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# Differential Search Evolution Algorithm for Solution of Optimal Power Flow Problem

*Dr. Prateek Nigam[1], Saurav Kumar[2]*
*[1]HOD Electrical Engineering, RNTU, Bhopal, India*
*[2]M-tech scholar Power system, RNTU, Bhopal, India.*

***Abstract*—In this paper, an easy nature stimulated search method primarily based on differential search set of rules (DSA) has been offered and used for most suitable electricity or power flow (OPF) problem in electricity structures. By the usage of the proposed DSA technique, the power strength machine system parameters along with actual energy or power generations, bus voltages, and load faucet or tap changer ratios and shunt capacitance values are optimized for the certain positive goal functions. The considered goal capabilities are fuel cost minimization, electricity losses minimization, voltage profile improvement, and voltage balance enhancement. Different sorts of single-objective and multi-objective capabilities on IEEE 9-bus and IEEE 30-bus power structures are used to check and confirm the efficiency of the proposed DSA method. By comparing with numerous optimization methods, the results received with the aid of the use of the proposed DSA approach are offered in element. The consequences carried out on this work illustrate that the DSA approach can effectively be used to remedy the non-linear and non-convex problems associated with electricity systems.**

***Keywords*—DSA, OPF, Optimization, Multi-Objective, Objective Functions.**

## I. INTRODUCTION

Nowadays, the increasing humanity's dependency on electric power energy is amplified and consequently the electrical demands have been expanded rapidly regarding the increase in population and industrial applications. This ever growing is accompanied with slow reinforcement in power system installations due to financial and political restrictions. On the other side, various aspects are required to be taken into account for adequate power system operation such as minimizing fuel costs, losses, environmental pollution, security, voltage profile, and stability etc. For these reasons and more, an extensive interest in the research field has been given to the optimal power flow (OPF) for both planning and operation of power systems. Even though the main purpose of the OPF problem is to minimize the fuel generation cost. OPF aims at reducing transmission losses, eliminating voltage violations, and improving system security while maintaining the different equality and inequality constraints.

In a typical system, network losses are in range of 5–10% of the total power system, which would cost millions of dollars every year. Moreover, the improvement of voltage profile is considered a power quality index which is very important in operating various loads types. Therefore, loss minimization and voltage profile improvement are as important as objectives of minimizing the fuel cost and enhancing the voltage stability in operating the transmission networks. The OPF formulation is generally identified as a non-linear constrained optimization problem matured with multi-objective (MO) functions subject to set of equality and inequality constraints.

The equality constraints are the load flow equations, while the inequality constraints are the limits of control and dependent variables. Control variables are typically the generator real powers, except slack bus, the generator voltages, transformer tap settings, and reactive power injection of switched capacitors and reactors. The dependent variables are slack bus power, load bus voltages, generator reactive powers, and line flows. It has been traditionally solved using a variety of conventional optimizations methods for years such as gradient projection method (GPM), interior point method, linear programming, quadratic programming, and non-linear programming.

In evolutionary computation, differential evolution (DE) is a technique that optimizes a hassle by iteratively seeking to enhance a candidate solution with regard to a given degree of pleasant. Such strategies are usually known as metaheuristics as they make few or no assumptions about the trouble being optimized and might seek very large areas of candidate solutions. However, metaheuristics consisting of DE do not guarantee a most desirable answer is ever discovered. DE is used for multidimensional real-valued capabilities but does no longer use the gradient of the problem being optimized, which means that DE does no longer require for the optimization problem to be differentiable as is needed with the aid of traditional optimization methods which includes gradient descent and quasi-newton methods. DE can therefore additionally be used on optimization troubles that are not even continuous, are noisy, change over time, and many others.

The rest of this paper is organized as follows: section 2 explains the problem formulation and the proposed method describe in section 3. Simulations and results of multiple DG unit placements are investigated and discussed in Section 4. Finally, Section 5 concludes this paper.The rest of this paper is organized as follows. Section II explains the characteristics of Wireless sensor networks. Section III presents the architecture of Wireless sensor networks. Section IV reviews different routing protocols. Section V explains the concept of Ant Colony Optimization algorithm. Section VI compares the performance of different routing protocols with Ant colony optimization algorithm.

## II. PROBLEM FORMULATION

The OPF downside is associate optimization downside that determines the ability output of every on-line generator that may lead to a least value system operational state. The OPF downside will then be written within the following form:

$$\left.\begin{array}{l} \text{Minimize } f(x) \\ \qquad \text{Subject to } \; g(x)=0 \\ H(x)\le 0 \end{array}\right\}$$

f(x) is that the objective operate, g(x) and H(x) area unit severally the set of equality and difference constraints. X is that the vector of management and state variables.

**Cost function:**

The objective of the OPF is to reduce the entire system value by adjusting the ability output of every of the generators connected to the grid. The entire system value is sculpturesque because the ad of the value operate of every generator. The generator value curves area unit sculpturesque with swish quadratic functions, given by:

$$f(x)=\sum_{i=1}^{n_g}\left(a_i+b_iP_{gi}+c_iP_{gi}^2\right) \quad \text{………..} (1)$$

**Equality Constraints:**

The equality constraint is diagrammatic by the ability balance constraint that reduces the ability system to a principle of equilibrium between total system generation and total system masses. Equilibrium is simply met once the entire system generation equals the entire system load and system losses .On other equilibrium is only met when the total system generation equals the total system load plus system losses.

$$\sum_{i=1}^{n_g}\left(P_{gi}-P_D-P_L\right)=0 \quad \text{………………. } (2)$$

The exact worth of the system losses will solely be determined by suggests that of an influence flow resolution. the foremost fashionable approach for locating Associate in Nursing approximate worth of the losses is by manner of Kron 's loss formula that approximates the losses as a operate of the output level of the system generators.

$$\sum_{i=1}^{n_g}\sum_{j=1}^{n_g}P_{gi}B_{ij}P_{gi}+\sum_{j=1}^{n_g}P_{gi}B_{io}+B_{oo}=0 \quad \text{….. } (3)$$

**Inequality Constraints:**

Following area unit the difference constraints

- Upper and lower bounds on the active generations at generator buses

$$P_{gi}^{\min}\le P_{gi}\le P_{gi}^{\max} \quad \text{………………. } (4)$$

- Upper and lower bounds on the reactive power generations at generator buses and reactive power injection at buses with power unit compensation

$$Q_{gi}^{\min}\le Q_{gi}\le Q_{gi}^{\max} \quad \text{……………….. } (5)$$

- Upper and lower bounds on the voltage magnitude at the all the buses

$$V_{gi}^{\min}\le V_{gi}\le V_{gi}^{\max} \quad \text{………………… } (6)$$

$P_{gi}$ : Real power injection at bus.

$Q_{gi}$ : Reactive power injection at bus,

$P_D$ : Total real power demand at all the buses,

$V_i$ : Magnitude of voltage bus

$G_g$ : Capacity of the DG,

$(P_L)$ : System losses

$n_g$ : Total number of generator buses,

$a_i$, $b_i$, $c_i$ : are cost coefficient.

## III.PROPOSED METHODLOGY

DE optimizes a retardant by maintaining a population of candidate solutions and making new candidate solutions by combining existing ones per its easy formulae, so keeping whichever candidate resolution has the simplest score or fitness on the optimization downside at hand. During this manner the optimization downside is treated as a black box that just provides a measure of quality given a candidate solution and also the gradient is therefore not required.

Various objective functions are handled as single-objective optimizations issues that are the fuel price reduction, power losses reduction, voltage profile improvement, and voltage stability improvement. Valueadded to it, the MO-OPF optimizations are thought of. For resolution these OPF formulations, and MO-DEA is planned, that relies on a combination between the DE variant (DE/best/1) and therefore the ε-constraint approach.

The notable features of the proposed approach are:

- It is very simple and easy to implement.
- The proposed DE variant is distinguished with a high capability of global search exploitation and faster convergence to optimize the considered OPF objectives.
- The ability to find Pareto-optimal solutions in a single simulation run by incorporating the ε-constraint with adaptive threshold value with the DE variant.
- Eachε-level is forcedly initialized by feeding it with the best individuals from previous level. This process raises the chance for obtaining more economical and technical operating settings.
- Involving the ε-constraint provides Pareto-optimal solutions without computational burden of Pareto ranking and updating or additional efforts to preserve the diversity of the non-dominated solutions.
- The best compromise solution is extracted based on fuzzy set theory.

**Generally proposed methodology consists of three step process:**

- Mutation
- Crossover
- Selection

**Proposed differential evolution optimization methodology process steps as following (Flow chart Shown in Figure 1):**

1.Start the environment.
2.Set the input system data, Branch data, Line data and generator data.
3.Specify differential evolution optimization search algorithm control parameter and penalty terms.
4.Initialize the population for the optimal power flow control variable j = 1.
5.Update the system bus and line data with population and solve the load power flow problem through newton Raphson iteration.
6.Evaluate the generalized fitness function with quadratic penalty terms.
7.Perform differential evolution mutation.
8.Perform differential evolution crossover.
9.Again update the system bus and line data with population and solve the power flow problem through newton iteration.
10.Again evaluate the generalized fitness function with quadratic penalty terms.
11.Perform selection process and form new population.
12.If the value j < Gen then done increment in j i.e. j+1, repeat step from 7.
13.If the value j > Gen, found optimal power flow solution.
14.End the simulation

 

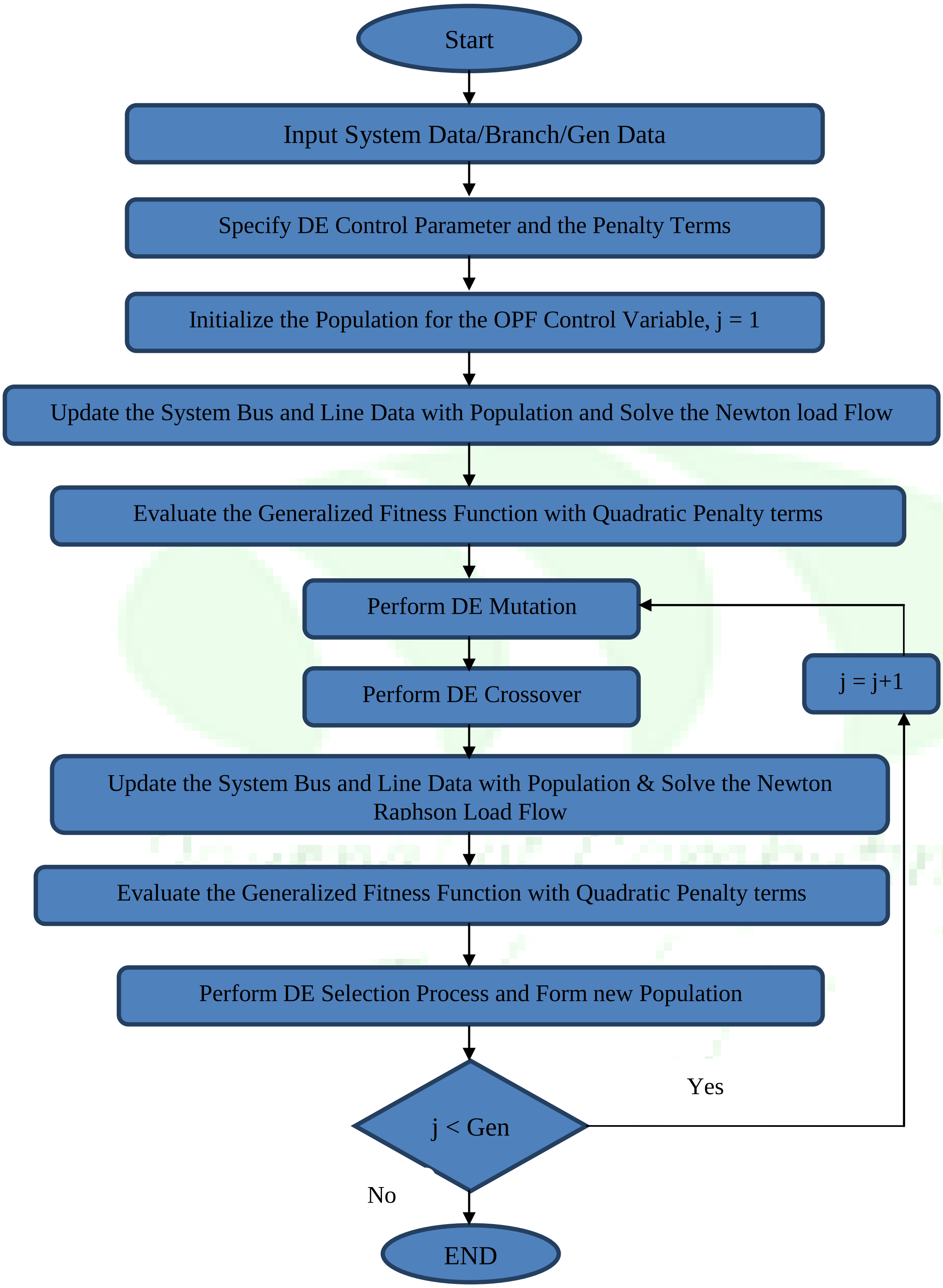


**Figure 1: Flow Process Chart for Proposed Mechanism**

## IV.SIMULATION & RESULT

To evaluate the effectiveness of the proposed approach, the standard IEEE 9-bus and IEEE 30-bus test systems have been considered. Initially, several runs are done with different values of the algorithm's parameters and they are optimally specified

**IEEE-9-bus power system:** The IEEE-9-bus power system consists of 9 buses, 9 branches, 3 generators, 3 under-load tap changing transformers.

**Newton's method power flow converged in 4 iterations. Converged in 0.05 seconds**

**Table 1: System Summary for IEEE-9-Bus**

| System Summary | | | | |
|---|---|---|---|---|
| **Power System Parameter** | | **Capacity** | **P (MW)** | **Q (MVAr)** |
| Buses | 9 | Total Gen Capacity | 820.0 | -900.0 to 900 |
| Generators | 3 | On-line Capacity | 820.0 | -900.0 to 900 |
| Committed Gens | 3 | Generation (actual) | 320 | 34.9 |
| Loads | 3 | Load | 315.0 | 115.0 |
| Fixed | 3 | Fixed | 315.0 | 115.0 |
| Dispatch able | 0 | Dispatch able | -0.0 of -0.0 | -0.0 |
| Shunts | 0 | Shunt (injection) | -0.0 | 0.0 |
| Branches | 9 | Losses (I^2 * Z) | 4.95 | 51.31 |
| Transformers | 0 | Branch Charging (injection) | - | 131.4 |
| Inter-ties | 0 | Total Inter-tie Flow | 0.0 | 0.0 |
| Areas | 1 | | | |

| | **Minimum** | **Maximum** |
|---|---|---|
| Voltage Magnitude | 1.072 p.u. @ bus 9 | 1.100 p.u. @ bus 1 |
| Voltage Angle | -4.62 deg @ bus 9 | 4.89 deg @ bus 2 |
| P Losses (I^2*R) | - | 1.39 MW @ line 8-9 |
| Q Losses (I^2*X) | - | 9.36 MVAr @line 8-2 |
| Lambda P | 24.03 $/MWh @ bus 2 | 25.00 $/MWh @ bus 9 |
| Lambda Q | 0.00 $/MWh @ bus 6 | 0.11 $/MWh @ bus 9 |
| **Fuel Cost** | **1132.176 $/h** | |

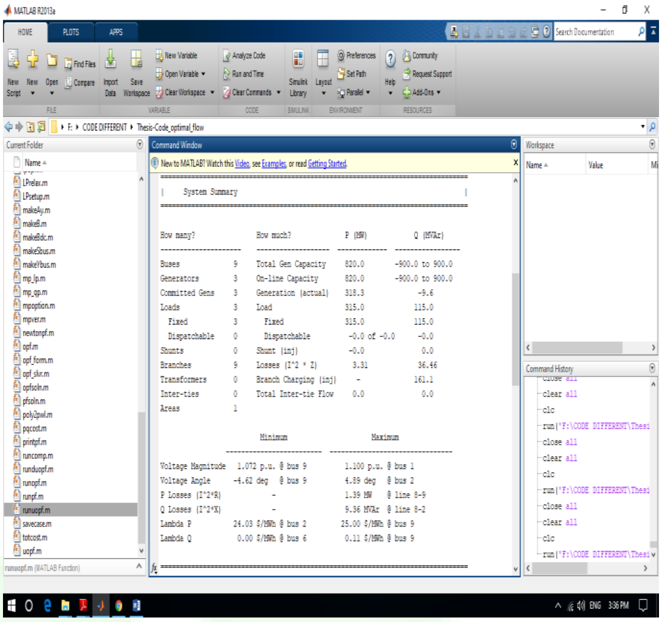

**Figure 2: MATLAB command window shows the system summary of proposed methodology for IEEE-9-Power System Bus**

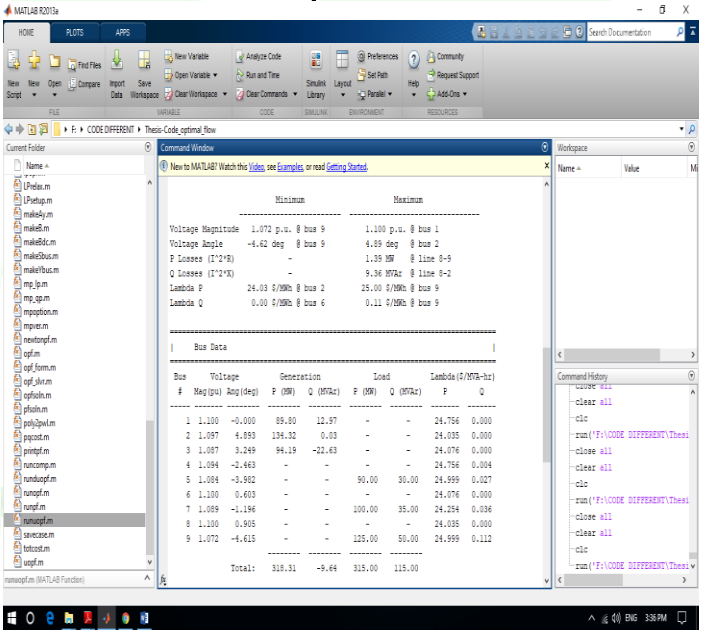

**Figure 3: Results window shows the updated bus data for IEEE-9-Power System Bus**

 

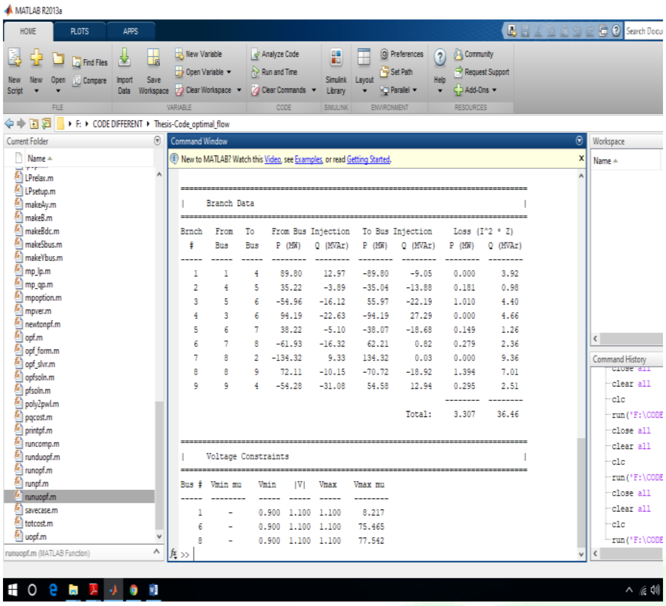

**Figure 4: Results window shows the updated Branch data and voltage constraints for IEEE-9-Power System Bus**

In Table 1 shows that the system summary of proposed methodology and set the input system, figure 2 shows the system summary and figure 3 depicted the updated bus data with new population and estimate the actual active and reactive load with generated active and reactive load, figure 4 shows that the updated branch data and voltage constraints and also shows the losses both active and reactive losses.

**IEEE-30-bus power system:** The IEEE 30-bus power system consists of 30 buses, 41 branches, 6 generators, 6 under-load tap changing transformers.

**Converged in 0.81 seconds**

**Table 2: System Summary for IEEE-30-Bus**

| **System Summary** | | | | |
|---|---|---|---|---|
| **Power System Parameter** | | **Capacity** | **P (MW)** | **Q (MVAr)** |
| Buses | 30 | Total Gen Capacity | 335.0 | 0.0 to 0.0 |
| Generators | 6 | On-line Capacity | 335.0 | 0.0 to 0.0 |
| Committed Gens | 6 | Generation (actual) | 189.2 | 0.0 |
| Loads | 20 | Load | 189.2 | 0.0 |
| Fixed | 20 | Fixed | 189.2 | 0.0 |
| Dispatch able | 0 | Dispatch able | -0.0 of -0.0 | -0.0 |
| Shunts | 0 | Shunt (injection) | -0.0 | 0.0 |
| Branches | 41 | Losses (I^2 * Z) | 0.0 | 0.0 |
| Transformers | 0 | Branch Charging (injection) | - | 0.0 |
| Inter-ties | 7 | Total Inter-tie Flow | 52.3 | 0.0 |
| Areas | 3 | | | |
| | | **Minimum** | | **Maximum** |
| Voltage Magnitude | | 1.000 p.u. @ bus 1 | | **1.000 p.u. @ bus 1** |
| Voltage Angle | | -6.16 deg @ bus 19 | | **0.00 deg @ bus 1** |
| Lambda P | | 3.79 $/MWh @ bus 1 | | **3.79 $/MWh @ bus 13** |
| Lambda Q | | 0.00 $/MWh @ bus 1 | | **0.00 $/MWh @ bus 1** |
| Fuel Cost | | 565.21 $/hr | | |

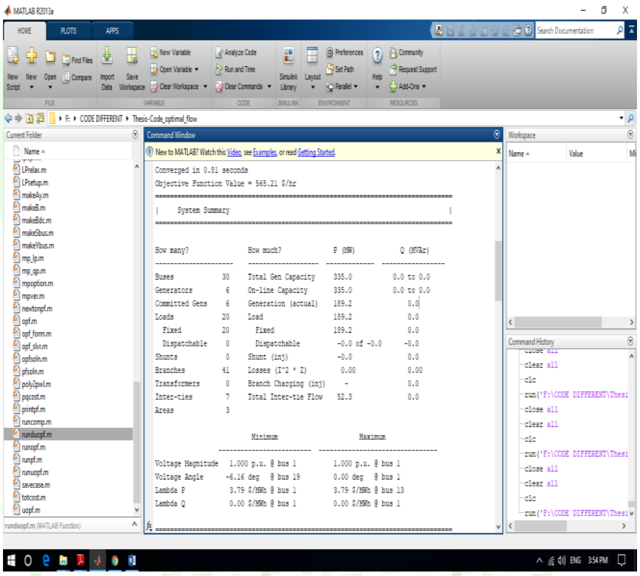

**Figure 5: MATLAB command window shows the system summary of proposed methodology for IEEE-30-Power System Bus**

In Table 2 shows that the system summary of proposed methodology and set the input system, figure 5 shows the system summary and also depicted the updated bus data with new population and estimate the actual active and reactive load with generated active and reactive load and updated branch data and voltage constraints and also shows the losses both active and reactive power losses.

## V.CONCLUSION

In this paper, differential search based, optimization method is proposed and successfully applied to solve various types of problems including complex, single and multi-type of objective functions within the constraints regarding to optimal power flow (OPF). The results obtained by using the proposed DSA method, provides better solution performance, robustness and superiority and can effectively be used in large scaled, nonlinear and non-convex problems of power system optimization owing to its high solution quality and rapid convergence speed.

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