

# Use of Genetic Algorithm on Optimal Power Flow: An Illustration of Transmission Line Loss Minimization

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**Abstract**— This paper presents the usefulness and effectiveness of Genetic Algorithm on solving Optimal Power Flow (OPF) problem formulation of a real world power system. Optimization is a broad concept that is generally directly or indirectly related to cost factor. In this case, transmission lines loss minimization is presented as the objective of optimization problem formulation keeping all other technical factors and parameters under operating constraints. Results of this study, presented in the Integrated Nepal Power System (INPS) transmission line network show that the Genetic Algorithm is effective method to optimize the power flow via assigned objective of transmission loss minimization in much quicker and effective way when compared to conventional Newton-Raphson method.

## I. INTRODUCTION

THE optimal power flow formulation optimizes the static operating condition of a power generation-transmission system. Optimal power flow is basically concerned to improving economy of operation through the full utilization of the system's feasible operating range and by the accurate coordination of transmission losses in scheduling process. The OPF has been usually considered as the minimization of an objective function representing the generation cost and/or the transmission loss [1]. The constraints involved are the physical laws governing the power generation transmission systems and the operating limitations of the equipment.

Until recently, the optimal power flow has been frequently solved using classical optimization methods. Effective optimal power flow is limited by (i) the high dimensionality of power systems and (ii) the incomplete domain dependent Knowledge of power system engineers. Also, the classical optimization methods often encounter the problem of local optima and slow operation as well[2].As modern electrical power systems become more complex, planning, operation and control of such systems using conventional methods face increasing difficulties. Intelligent systems have been developed and applied for solving problems in such complex power systems. [2].

There have been some studies and researches that emphasize the use of a genetic algorithm on the optimal power flow problem usually using minimization of the fuel cost as objective function [3]. In this paper, however, we illustrate the usability and performance of Genetic Algorithm on minimization of transmission line loss that would eventually lead to optimal power flow on the Integrated Nepal Power System. The controllable system parameters are Generator active power (MW), Generator reactive power (MVAR) and voltage magnitude of the buses. Out of the mentioned parameters or variables, generator active power generation is the most prominent control variable and others depend upon the contingency of the system. The violation of the

operating condition of the grid is kept in check by different constraints like generator MVAR limit, bus voltage magnitude, power flow in lines, etc.

## II. PROBLEM FORMULATION

The standard optimization problem is presented as [4]:

Minimize  $F(x)$ ;  
 Subjected to  $g(x) = 0$ ; Equality constraints  
 And,  $h(x) \geq 0$ ; Inequality constraints

### A. Objective Function

The objective function in this research is to minimize the total transmission line loss of power networks considering the cost factor or the power generation cost almost constant.

Minimize:

$$F_{TLOSS} =$$

$$\sum_{i=1}^{NL} \sum_{j=1}^{NL} g_{i,j} \{V_i^2 + V_j^2 - 2 \times V_i \times V_j \cos(\delta_i - \delta_j)\}$$

Where,

$V_i$  is voltage magnitude at bus  $i$   
 NL is the total number of transmission lines  
 $\delta_i$  is the voltage angle at bus  $i$   
 $g_{i,j}$  is the conductance of line  $i-j$

### B. Systems Constraints

The system constraints make sure that the obtained solution is kept under permissible limit. These constraints in case of optimal power flow formulation are presented as equality and non-equality constraints. The power flow equation themselves serve as equality constraints.

$$\sum_{i=1}^{NG} P_{gi} - \sum_{j=1}^{ND} P_{dj} - P_L = 0$$

$$\sum_{i=1}^{NG} Q_{gi} - \sum_{j=1}^{ND} Q_{dj} - Q_L = 0$$

Where,

$P_{gi}$ = Active power produced by Generator  $i$   
 $Q_{gi}$ = Reactive power produced by Generator  $i$   
 PL and QL are active and reactive losses

And, the inequality constraints for this problem formulation are presented as:

$$V_i^{min} \leq V_i \leq V_i^{max}$$

$$T_i^{min} \leq T_i \leq T_i^{max}$$

$$Q_i^{min} \leq Q_i \leq Q_i^{max}$$

Where,

$V_i, T_i, Q_{Gi}$  represents voltage, transformer tap position and reactive power produced respectively at  $i^{th}$  bus.

These are the values of parameters that are adjusted or changed during each iteration such that the minimum value of the objective function is obtained. In this case, the control variables is the active power ( $P_{Gi}$ ) produced by each of the generators.

$$P_{G,i}^{min} \leq P_{G,i} \leq P_{G,i}^{max}$$

### III. GENETIC ALGORITHM IN OPTIMAL POWER FLOW

Genetic algorithm is the most popular and widely used evolutionary algorithm, a global adaptive search technique inspired by genetics and analogous to natural behavior [5]. It transforms a set or population of individual mathematical objects, each with as associated fitness value, into a new population using genetic operations similar to the corresponding operations of genetics in nature. Genetic Algorithm seem to perform a global search in the solution space of a given problem domain [6][9].

The basic concept of the genetic algorithm is to extract the best possible combination of pre-defined changing variables within preset range so as to minimize the objective function. Each candidate solution has a set of properties usually called as chromosome represented by the binary string which can be mutated and altered. The evolution initiates from a set of randomly generated individuals and undergoes iterations. In iteration, the fitness of every individual in the population set is evaluated where the fitness is the value of objective function itself.

Continuing the iteration, more fit individuals are stochastically selected from the current population set and each individual is modified via mutation or recombination to form a new population set. The new generation set or population set is then used in the next iteration of the algorithm. The termination of the iteration depends upon the termination criteria defined. It could be the number of generation or value if fitness function or so on.

### IV. APPLICATION STUDY

The Optimal Power Flow using Genetic Algorithm has been developed based on MATLAB version 8.2.0 (R2013b) for this study. Integrated Nepal Power System (INPS) with simplified bus network and lumped load considered with total of 47 buses including 18 PV buses and 1 Slack bus is considered as test network for this application study. In order to simplify the study, only major generating stations of capacity above 10 MW and load center above 10 MVA are considered in the test network [7][8].

Figure 1 show figurative illustration of the simplified Integrated Nepal Power System (INPS) transmission line network while Table I shows technical parameters of the

generating stations considered for this study, of the Integrated Nepal Power System (INPS).

TABLE I  
Generator parameters of integrated Nepal power system

Bus	Power Plant	Capacity (MW)	Pg Min	Pg Max
1	U. Tamakoshi*	456	0	456
3	Jhimruk	13	12	12.5
6	Kaligandaki	144	0	144
7	Gandak	15	0	15
12	Modi	14	1	14
13	Marsyangdi	69	20	69
14	M. Marsyangdi	70	0	70
15	U. Marsyangdi	50	0	50
17	Kusha	0	0	60
18	Duhabi Multifuel	39	0	39
25	Kulekhani II	30	0	30
26	Hetauda Diesel	14	0	14
30	Kulekhani I	60	0	60
37	Khimti	60	30	60
38	Bhotekoshi	36	20	36
39	Sunkoshi	10	3	10
40	Indrawati	7	2.5	7
42	Devighat	14	4	14
43	Trisuli	21	3	21
44	Chilime	20	20	20
Total		1142		

\*Indicates the generating stations supposed to be in operation in imminent future. These too are included to extract feasible load flow solution.

Table II summarizes the result on this INPS transmission line network for total load demand of 672 MW while using Genetic Algorithm to find the optimal solution of load flow while presenting the same for conventional load flow using Newton- Rapshon too. This serves as comparison of two approaches adopted.

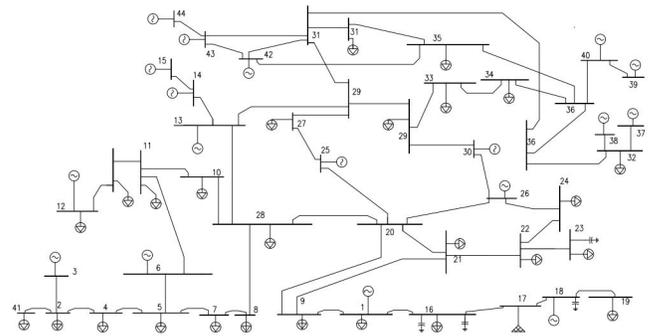


Fig.1. Simplified Single Line diagram of INPS

Figure 2 along with table II shows that Genetic Algorithm optimizes the power flow by minimizing the transmission line loss from around 36 MW to around 26 MW for loading condition of 672 MW.

TABLE II  
Simulation result for load demand of 672 mw

Bus	NR Load Flow			GA based Load Flow		
	V (p.u)	Delta	Pg (MW)	V (p.u)	Delta	Pg (MW)
1	1.00	0.00	106.07	1.00	0.00	194.18
3	0.95	-15.88	13.00	0.95	-14.87	13.00
6	1.00	-3.03	60.00	1.00	0.00	128.91
7	0.97	-4.46	15.00	0.97	-4.77	12.00
12	1.00	-1.76	14.00	1.00	-2.41	9.51
13	1.00	8.42	69.00	1.00	-1.88	69.00
14	1.00	18.98	70.00	1.00	-0.29	-3.18
15	1.01	20.97	50.00	1.01	0.47	21.14
18	1.00	-11.25	39.00	1.00	-12.02	39.00
25	1.00	-2.27	30.00	1.00	-7.48	30.00
26	1.00	-2.52	14.00	1.00	-7.72	14.00
30	1.00	0.35	60.00	1.00	-6.30	35.70
37	1.01	1.43	60.00	1.01	0.74	60.00
38	1.01	1.94	36.00	1.01	0.92	36.00
39	1.01	5.06	10.00	1.01	-1.91	10.00
40	1.00	2.97	7.00	0.99	-3.53	-1.90
42	1.00	1.47	14.00	0.99	-5.23	5.52
43	1.00	2.03	21.00	0.99	-4.84	5.98
44	1.00	9.79	20.00	1.00	2.72	20.00
Total			708.07	Total		698.86

Table III summarizes the result on this INPS transmission line network for total load demand of 840 MW while using Genetic Algorithm to find the optimal solution of load flow while presenting the same for conventional load flow using Newton- Raphson too. This serves as the comparison of two approaches adopted.

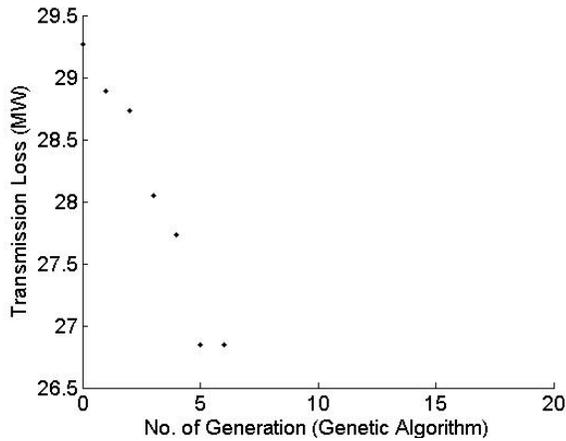


Fig.2. Optimization Plot for total Load demand of 672 MW

Figure 3 along with table III shows that Genetic Algorithm optimizes the power flow by minimizing the transmission line loss from around 48 MW to around 40 MW for loading condition of 840 MW.

TABLE III  
Simulation result for load demand of 840 mw

Bus	NR Load Flow			GA based Load Flow		
	V (p.u)	Delta	Pg (MW)	V (p.u)	Delta	Pg (MW)
1	1.00	0.00	202.02	1.00	0.00	291.00
3	0.95	-16.25	13.00	0.95	-21.85	12.81
6	1.00	5.15	144.00	1.00	0.00	144.00
7	0.96	-0.03	15.00	0.96	-6.04	15.00
12	1.00	3.40	14.00	1.00	-2.58	14.00
13	1.00	8.13	69.00	1.00	-1.75	65.77
14	1.00	18.68	70.00	1.00	-1.75	20.51
15	1.01	20.67	50.00	1.01	-1.75	32.03
18	1.00	-16.29	39.00	1.00	-1.75	39.00
25	1.00	-5.30	30.00	1.00	-1.75	30.00
26	1.00	-5.53	14.00	1.00	-1.75	12.74
30	1.00	-2.85	60.00	1.00	-1.75	52.97
37	1.00	0.80	60.00	1.00	-1.75	60.00
38	1.01	1.15	36.00	1.01	-1.75	34.78
39	1.01	2.40	10.00	1.00	-1.75	5.22
40	0.99	0.79	7.00	0.99	-1.75	4.06
42	0.99	-1.33	14.00	0.99	-1.75	11.77
43	0.99	-0.77	21.00	0.99	-1.75	13.24
44	1.00	6.79	20.00	1.00	-1.75	20.00
Total			888.02	Total		878.90

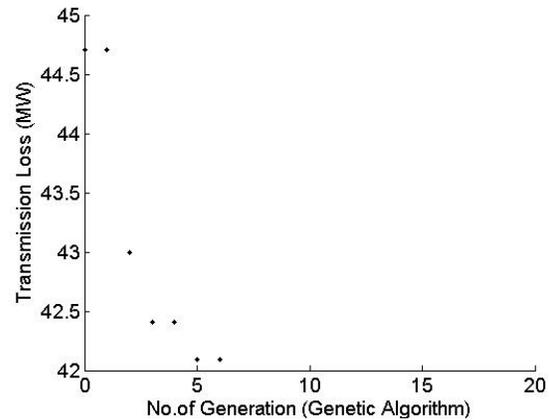


Fig. 3. Optimization Plot for total load demand of 840 MW

V. CONCLUSION

This paper presents the significance of Genetic Algorithm in optimal power flow which is illustrated by a study case of minimization of transmission line loss in Integrated Nepal Power System transmission line network simplified into 47-bus network with 18 Generating stations. The simulation results shows that the Genetic Algorithm can achieve very good result to meet the defined objective. In this study, only the active constraints or the changing variables are taken in account to calculate the optimal solution set while the passive or secondary constraints keep the solution set within bound.

VI. REFERENCES

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## VII. BIOGRAPHIES

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