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Comparative Studies on a Fourteen-Bus Power System Between Conventional, Particle Swarm Optimization and Deep Learning Solutions for Optimal Allocation for Generation

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Abstract: *This research paper aims to find optimal allocation of active power to generator and estimate the transmission losses for the specific demand using three different computational techniques like conventional method which is Lambda Iteration method, Particle Swarm Optimization method and also Deep learning Method. These methods were applied to IEEE 14 bus test system. This test system was imposed different loading conditions and transmission losses were estimated.*

Keywords: *Lambda Iteration, Particle Swarm Optimization, Deep Learning.*

1. INTRODUCTION

The demand of power is expanding day by day all over the world. Continuous study and analysis is required for Power system planning, design and operation to evaluate system Performance. This study play a significant role in providing a high standard of reliability and for maximum utilization of capital investment in power system. Optimal allocation of active power helps in estimating transmission losses. Transmission losses account for 5 to 10 percent of total generation. With different modern techniques generation and transmission can be done in an optimal way to reduce cost and optimally allocate the generation for longer sustainability of the systems as well as resources.

2. LITERATURE REVIEW

Economic load dispatch (ELD) is a common task in the operational planning of a power system, which requires to be optimized. The paper by N. Singh et.al introduces a novel PSO variant, the Moderate Random Search PSO (MRPSO), to address multi objective ELD problems, balancing fuel cost and environmental emissions. The method demonstrates improved convergence and solution quality on the IEEE 30-bus system [1]. N. K. Jain et.al. have applied PSO to multi objective ELD problems, visualizing trade-offs among cost, transmission losses, and emissions in both 2D and 3D spaces across various IEEE bus systems [2]. Paper by author M. Abuella et. al. addresses ELD in systems integrating wind power, utilizing PSO to manage the variability of wind energy alongside thermal generation in a 6-bus system. A paper by H. Shahin et.al [4] presents a PSO-based approach for dynamic ELD, considering generator constraints, ramp rate limits, and transmission losses, tested on a 26-bus, 6-unit system. Paper [6] Implements PSO for economic dispatch in the Kerala power system, aiming to minimize operating costs while satisfying system constraints.

Literature review reveals that Economic Load Dispatch (ELD) remains a critical optimization problem in electrical power systems, aimed at minimizing the total generation cost while satisfying system constraints. This review highlights various methodologies employed to address ELD, with an emphasis on classical, artificial intelligence-based, and hybrid techniques, as well as the integration of renewable energy resources

3. PROBLEM FORMULATION

The factors influencing power generation at minimum cost are operating efficiency of generators, fuel cost, and transmission losses. For this paper the IEEE 14-bus power system is considered for studies which consists of 14 buses, 5 generators, 11 loads, and 20 transmission lines.

The objective function for the ELD problem can be formulated by quadratic equation as:

$$F(Pgi) = \sum_{i=1}^{N_g} Fi\ (Pgi) \quad (1)$$

The fuel cost of i^{th} generator can be expressed as,

$$F_i(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i \quad i=1 \text{ to } N_g \quad (2)$$

Where, a_i, b_i and c_i are fuel cost coefficients of ith generator.

The objective function of the system should be achieved while satisfying the equality and inequality constraints of the system.

Equality Constraint:

The constraint of real power is considered here which also includes transmission losses as power balance constraint.

$$\sum_{i=1}^{N_g} P_{gi} = P_d + P_L \quad (3)$$

Where, subscript g, d and L addresses to generation, demand and loss for Power

Inequality Constraint:

Inequality constraints for the generating unit can be given as follows:

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \quad (4)$$

Where,

P_{gi}^{min} and P_{gi}^{max} minimum and maximum limit of the power generation of i^{th} generator respectively.

4. METHODOLOGY

This section provides the brief description of methods which are used to find min allocation to generators in comparison to conventional method

Algorithm for PSO

- Set up the total fuel cost function and system constraints, including generator limits, B-matrix for transmission losses, and total load demand.
- Randomly generate a population of particles (power outputs) within generator limits. Assign initial velocities and set PSO parameters
- For each particle, calculate the total generation cost and update each particle's personal best (Pbest) and the global best (Gbest).
- Adjust velocities and positions using PSO update equations. Apply generator limits and recalculate fitness. Repeat until convergence or max iterations.
- Return the best-found generation schedule (Gbest) that minimizes cost and satisfies system constraints.

Deep Learning is used as another alternative to optimal allocation to generators.

5. SIMULATION ANALYSIS AND DISCUSSION

The problem solving capability of three methods Conventional, Particle swarm optimization and Deep learning was applied to 14 bus IEEE system shown in figure-1, and verified for different Load demand like 100MW, 150MW, 180MW and 220MW.

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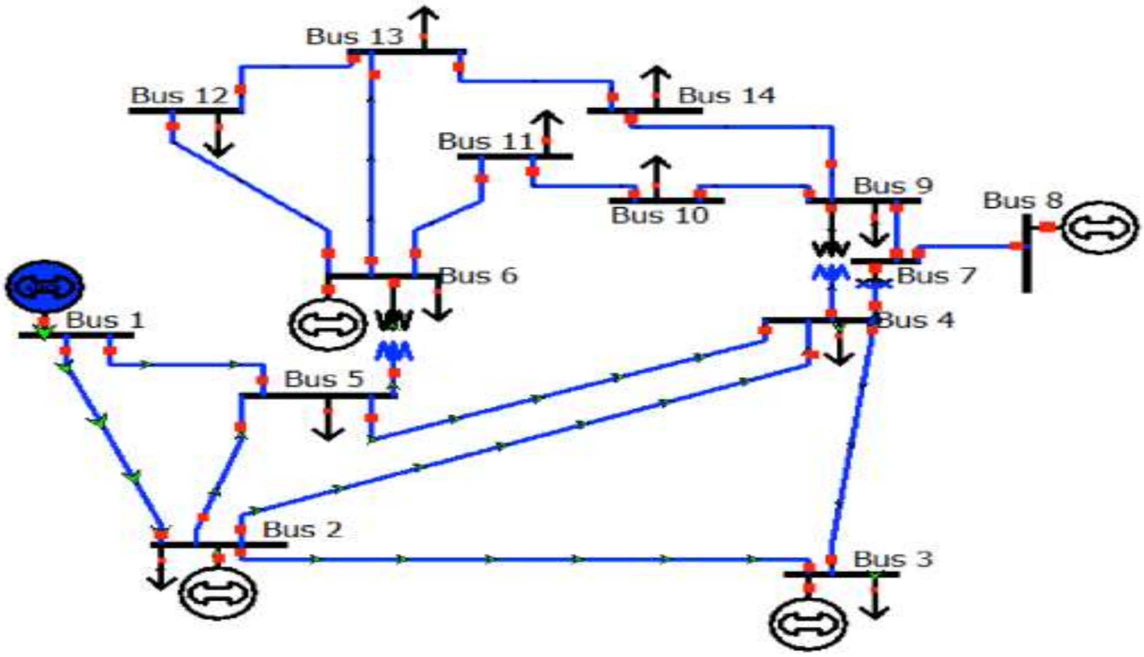

Figure-1 IEEE 14 bus system

The Simulated results for allocated power to different generators are given in table 1, 2, 3 and 4.

Table-1 (Best power output among 5 generators for demand of 100MW)

Techniques	Power Units are in MW					
	PG1	PG2	PG3	PG4	PG5	Tr.Loss
Conventional	10	10	22.09	50	10	2.09
PSO	10.01	10	21.28	45.41	15.22	1.92
Deep learning	10.06	9.99	22.11	50.00	10.09	2.25

Table-2 (Best power output among 5 generators for demand of 150MW)

Techniques	Power Units are in MW					
	PG1	PG2	PG3	PG4	PG5	Tr.Loss
Conventional	10	10	50	50	34.14	4.14
PSO	39.68	10.01	46.07	47.83	10	3.59
Deep learning	10.04	10.09	49.97	50.00	34.19	4.29

Table-3 (Best power output among 5 generators for demand of 180MW)

Techniques	Power Units are in MW					
	PG1	PG2	PG3	PG4	PG5	Tr.Loss
Conventional	10	30.3	50	50	45	5.30
PSO	50.16	29.96	42.53	49.88	12.02	4.55
Deep learning	9.99	30.4	49.99	49.99	44.99	5.36

Table-5 (Best power output among 5 generators for demand of 220MW)

Techniques	Power Units are in MW					
	PG1	PG2	PG3	PG4	PG5	Tr.Loss
Conventional	21.95	60	50	50	45	6.95
PSO	48.71	59.69	36.52	49.98	31.52	6.42
Deep learning	22.03	59.5	50.06	50.00	45.26	6.85

6. CONCLUSION

This paper presents the comparative allocation of power to generator to minimize the transmission losses for bus system as much as possible. It is found that the transmission losses are in the range of 1.92% to 3.11% only using conventional, particle swarm optimization and deep learning method. As the system size increases transmission losses may also increase.

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