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Optimal Power Flow Simulation using Linear Programming

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Abstract
This work is based on the application of Linear programming tool. to find the technically high quality power supply with minimum cost. The idea is to dispatch the economical power by predicting the dispatch in such a way that the minimum generation of the cost is allowed and at the same time the allowed range of voltage is maintained along with limitations of upper and lower reactive power and current carrying capacity of the conductors is also taken care of. The entire power flow is digitally controlled with the Power World Simulation. The global power standards are maintained. The power generation is kept green as far as possible. The most important criteria is uninterrupted power supply in odd circumstances. The economy and uninterrupted power supply conditions are modelled mathematically and these equations are solved using Linear Programming. This minimizes the cost of generation of power. The PWT uses linear programming to work out the optimal power flow. The is solution is based on finding the operating point that keeps the minimum cost and still maintaining all the parameters of the power. This paper focuses on generating world class power supply at most economical level. The very objective this work is to workout the OPF of IEEE-14 Bus System

***Keywords-* Optimal power flow, reactive power, economy, reliability, power world simulator, IEEE-14 Bus System**

I.
INTRODUCTION

Entire Human Civilisation is fully relying upon the use of power. In India, the expanding economy is influenced by the cost and quality of power supply. It is remarkable that power supply amidst Covid-19 pandemic crisis remained uninterrupted and kudos to all the companies and their employees who maintained the supply irrespective of threat to their lives. Looking at the importance of the power supply it becomes necessary to see that electricity must be generated and supplied most economically. The transmission system should consume the supply itself. The power network must be maintained and timings of the generation, quantity of the generation of the power must meet out the requirements of the consumer in real-time. Another important point is that continuity must be at the required quality standards. The generation has the environmental impact as well. The modern power plants and the supply network has been automated. The generation is optimally controlled by the demand and supplied instantly at lowest cost. This is termed as the Optimal Power Flow (OPF). This is also known as the Economic Dispatch. The optimal power flow method is used to find technical settings to generate the required power with minimum use of resources. It also considers the upper capacity of the supply network. The researchers have developed a range of optimizing methods. Large number of algorithms have been developed. The most common are Genetic Algorithm, Swarm optimization, Quadratic Programming, Newton’s Technique etc. These methods have their merits and demerits both. Newton’s Method is most efficient. Lambda method is tedious in case of the complex cost function [1].

II . Literature Review

Hanyue Li et al (2020)[1] This research is based on the simulation based on precise approximation to control the accuracy of frequency and stability of power supply. The dc based approach is tested in this work.

Hamid Eghbalpour, et al.(2019)[2] The authors have worked on distributed optimization methodology. ADMM (Alternating Direction Method of multipliers has been modified for both AC and DC and applied on 2-six-bus power system and 3-bus power system.

Muhammad Abdullah et al.(2019)[3] In this paper, the usefulness and application of FPA to solve OPF problem has been incorporated with stochastic nature wind power, solar PV, and small hydro generation in the power system is presented. IEEE 30-bus system is adapted to compare the effectiveness of SHADE-SF and FPA by considering the total generation cost minimization.

Muhammad Abdullah et al.(2019)[4] The novel IMOVO algorithm has been designed and tested on MOOPF problem. The IEEE 30-bus system has been changed for the positive results by the application of the proposed algorithm. The improved power factor proves the supremacy over NSGA-II and MOMVO.

A.farnadez et al. (2019)[5] The authors have made a comparative study of Free Tools and commercial Tools used in Power Flow Simulations. The Grid is modelled as a Mesh. WSCC-9-Bus has been evaluated for the wind power integration with the classical Grid .

III. METHEMATICAL MODEL OF THE PROBLEM

The standard Optimal Power Flow Problem is modelled mathematically as suggested by Dommel and Tinney [10]: a many different techniques have been worked out to find solution to the OPF. A overall minimization problem can be in black and white in the following formula. Minimize: f(x, u) (the objective function) Subject to: $h_i(x,u) = 0$, i =1,2,3, . . . , m (parity restraints)

$g_j(x,u) \leq 0$, j =1 , 2,3 . . . , n (disparity restraints)

A. Independent function

The result of Optimal Power Flow , the major target is to reduce total running expenditures of the system. In Optimal Power Flow, when the burden of electrical requirement is low, the minimum cost power generating machines are always the ones selected to operate first. It mentions the association between how much warmth must be input to the producer and its output energy in Mega Watt. In every real life condition, the price of producing power i can be symbolized as function of real power generation articulated in $/hr,

Ci = (ai+biPi +ci Pi2) * fuel cost (2.1)

B. regulator parameters

The regulator parameters in an optimal power flow problem are the magnitudes whose value can be attuned straight to help lessen the objective function and fulfil the restraints.

The regulator parameters can be given as:

Active power generation, Reactive power generation and Transformer tap ratio Generator bus voltage

C. Reliant parameters

These parameters are the optimal power flow parameters that are not controlled. These include all type of variables that are free, within limits, to assume value to solve the problem. The main dependent variables are complex bus voltage angles and magnitude.

D. Parity Restraints

The equality constraints of the OPF reflect the physics of the power system as well as the desired voltage set points throughout the system.

Pi =P Load + P Loss

Q i = Q Load + Q Loss ,Where ,Pi & Q i are the active and reactive power outputs.

E. Inequality constraints

In a electrical system components and devices have working boundaries & these boundaries are created for security controls. Thus the required objective function can be minimized by maintaining the network components within the security limits.

Disparity controls. **Pgi min ≤ Pgi ≤ Pgimax Qgimin ≤ Qgi ≤ Qgi max**

∑Pgi -PD- PLoss = 0

Where P_{gi} is the amount of generation in MW at generator i.

Q_{gi} is the amount of generation in MVAR at generator i.

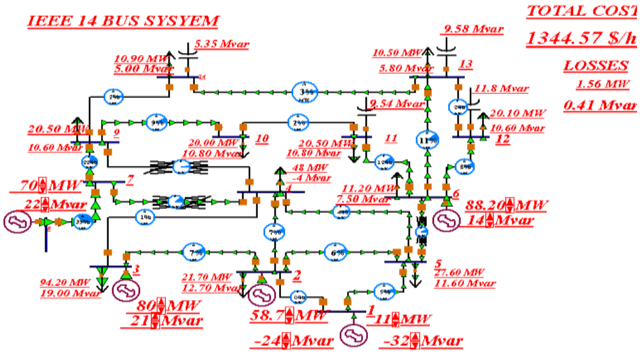

Figure 1 OPF case as minimum losses

IV. SIMULATION AND RESULTS

The Optimal Power Flow has improved many folds because very efficient power simulation tools are readily available. It is possible to simulate the power system, generation, supply and control in a very realistic way and still the quality standards of the power supply can be taken care of. Voluminous data concerning economics of the supply and generation can be collected from the simulation.

Solving Line Overload: The overload conditions can be identified through a feedback and this negative feedback can help to control the power generation as per the demand. In case of line outage the problem is detected and the simulation system

Can assist in the economic dispatch of the power flow. The total cost optimized by OPF is 1071 $/hr. and loss is 3.94 Mega Watt. The OPF keeps the losses at minimum and final running cost is 1344$/hr and loss is estimated as 1.58 MW.

Shunt regulator

The method of minimizing the reactive power is to incorporate the shunt and this reduces the cost. The provision of smart shunt can further reduce the running cost and this is feasible using Power World Simulator. The auto

Shunts can smartly adjust values as per the changing conditions of the supply. The type of the shunt, magnitude can be calculated dynamically as the system is responsive to the line parameters. The Bus is identified which requires the injection or the withdrawal of the power from the system. we can see in the table below that ,bus no 11, 12, 13 ,14 are most sensitive and positive sensitivity indicate that we have to apply capacitive shunt to minimize our objective. Total cost without shunt is 1071.79$ and with shunt it is 1069 $ and the loss difference is 0.43 Mega Watt.

V. CONCLUSION

On the basis of the simulation results the present research has met its objective of finding the solution to power system optimally for IEE-14 bus system. The Power World Simulator has been used and all the objectives can been simulated in order to find the Optimal Power Flow at the minimum investment. This thesis covers the Optimal Power Flow (OPF) problem in detail using standard IEEE 14 BUS . The strategies were developed and tested using standard IEEE 14 bus system for finding an optimal operating point guarantees a secure, economical and reliable power system. The LP (Linear programming)-based method has been effectively used to achieve the OPF goal in this paper of Minimization of system costs and Minimization of system losses. System security was also maintained by making improvements like line over load removal, uniform bus voltage profile etc.

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Appendix A

System Data: • Case Summary for 14- Bus, 2,1-Area System

1. Total No. of Buses – 14
2. Generators – 5
3. Loads – 11
4. Switched Shunts – 4
5. Lines / Transformer – 20
6. Control area – 2
7. Zones – 1

Table A 1: Real & Reactive Power Data

	MW	**MVAr**
Load	305	100.5
Generation	308.6	51.9
Shunts	0.0	-37.5
Losses	3.6	- 11.1

2. Generator Spinning Reserves: • Positive MW – 341.4 • Negative MW – 308.6

A 2 Line data For the IEEE-14 Bus system

Branch No.	**Bus No.'s**	**R p.u.**	**X p.u.**	**B (total) p.u.**	**Rating**
1.	1-2	0.01938	0.05917	0.0528	60
2.	1-5	0.05403	0.22304	0.0492	200
3.	2-3	0.04699	0.19797	0.0438	200
4.	2-4	0.05811	0.17632	0.0374	200
5.	2-5	0.05695	0.17388	0.0340	200
6.	3-4	0.06701	0.17103	0.0340	200
7.	4-5	0.01335	0.04211	0.0128	200
8.	4-7	0.00000	0.20912	0.0000	200
9.	9-4	0.00000	0.55618	0.0000	200
10.	5-6	0.00000	0.25202	0.0000	200
11.	6-11	0.09498	0.19890	0.0000	200
12.	6-12	0.12291	0.25581	0.0000	200
13.	6-13	0.06615	0.13027	0.0000	200
14.	7-8	0.0000	0.17615	0.0000	200
15.	7-9	0.0000	0.11001	0.0000	200
16.	9-10	0.03181	0.08450	0.0000	200
17.	9-14	0.12711	0.27038	0.0000	200
18.	10-11	0.08205	0.19207	0.0000	200
19.	12-13	0.22092	0.19988	0.0000	200
20.	13-14	0.17093	0.34802	0.0000	200

A 3 Bus data for the IEEE-14 bus system

Bus No.	Load P MW	Load Q MVAr
1	**0**	**0**
2	**21.7**	**12.7**
3	**94.2**	**19.0**
4	**47.8**	**-3.9**
5	**27.6**	**11.6**
6	**11.2**	**7.5**
7	**0**	**0**
8	**0**	**0**
9	**20.5**	**10.6**
10	**20.0**	**10.8**
11	**20.5**	**10.8**
12	**20.1**	**10.6**
13	**10.5**	**5.8**
14	**10.9**	**5.0**

A 4 Generator data for the IEEE-14 Bus system

Bus No.	**P_{Gmin} MW**	**P_{Gmax} MW**	**Q_{Gmin} MVAR**	**Q_{Gmax} MVAR**	**a**	**b**	**c**
1	**0**	**340**	**-50**	**200**	**0**	**2.25**	**0.0083**
2	**0**	**70**	**-40**	**50**	**0**	**1.00**	**0.0625**
3	**0**	**80**	**0**	**40**	**0**	**1.75**	**0.0175**
6	**0**	**90**	**0**	**50**	**0**	**3.00**	**0.0250**
8	**0**	**70**	**0**	**50**	**0**	**3.00**	**0.0260**