Economic load dispatch problems in smart grid: A review

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Abstract

Many researchers prove that one of the fundamental problems in the power system is economic dispatch problem. Since working on smart grid at lowest cost is a big challenge. Future work on this area is to solve these problems. Under this paper we are going to show detail description of progress on economic dispatch, centralized and decentralized algorithm, demand side management, classical and modern techniques by looking for the way and key factors on their progress. Many countries work on demand side management and using different alternatives since related to optimization of generation and system load cost models. With this scope of research in various ways of economic dispatch problem on the smart grid has been investigated.

Economic Dispatch and the Unit Commitment are essential problems to be solved in order to supply high-quality electric power to customers in when working in a smart grid context some extra consideration must be taken into account. The high penetration of renewable energy sources, the large amount of energy that can be stored and different methods used in economic dispatch algorithm that are conventional and modern techniques, comparison between them these all are what we are going to show in our review. Customer’s requirement for this time is quality power and minimum cost so for future work we recommend to work with stability since the most journals that we are used as reference was done to minimize cost only we should look for stability also looking for operation and maintenance cost as factor is also necessary.

Key Words: Smart grid, Centralized algorithm, Distributed algorithm, Demand side management, Demand response, Economic dispatch

Introductıon

The main aim of days’ electrical utility is to provide electrical power in a reliable way and in a possible low cost. Electrical Energy cannot be stored, but it can be generated form available sources be it conventional resources or Renewable energy sources [1]. The economic dispatch problem has been solved via many traditional optimization methods, including: Gradient-based techniques, Newton methods, linear programming, and quadratic programming. The greater part of these methods are not equipped for taking care of effectively advanced issues with a non-curved, nonstop and exceedingly non-straight arrangement [2]. These methods need to derivative about of the objective function, which give non acceptable results and require expansive computational time for non-linear complex problem. Direct programming experiences the constraint method as it requires piece wise linear cost approximation. Newton based methods struggle with handling large numbers of inequality constraints [2, 7].

The current electricity grid is gradually transforming, focusing on harnessing the potential management from the demand side with the support of widespread decentralized energy resources and active customer participation. To support this transformation, within the smart grid vision, intelligent agents will coordinate the production, transmission, and consumption of energy in a distributed and reliable way [3].

Conventional methods lack to solve this complex problem and may get struck to local minimum. Hence to search the global minimum intelligent techniques may be used. Recently various heuristic intelligent techniques such as Redefined Genetic Algorithm (RGA), Modulated Particle Swarm Optimization (MPSO), Gravitational Search Algorithm (GSA), Radial Basis Function (RBF) Flower Pollination Algorithm (FPA) and other alternative methods have been used to solve complex optimization problem [2 ,4].

The remaining paper is organized as motivation of the review, objectives of the review, Smart grid views and its elements which presents electricity networks are discussed Definition of economic dispatch problem and its general mathematical equations discussed. Energy sources, conventional and modern methods, reduction of different types of costs, energy managements, conclusions and recommendations for future works are including in different sections.

Motivation of the review

The review presented is inspired by the issue of continually increasing demand and price of electricity at the consumer end. For a better knowledge how we have to reduce the price by searching and knowing of economic dispatch problems for smart Technologies.

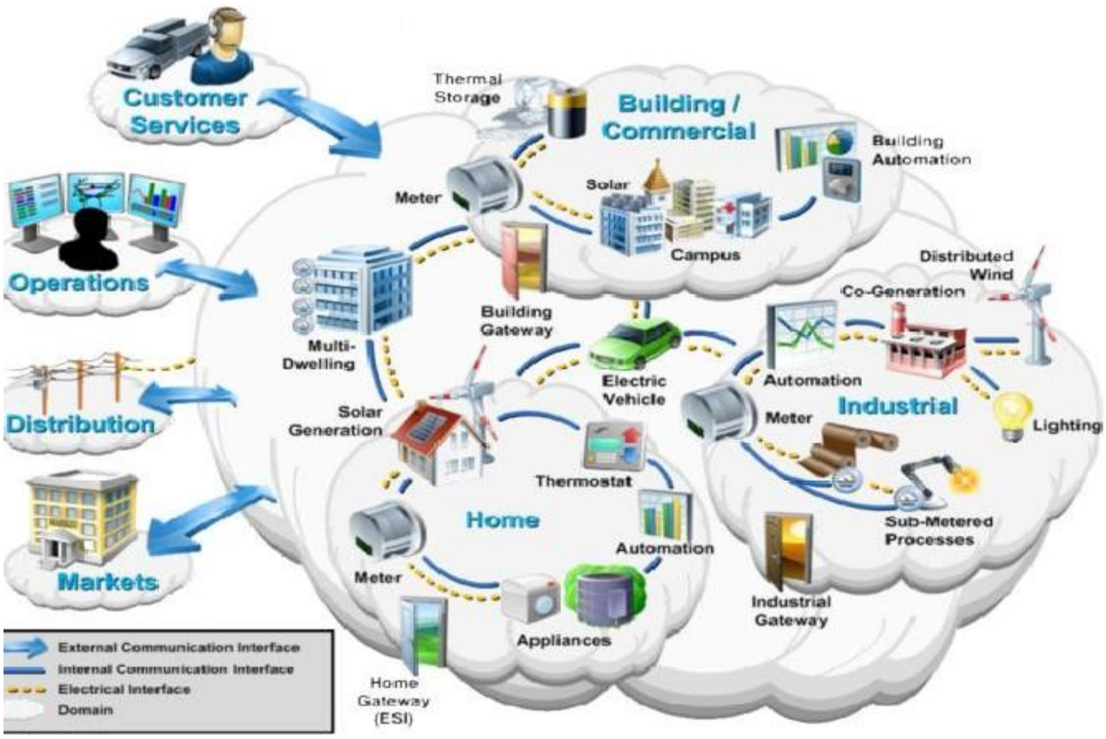

Figure 1: Overview of smart grid

Objective of the review

The objective of the review is to discuss in detail about the various smart grid components, their continuous development, technical challenges faced during their development, outcomes achieved and how can we reduce the price of electricity with related to smart grid and finally to find out the research scope in these areas.

Smart Grid View

The integration of electrical and information infrastructures, and the incorporation of automation and information technologies with our existing electrical network.
Comprehensive solutions that:

- Improve the utility's power reliability, operational performance and overall productivity
- Deliver increases in energy efficiencies and decreases in carbon emissions
- Empower consumers to manage their energy usage and save money without compromising their lifestyle
- Optimize renewable energy integration and enabling broader penetration

That deliver meaningful, measurable and sustainable benefits to the utility, the consumer, the economy and the environment [5,17].

Old Grid

- Utility pays whatever it takes to meet peak demand.
- Difficult to manage high Wind and Solar penetration
- Cannot manage distributed generation safely.
- ~10% power loss in Transmission & Distribution

Smart Grid

- Utility knows power is out and usually restoring it automatically.
- Utility suppresses demand at peak. Lowers cost.
- No problem with higher wind and solar penetration.
- Can manage distributed generation safely.
- Power Loss reduced by 2+%… lowers emissions & customer bills.

Elements of Today's Smart Grid

Table 1: Elements of smart grid

	Offerings	Customer Benefits	Future Enablers
	Grid Friendly Renewable s	● Controllability: Ramp, Curtail ● Reduce uncertainty forecast	● Stronger tie with utility Ems ● Coordination with DER and Load
	Grid control system	● Operating efficiency ● System reliability	● Ever green service ● Modular applications
	Substation Digitization	● Modular/standard ● Less cost, time, risk	● IEC 61850 compliant ● Open architecture
	Intelligent Electronics	● Performance monitoring ● Control devices	● Standards based ● IEC 61850 compliant
	Monitoring &Diagnostics	● Asset protection ● Life extension	● Progressive offering ● Long term services
	Communication s infrastructure	● Performance visibility ● Remote control	● Seamless NMS, security ● Multi-applications
	Smart Metering	● Customer billing ● Demand management	● Software upgradeable
	Smart Applications & home controls	● Participation in DR programs ● Utility bill savings	● Standards Based ● Software upgradeable

Definition of economic dispatch problem

Economic dispatch is the short-term determination of the optimal output of a number of electricity generation facilities, to meet the system load, at the lowest possible cost, subject to transmission and operational constraints [6].

General Mathematical modeling of smart grid economic dispatch

One of the fundamental problem in power system is economic dispatch problem. In this section, we explain the EDP with transmission losses and generator constraints in a smart grid [36].

The objective of the EDP is to minimize the total cost of power generation. A quadratic cost function of i-th generator is given as follows:

$$F(P_G) = a.{P_G}^2 + b.P_G + c \tag{1}$$

Where $P_G$the generator power output.

a,b and c –the coefficient of generation function. For the reduction of costs, we can use incremental cost is expressed is $/MWhr. It can be expressed as:

$$IC = \frac{d}{dt}F(P_G) \quad , IC = 2a.(P_G) + b \tag{2}$$

Consider a system with n generators committed

$$F_r = \sum_{i=1}^{m} C_i \, (P_{Gi}) \tag{3}$$

Where Ci is equal to Fi is cost function

Subjected to the satisfaction of the power flow equations and the following inequality constraints on the generator power, voltage magnitude and line power flow.

$$\begin{aligned} &1. {P_{Gi}}^{min} \leq P_{Gi} \leq {P_{Gi}}^{max} \\ &2. \left|{V_i}^{min}\right| \leq \left|{V_i}^{min}\right| \leq \left|{V_i}^{max}\right| \\ &3. \left|P_{ij}\right| \leq \left|{P_{ij}}^{max}\right| \text{ for all lines.} \end{aligned} \tag{4}$$

Transmission loss

The total transmission loss is a function of the generator power outputs, which can be represented using B coefficients as follows [16,27]:

$$P_L = \sum_{i=1}^{n}\sum_{i=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{0i} P_i + B_0 \tag{5}$$

Where, B_{ij}, B_{0i} and B_{00} are the transmission loss coefficients.

C. Economic dispatch without transmission losses

Let as assume that which generators are to run to meet a particular load demand are known as priority [36].Total fuel cost is given by:

$$F_T = \sum_{i=1}^{m} C_i(P_{Gi}) \tag{6}$$

Such that:

$$\sum_{i=1}^{m} P_{gi} = P_D = \sum_{i=1}^{n} P_{di} \tag{7}$$

Where, P_D is demand power.

Conventional and modern method ın Energy sources

Based on energy source some of author’s doing their paper for minimization of cost either conventional energy, renewable energy, electric vehicle or fuel as source shown in figure 2.

Table 2: Classification of energy sources

Energy sources	Conventional energy sources	[16][19][23][43][45]
	Electric vehicle and Energy storage system	[34][35][40]
	Renewable energy sources	[2][3][4][7][9][11][18][20][21][31][37][39][41][46]
	Fuel cell and others	[14][46]

Since centralized economic dispatch algorithm methods are Lagrangian Lambda iteration, quadratic equation and so on distributed one use artificial intelligent techniques like fussy logic particle swarm optimization and genetic algorithm [2, 3]. Economic dispatch problem solved by many traditional methods or by using conventional methods that are used in centralized algorithm it has difficulty on local minima [11].

The conventional methods or traditional methods

Newton Rapson method, well suited to different power flow problem. Its advantage is it has different application for different problem, for problem of any practical size efficient and robust solution can be obtained and for tuning and scaling factor in optimization process user requirement is not necessary. Also its disadvantage is there is small penalty near the limit, without employing sparest techniques it is difficult to develop optimal power flow program and it has limitation on convergence characteristics [14].

Linear programming methods, linear programming is very fast and totally reliable method since it's sufficient for most engineering purpose. Its advantage is non linearity problem can easily solved and it is suitable for real time and steady state mode purpose since it is very fast. But it has its own disadvantage it has difficulty on piecewise linear cost approximation and it suffers from lack of accuracy [11].

Quadratic programming methods, based on its approach it has higher accuracy than linear programming method. Its objective function is in quadratic form and constraint will be in linear form. The advantages of quadratic programming are appropriate to infeasible or divergent starting point, it can sole local flow or economic dispatch problem and it does not use penalty factor convergence is very fast. Also its disadvantage is in large dimension of approximating quadratic programming problem obtaining its solution is difficult and difficulty on piecewise cost approximation [11,19].
Interior point methods, is a solution for large scale linear programming problem. The advantage of this method is it has great maintenance accuracy, it is also the most efficient algorithm and due to its reliability, speed and accuracy its adopted method or optimal power flow [23].
Lagrange multiplier method, the extreme value of the objective function is obtained by multiplying the constraint function by an undetermined multiplier and is added to the objective function [16].

$$F = \sum_{i=1}^{m} C_i(P_{Gi}) + \lambda(P_D - \sum_{i=1}^{n}(P_i) \qquad (19)$$

Modern methods (distributive algorithm)

Genetic algorithm (GAs), general-purpose search techniques based on principles inspired from the genetic and evolution mechanisms observed in natural systems and populations of living beings [8]. Steps in genetic algorithm are as follows;

- Initialization: The initial population of candidate solutions is usually generated randomly across the search space

- Evaluation: Once the population is initialized or an offspring population is crated the fitness values of the candidate solutions are evaluated.
- Selection: Selection allocates more copies of those solutions with higher fitness values and thus imposes the survival of the fittest mechanism on the candidate solutions
- Recombination: Recombination combines parts of two or more parental solutions to new possible better solutions.
- Mutation: While recombination operates on two or more parental chromosomes, mutation locally but randomly modifies a solution.
- Replacement: The offspring population created by selection, recombination and mutation replaces the original parental population [8].

Advantage of genetic algorithm

- Can use in both Integer or discrete variables.
- It can globally optimum solution as it can avoid the trap of local optima.
- Deal with the non-smooth, non-continuous, non-convex and non-differentiable functions which actually exist in practical optimization problem
- It works on also on parallel computers

Disadvantage of genetic algorithm

- Have no guaranteed to be optimum for optimal power flow solution
- The execution time and the quality of the solution, deteriorate with the increase of the chromosome length,

Particle swarm optimization(PSO), based on the behavior of individuals (particles or ingredients) of a group. This technique refers to the zoology and the moving model of subjects within a group. It seems that the group members share data and this leads to the group's performance increase.

Steps in PSO algorithm

- Creating random initial population and particle initial velocity,
- Calculating the cost, sorting the cost, GP_{best} best and selecting,
- Updating the position and the velocity of particles,
- Correcting new particles positions to satisfy the problem constraints,
- Jumping to step 2 if the program ending criterion is not achieved,
- Applying the best values of the particles [19].

Radial Basis Function (RBF) Networks method alternative approach to Multi-Layer Perception (MLP) in universal function approximation. Their prospect is similar in neural network applications; the training and query target are continuous. The units (in the hidden layer) receiving the direct input from a signal may see only a portion of the input pattern, which is further used in inter constructing a surface in a multidimensional space that furnishes the best fit to the training data. This is th e special ability of the RBF network to recognize whether an input is near the training set or outside the trained region [23].

Advantage of radial basis function

- RBF trains faster than a MLP and that it produces better decision boundaries
- Hidden layer is easier to interpret than the hidden layer in an MLP

Neural network, applied widely for solving different problems which in general are difficult to solve by humans or conventional computation algorithms. In order to design a neural network for addressing the one-day load forecasting problem, several different training data and training time are studied.

Robust Optimization, problems containing uncertain data can also be handled by a special class of optimization technique called Robust Optimization (RO). The objective functions and constraints are modeled as uncertainty sets in this optimization framework. It does not assume a probability distribution for the input data set, but assumes that the data belong to an uncertainty set [37].

Energy managements

Energy managements also one of the method of reduction of cost of power systems. We can see also their work based on energy management

- Utility management: under utility management we are looking their work as load research, load shape objective, program implementation strategy, implementation, monitoring and e valuation [6][7][8][9][11][13][14][19][20][31][45].
- Generation planning and management: load forecasting, generation planning, generation costing, financial analysis, price allocation are included under this [5][23][27][28][36][38][43][4].
- Demand side management: demand response program, smart metering, distributed generation under this small scale renewable generation, battery energy storage system, electric vehicles, Distribution generation DG sets, fuel cells [4][15][16][18][24][30][32][34][35][37][39][40][41][46].
- Smart metering under this we are looking smart metering and monitoring and security and privacy [22].

The journals that we are referring is done with distributed algorithm techniques among the reference some author's compare the results of conventional techniques with modern one [36].

Conventional techniques

- Old or traditional methods
- Less cost
- Uses more time for responses
- It uses iterations, this lose more time

Modern methods

- New or distributive methods
- High cost
- Used for smart grid
- Uses simple algorithm

Conclusion

Economic Dispatch and the Unit Commitment are essential problems to be solved in order to supply high-quality electric power to customers in when working in a smart grid context some extra consideration must be taken into account. The high penetration of renewable energy sources, the large amount of energy that can be stored and different methods used in economic dispatch algorithm that are conventional and modern techniques, comparison between them these all are what we are going to show in our review. Customer's requirement for this time is quality power and minimum cost so for future work we recommend to work with stability since the most journals that we are used as reference was done to minimize cost only we should look for stability also looking for operation and maintenance cost as factor is also necessary.

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