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Load Flow Analysis on 400 KV Sub-Station- A Case Study

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ABSTRACT

The paper attempts to a basic concept for a Load flow analysis with a sense of the optimal load flow analysis The objective of an Optimal Power Flow (OPF) is to find steady state operation point which minimize generation cost, loss etc. or maximize social welfare, load ability etc. while maintaining an acceptable system performance or limits on generators active and reactive powers, line flow limits, etc. The paper contains a overview of the session followed by summaries. Load flow analysis software package develops by the author use MI-POWER. To demonstrate its use, a simple 19-bus system was selected as a example of 400kV SOJA substation. The purpose of this paper is to present a comprehensive survey of various optimization methods to solve load flow and optimal load flow problems.

Key words: *Load Flow Analysis (LFA), Optimal Load Flow Analysis (OPFA), Mathematical formulation*

1. INTRODUCTION

Since its existence, the power system was produced, transported and distributed in AC current. But in the last few years, the incorporation of subsets of transmission high voltage in D.C. current HVDC in networks of transmission in AC current brought a significant change in the transport of the electric power. The technical and economic factors were modified and must obey decision and selection criteria for a good mixed farm. The lines of high voltage in D.C. current are much more preferable with those in AC current because they are more economic and more reliable, in particular applicability such as

- Interconnection between two very distant blocks, where transport by air line proves to be impossible.
- Connection between two systems with different frequencies.

The basic of the power flow in a system (AC/DC) has the same interest as that in the three phase systems in AC current. It will enable us to know the energy state of the system in any point and constantly, in order to exploit it well. The knowledge of the bus tensions of the network is very significant because they make it possible to calculate exactly the power flow between the buses. The resolution of the problem of the load flow in a system (AC/DC) is different with that which we knew in the systems (AC); we must, for that, to introduce new parameters and to make other modifications in the methods of basic to simplify the complexity of the problem.

This paper presents a new and efficient methodology for network reconfiguration with optimal power flow based on Benders Decomposition approach. The objective minimizes the power losses, balancing load among the feeders and subject to the constraints: capacity limit of the branches, minimal and maximal limits of the substation or generator, minimum deviation of the nodes voltages and radial operation of the networks.

In a 3-Phase ac power system active and reactive power flows from the generating station to the load through different networks buses and branches. The flow of active and reactive power is called power flow or load flow. Load flow is a very important and fundamental tool for the analysis of any power system and is used in the operational as well as planning stages [1]. Further study and analysis of future expansion, stability and reliability of the power system network can be easily analyzed through this study [2]. Load flow studies are used to ensure that electrical power transfer from generators to consumers through the grid system is stable, reliable and economic.

Load 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.

Load flow analysis is the backbone of power system analysis and design [3]. Load 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 [2]. Load flow studies provides mathematical approach for the determination of various bus voltage, phase angle, active & reactive power flows through different branches, generators and loads under steady state condition. Power flow/Load flow analysis is used to determine the steady state operating condition of a power system.

2. OBJECTIVES OF LOAD FLOW STUDY

- Load 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.
- The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels.
- It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines.
- It determines the voltage of the buses. The voltage level at the certain buses must be kept within the closed tolerances.
- The line should not be overloaded, it means, we should not operate the close to their stability or thermal limits.
- The line flows can be known.
- System transmission loss minimizes.
- Economic system operation with respect to fuel cost to generate all the power needed.

3. LOAD FLOW STUDY[4]

There are four quantities of interest associated with each bus:

1. Real Power, P
2. Reactive Power, Q
3. Voltage Magnitude, V
4. Voltage Angle, δ

At every bus of the system, two of these four quantities will be specified and the remaining two will be unknowns. Each of the system buses may be classified in accordance with which of the two quantities are specified.

3.1BUS CLASSIFICATIONS

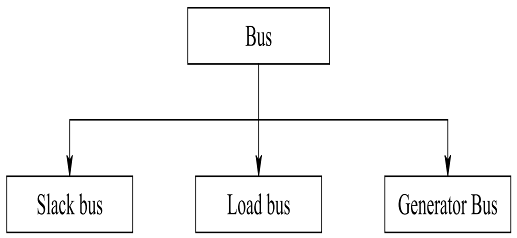

Fig.1 Bus classification

Slack Bus

The slack bus for the system is a single bus for which the voltage magnitude and angle are specified. The real and reactive power are unknowns. The bus selected as the slack bus must have a source of both real and reactive power, since the injected power at this bus must "swing" to take up the "slack" in the solution.

Load Bus (PQ Bus)

A load bus is defined as any bus of the system for which the real and reactive powers are specified. Load buses may contain generators with specified real and reactive power outputs; however, it is often convenient to designate any bus with specified injected complex power as a load bus.

Voltage Controlled Bus (PV Bus)

Any bus for which the voltage magnitude and the injected real power are specified is classified as a voltage controlled (or PV) bus. The injected reactive power is a variable (with specified upper and lower bounds) in the power flow analysis.

3.2 SOLUTION METHODS

The solution of the simultaneous nonlinear power flow equations requires the use of iterative techniques for even the simplest power systems.

There are many methods for solving nonlinear equations, as shown in Fig.2.

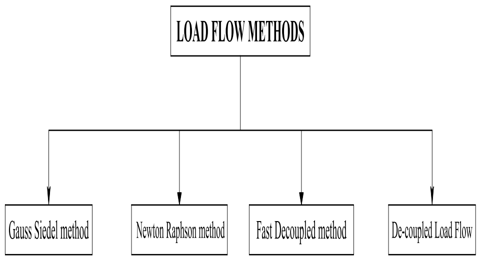

Fig.2 Types of Load flow methods

4. INTRODUCTION OF OLF:

The objective of an Optimal Power Flow (OPF) algorithm is to find out steady state operation point which minimizes generation cost, loss etc. or maximizes social welfare, load ability etc. while maintaining an acceptable system performance in terms of limits on generators' real and reactive limits, output of various compensating devices etc. Traditionally, classical optimization methods were used to effectively solve OPF.

A first comprehensive survey regarding optimal power dispatch was given by H.H. Happ [5] and subsequently an IEEE working group [6] presented bibliography survey of major economic-security functions in 1981.Thereafter in 1985,Carpentair [7] presented a survey and classified the OPF algorithms based on their solution methodology.

4.1OPTIMAL POWER FLOW FORMULATION

OPF is formulated mathematically as a general constrained optimization problem.

Minimize a function F(u,x) -(1)

Subject to h(u,x) = 0 - (2) and

$g(u,x) \geq 0$ -(3)

Where, u is the set of controllable quantities in the system and x is the set of dependent variables. F (u,x) is an objective function which is scalar. Equality constraints (2) are derived from conventional power balance equation. Inequality constraints (3) are the limits on control variables u and the operating limit on the other variables of the system.

4.2LINEAR PROGRAMMING (LP) &NEWTON-RAPHSON (NR) METHOD

Linear programming formulation requires linearization of objective function as well as constraints with nonnegative variables. T.S. Chung *et al.* [8] presented recursive linear programming based approach for minimizing line losses and finding the optimal capacitor allocation in a distribution system. Cost-benefit calculation is carried out for 14-bus system and this method does not require any matrix inversion, thus saves computational time and memory space.

The necessary conditions of optimality referred to as the Kuhn- Tucker conditions are obtained in NR method. S.Chen *et al*.[9] proposed a new algorithm based on Newton- Raphson (NR) method with sensitivity factors incorporated to solve emission dispatch in real-time. The Jacobian matrix and the B coefficients have been developed in terms of the generalized generation shift distribution factor. So the penalty factor and the incremental losses are easily obtained. Execution time is lesser than that of the conventional one.

4.3QUADRATIC PROGRAMMING (QP) METHOD

It is a special form of nonlinear programming whose objective function is quadratic and constraints are linear. J.A.Momoh [10] presented an extension of basic Kuhn-Tucker conditions and employing a generalized Quadratic-Based model for OPF. The conditions for feasibility, convergence and optimality are included in the construction of the OPF algorithm. Computational memory and execution time required have been reduced.

X.Lin *et al.* [11] integrated cost analysis and voltage stability analysis using an OPF formulation for competitive market. Optimum reactive power dispatch are obtained under various voltage stability margin requirements in both normal and outage conditions for IEEE 14-bus test system.

4.4NON-LINEAR PROGRAMMING (NLP) METHOD

Nonlinear programming (NLP) deals with problems involving nonlinear objective and/or constraint functions. J.A. Momoh *et a.*[10] proposed a new nonlinear convex network flow programming (NLCNFP) model and algorithm for solving the security constrained multi-area economic dispatch (MAED) problem. It is solved by using a combined method of quadratic programming and network flow programming.

4.5INTERIOR POINT (IP) METHOD

Karmarkar proposed a new method in 1984 for solving large scale linear programming problems very efficiently.It is known as an interior method since it finds improved search directions strictly in the interior of the feasible space

.

4.6ANT COLONY OPTIMIZATION (ACO)

It is based on the ideas of ant foraging by pheromone communication to make path. I.K.Yu *et al.* [6] presented a novel co-operative agents approach, Ant Colony Search Algorithm (ACSA)-based scheme, for solving a short-term generation scheduling problem of thermal power systems. The feasibility of the algorithm in large systems with more complicated constraints is yet to be investigated.

5 AN INTRODUCTION ABOUT 400KV S/S SOJA

The Gujarat Energy Transmission Corporation has established a 400kV SOJA sub-station it is 1.5km between from Gojariya- Gandhinagar highway.

The incoming line of 400kV at Soja s/s is from Wanakbori and PGCIL 400kV s/s which is single circuit type transmission line. The tower required for eraction of 400kV transmission line which is coming from Wanakbori and PGCIL s/s are of three type i.e., A, type C and type D tower. The total number of tower required between Wanakbori & PGCIL and soja s/s is 412. The line has charged since 28th January 1987.In single line diagram two incoming lines from Wanakbori and PGCIL of 400kV, and two incoming line from Gandhinagar of 220kV.

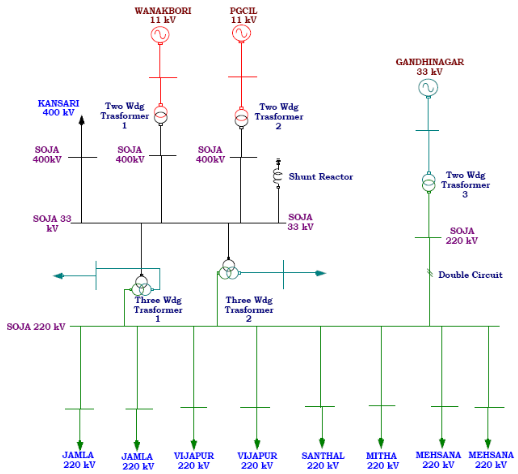

Figure-3 Single Line Diagram of 400 kV Soja Substation

5.1 Objective

Load flow analysis and optimal load flow analysis taken here for case study is with reference to the 400 kV sub-station of Soja, Gandhinagar. In the load flow and optimal load flow analysis, fast decoupled method is taken for case study. The network shown in Figure-3 a single line diagram is prepared using Mi-Power software. The data required for the network, some of which are taken from 400 kV Soja sub-station. Entered in the Mi-Power database.

- In the network taken here, there are 19buses,3transformers,12transmissi-on lines and 3 generators.

5.2 SUMMARY OF RESULTS:

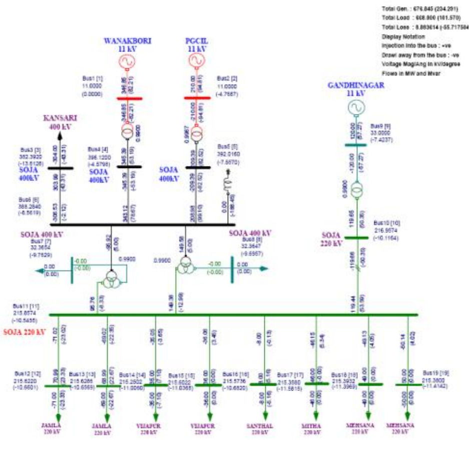

Fig. Load-Flow Diagram Of 400 kV Soja Substation

Fig.4 Output Result Of Load Flow Analysis

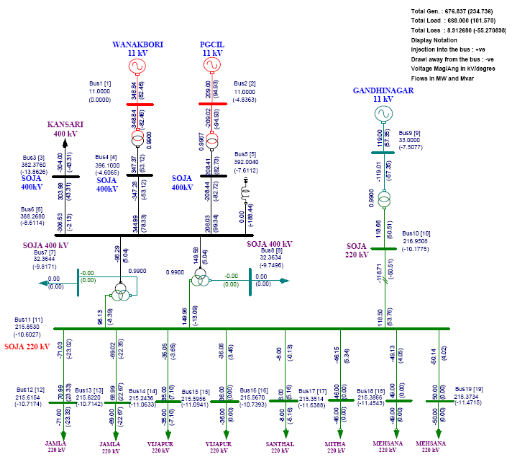

Fig.Optimal Load-Flow Diagram Of 400 kV Soja Substation

Fig.5 Output Result Of Optimal Load Flow Analysis

<u>Summary of results of LFA</u>

Total Real Power Generation : 676.845 Mw
Total React. Power Generation : 234.291 Mvar
Generation Pf : 0.945

Total Shunt Reactor Injection : 0.000 Mw
Total Shunt Reactor Injection : -188.455 Mvar

Total Shunt Capacit.Injection : 0.000 Mw
Total Shunt Capacit.Injection : 0.000 Mvar

Total Real Power Load : 668.000 Mw
Total Reactive Power Load : 101.570 Mvar
Load Pf : 0.989

Total Real Power Loss (Ac+Dc) : 8.883614 Mw
(8.883614+ 0.000000)
Percentage Real Loss (Ac+Dc) : 1.313
Total Reactive Power Loss : -55.717504 Mvar

<u>Summary Of Results of OLFA</u>

Total Real Power Generation : 676.837 Mw
Total React. Power Generation : 234.736 Mvar
Generation Pf : 0.945

Total Shunt Reactor Injection : 0.000 Mw
Total Shunt Reactor Injection : -188.440 Mvar

Total Shunt Capacit.Injection : 0.000 Mw
Total Shunt Capacit.Injection : 0.000 Mvar

Total Real Power Load : 668.000 Mw
Total Reactive Power Load : 101.570 Mvar
Load Pf : 0.989
Total Compensation At Loads : 0.000 Mvar
Total Hvdc Reactive Power : 0.000 Mvar

Total Real Power Loss (Ac+Dc) : 8.912680 Mw
(8.912680+ 0.000000)
Percentage Real Loss (Ac+Dc) : 1.317
Total Reactive Power Loss : -55.270898 Mvar

6. CONCLUSION

For live system the total real power generation is 676.845 MW and total reactive power generation is 234.291 MVAR So, **Generation power factor is 0.945.** Total real power load is 668.00 MW and total reactive power load is 101.570 MVAR. So,

Load power factor is 0.989. In a circuit diagram Value of **Red** color sign is overload condition, **Value of Blue color sign is normal condition** and Value of **Green** color sign is under load condition but in live system no over load line. In a live system load flow analysis for soja sub-station most of line loaded between **25 to 50%** and highest percentage line loading between bus11 and bus12 is **76.2%.** System Frequency is 50 Hz.For live system the total real power generation is 676.837 MW and total reactive power generation is 234.736 MVAR. So, **Generation power factor is 0.945.** Total real power load is 668.00 MW and total reactive power load is 101.570 MVAR. So, **Load power factor is 0.989.**

In live system, the optimal load flow analysis for soja substation has two conditions.

a) minimum cost and
b) b) maximum cost. Cost in Rs.

For Min. Cost i) total cost = 9714.98, ii) generating cost = 6902.58 and iii) loss cost = 2812.40 of the system.

For Max. Cost i) total cost = 9725.18, ii) generating cost = 6902.58 and iii) loss cost = 2822.60 of the system.

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