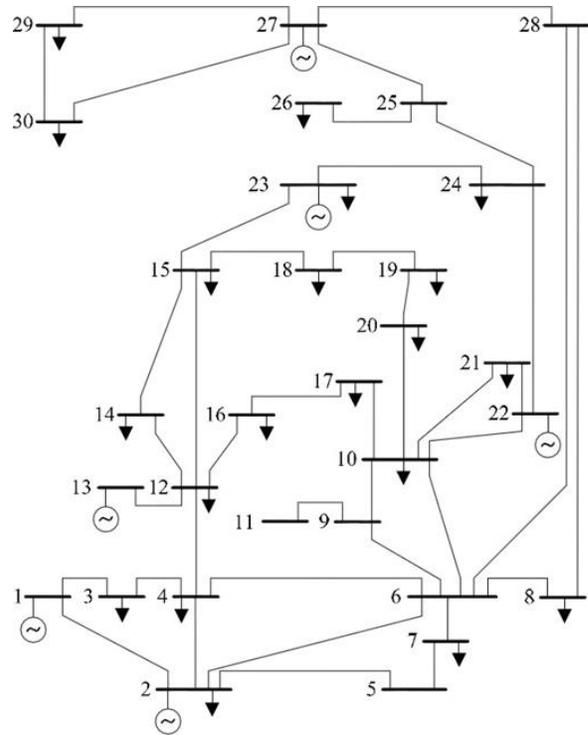

Figure 1. IEEE-30 bus test system

Optimal Power Flow system solves power system load flow, optimizes system operating conditions, and adjusts control variable settings, while ensuring system constraints are not violated. An optimized system will reduce the installation and/or operating cost, improve overall system performance, and increase its reliability and security. It isalso provides a variety of other choices of optimization objectives, which covers virtually all the optimization criteria for a real power system. Any practical control methods in a power system are considered in the calculation. Constraints for bus voltage, branch flow in different types (MVA, MW, Mvar, and Amp), as well as control variable adjustable bounds are also available for users to select and utilize.

The Load Flow Analysis can create and validate system models and obtain accurate and reliable results. It can calculate bus voltages, branch power factors, currents, and power flows throughout the electrical system. Load flow also allows for swing, voltage regulated, and unregulated power sources with multiple power grids and generator connections. It is also capable of performing analysis on both radial and loop systems and has an optionto select from several

different methods in order to achieve the best calculation efficiency and accuracy.

The number of iterations for Optimal Power Flow system is 11 and for Load Flow Analysis is 3. The system frequency is assumed to be 50 Hz. Bus 1 is considered to be the swing bus. The bus input data, line/cable data, generator data and branch connections are input to the system with reference to the Alsac O.

& Stott B, "Optimal Load Flow with Steady State Security". Electrical loads those are active during normal power operation mode of plant are identified and their breaker are set to closed state. Voltage ratings, power rating, impedances, RPMs etc., are entered into load data, generator and transformer data. The Summary of total generation, loading & demand isshown in Table 1 and Table 2.

Table 1. Power Flow Summary

Label	No-PV Generation			%10 PV Generation			%20 PV Generation			%30 PV Generation		
	MW	Mvar	MVA	MW	Mvar	MVA	MW	Mvar	MVA	MW	Mvar	MVA
Source (Swing Buses)	40.978	1.921	41.023	41.360	1.922	41.405	25.041	0.918	25.057	15.627	0.772	15.646
Source (Non-Swing Buses)	0	0	0	0	0	0	0	0	0	0	0	0
Total Demand	56.969	0.622	56.972	56.969	0.622	56.972	57.056	0.624	57.060	62.547	0.696	62.550
Apparent Losses	0.046	1.299		0.046	1.300		**0.017**	0.294		0.044	**0.086**	

Table 2. Load Flow Summary

Label	No-PV Generation			%10 PV Generation			%20 PV Generation			%30 PV Generation		
	MW	Mvar	MVA	MW	Mvar	MVA	MW	Mvar	MVA	MW	Mvar	MVA
Source (Swing Buses)	227.948	7.857	228.083	211.913	7.799	212.056	25.041	0.918	25.057	180.095	5.393	180.176
Source (Non-Swing Buses)	0	0	0	16.036	0	16.036	32.032	0	32.032	47.988	0	47.988
Total Demand	227.948	7.857	228.083	227.949	7.799	228.082	57.056	0.624	57.060	228.083	5.393	228.147
Total Static Load	227.711	2.485	227.725	227.730	2.485	227.743	227.839	2.488	227.852	227.949	2.491	227.962
Apparent Losses	0.237	5.371		0.219	5.313		0.173	4.012		**0.135**	**2.902**	

Optimum power flow and load flow analysis results are seen in the tables above. First, the optimum power flow results are examined. Different production values of the PV plant are taken into account. These values are No-PV,10%, 20% and 30%. When the results are examined, it is seen that 10% PV production has no significant effect onthe system. Active losses in 20% production are minimum. However, reactive losses are minimum in 30% production. According to these values, active and reactive power losses are minimized at different production values. Secondly, the results of load flow analysis are examined. When these results are examined, it is seen that losses decrease as PV production increases. It is seen that active and reactive losses are minimum in 30% production. More than 30% PV contribution in transmission and distribution systems can make the system unbalanced. The reason

of this is PV production is variable. Production is constantly changing due to weather conditions. This variability can adversely affect the system. For this reason, the PV contribution limit is set at 30%.In order to study more PV contribution, it is necessary to consider the system balance.

CONCLUSION

In this work, optimum power flow and load flow problems are solved for the IEEE-30 bus test system. Meta-heuristic algorithms were used to solve the problem of optimum power flow. For load flow analysis, Adaptive Newton-Raphson was used. In order to measure the reaction of the system, PV generation plants with No-PV, 10%, 20% and 30% generation rates were added to the system. Firstly,

when the optimum power flow results are examined, it is seen that 10% PV production has no significant effect on the system. Active losses in 20% production are minimum. However, reactive losses are minimum in 30% production. According to these values, active and reactive power losses are minimized at different production values. Secondly, when the results of load flow analysis are examined, it is seen that losses decrease as PV production increases. It is seen that active and reactive losses are minimum in 30% production. Furthermore, more than 30% PV contribution in transmission and distribution systems can make the system unbalanced. The reason of this is PV generation is variable. Generation is constantly changing due to weather conditions. This variability can adversely affect the system. For this reason, the PV contribution limit is set at 30%. In order to study more PV contribution, it is necessary to consider the system balance.

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