Economic Load Dispatch Problem using PSO

Dr B Mouli Chandra,
Professor and HoD, Department of EEE, QIS College of Engineering and Technology, Ongole.
Dr B Venkata Prasanth,
Professor in EEE, QIS College of Engineering and Technology, Ongole
Dr.C.Chandru Vignesh,
School of Computer Science and Engineering, Vellore Institute of Technology, Vellore
Email :Chnadru.vignesh@vit.ac.in
Dr Ravindra Sangu,
Professor, EEE department, VVIT, Guntur INDIA
D. Prasad,
Department of EEE ,Ongole,India

Article Info
Page Number: 9998 – 10007
Publication Issue:
Vol 71 No. 4 (2022)

Abstract: — In this paper particle swarm optimization (PSO) is applied to allot the active power among the generating stations satisfying the system constraints and minimizing the cost of power generated. The modern power system around the world has grown in complexity of interconnection and power demand. The focus has shifted towards enhanced performance, increased customer focus, low cost, reliable and clean power. In this changed perspective, scarcity of energy resources, increasing power generation cost, environmental concern necessitates optimal economic dispatch. In reality power stations neither are at equal distances from load nor have similar fuel cost functions. Hence for providing cheaper power, load has to be distributed among various power stations in a way which results in lowest cost for generation. Practical economic dispatch (ED) problems have highly non-linear objective function with rigid equality and inequality constraints. The viability of the method is analyzed for its accuracy and rate of convergence. The economic load dispatch problem is solved for three and six unit system using PSO and conventional method for both cases of neglecting and including transmission losses. The results of PSO method were compared with conventional method and were found to be superior.

Article History
Article Received*: 15 September 2022*
Revised: *25 October 2022*
Accepted: *14 November 2022*
Publication: *21 December 2022*

Keywords: Practical economic dispatch (ED), particle swarm optimization (PSO), Generation fuel cost.

Introduction

The economic load dispatch (ELD) of power generating units has always occupied an important position in the electric power industry. ELD is a computational process where the total required generation is distributed among the generation units in operation, by minimizing the selected cost criterion, subject to load and operational constraints. For any specified load condition, ELD determines the power output of each plant (and each generating unit within the plant) which will minimize the overall cost of fuel needed to serve the system load [1]. ELD is used in real-time energy management power system control by most programs to allocate the total generation among the available units. ELD focuses upon coordinating the production cost at all power plants operating on the system.

In the traditional ELD problem, the cost function for each generator has been approximately represented by a single quadratic function and is solved using mathematical programming based optimization techniques such as lambda iteration method, gradient based method, etc [2]. These methods require incremental fuel cost curves which are piecewise linear and monotonically increasing to find the global optimal solution.

Dynamic programming (DP) method [3] is one of the approaches to solve the non-linear and discontinuous ELD problem, but it suffers from the problem of “curse of dimensionality” or local optimality. In order to overcome this problem, several alternative methods have been developed such as genetic algorithm [4], evolutionary programming [5, 6], tabu search [7], neural network [8], and particle swarm optimization [911].

Particle swarm optimization (PSO) is suggested by Kennedy and Eberhart based on the analogy of swarm of birds and school of fish [12]. PSO mimics the behavior of individuals in a swarm to maximize the survival of the species. In PSO, each individual makes his decision using his own experience together with other individuals‟ experiences. The algorithm, which is based on a metaphor of social interaction, searches a space by adjusting the trajectories of moving points in a multidimensional space. The individual particles are drawn stochastically toward the position of present velocity of each individual, their own previous best performance, and the best previous performance of their neighbors. The main advantages of the PSO algorithm are summarized as: simple concept, easy implementation, robustness to control parameters, and computational efficiency when compared with mathematical algorithms and other heuristic optimization techniques [12, 13]. PSO can be easily applied to nonlinear and non-continuous optimization problem.

In this paper, a PSO technique for solving the ELD problem in power system is proposed. The feasibility of the proposed method was demonstrated for a three units and six units system and the results were compared with quadratic programming method [14]. The results indicate the applicability of the proposed method to the practical ELD problem.

The rest of this paper is organized as follow. Section 2 present the ELD formulation. Section 3 presents quadratic programming method. Section 4 proposes PSO technique to solve ELD problem. Results and discussions are given in section 5, and section 6 gives some conclusions.

I. PROBLEM FORMULATION

The objective of the economic load dispatch problem is to minimize the total fuel cost.

$$\text{Min } C_T = \sum_{i=1}^{N} C(P_{Gi})$$

$$\text{Subject to } P_D + P_L = \sum_{i=1}^{N} C(P_{Gi})$$

II.I ELD **NEGLECTING LOSSES** [3]

LAMBDA-ITERATION METHOD:

This is a constrained optimization problem. To get the solution for the optimization problem, we will define an objective function by augmenting equation with an equality constraints equation through the lagrangian multiplier (λ).

$$L = C_T + \lambda\left(P_D - \sum_{i=1}^{N} C(P_{Gi})\right)$$

Where λ is the Lagrangian Multiplier.

Differentiating C with respect to the generation P_{Gi}

and equating to zero given the condition for optimal operation of the system.

$$\frac{dC_T}{dP_{Gi}} = \lambda$$

Therefore the condition for optimum operation is

$$\frac{dC_T}{dP_{Gi}} = \frac{dC_2}{dP_{G2}} = \frac{dC_3}{dP_{G3}} = \cdots = \frac{dC_n}{dP_{Gn}} = \lambda$$

II.II ELD WITH LOSS:[3]

The optimal load dispatch problem including transmission losses is defined as

$$\text{Min } C_T = \sum_{i=1}^{N} C(P_{Gi})$$

$$\text{Subject to } P_D + P_L = \sum_{i=1}^{N} C(P_{Gi})$$

Where P_L is the total system loss which is assumed to be a function of generation.
Making use of the Lagrangian multiplier λ, the auxiliary function is given by

$$L = C_T + \lambda\left(P_D + P_L - \sum_{i=1}^{N} C(P_{Gi})\right)$$

The partial differential of this expression when equated to zero gives the condition for optimal
Load dispatch, i.e.

$$\frac{dC_T}{dP_{Gi}} = \lambda(1 - \frac{dP_L}{dP_{Gi}})$$

Here the term $\frac{dP_L}{dP_{Gi}}$ is known as the incremental transmission loss at plant n and λ is known as the incremental cost of received power in Rs.per MWhr. The above equation is a set of n equations with (n+1) unknowns ie. 'n' generations are unknown and λ is unknown. These equations are also known as coordination equations because they coordinate the incremental transmission losses with the incremental cost of production.
To solve these equations the loss formula is expressed in terms of generations as

$$P_L = \sum_{m=1}^{k}\sum_{n=1}^{k} P_{Gm} B_{mn} P_{Gn}$$

Where P_{Gm} and P_{Gn} are the source loadings, Bmn the transmission loss coefficient.

$$\frac{dP_L}{dP_{G_i}} = \sum_{j=1}^{k} 2B_{ij}P_{Gj}$$

∴ The coordination equation can be rewritten as

$$\frac{dP_L}{dP_{G_i}} = \sum_{j=1}^{k} 2B_{ij}P_{Gj}$$

When transmission losses are included and coordinated, the following points must be
Kept in mind for economic load dispatch solution

1. Whereas incremental transmission cost of production of a plant is always positive, the Incremental transmission losses can be both positive and negative.
2. The individual generators will operate at different incremental costs of production.
3. The generation with highest positive incremental transmission loss will operate at the lowest incremental cost of production.

II. PARTICLE SWARM OPTIMIZATION

Most of the conventional computing algorithms are not effective in solving real-world problems because of having an inflexible structure mainly due to incomplete or noisy data and some multi-dimensional problems. Natural computing methods are best suited for solving such problems. In general Natural computing methods can be divided into three categories:

1) Epigenesis
2) Phylogeny
3) Ontogeny.

PSO belongs to the Ontogeny category in which the adaptation of a special organism to its environment is considered.

DESCRIPTION OF PSO:

Particle Swarm Optimization (PSO) is a biologically inspired computational search and optimization method developed by Eberhart and Kennedy in 1995 based on the social behaviours of birds flocking and fish schooling.

Particle (X): It is a candidate solution represented by an m-dimensional vector, where m is the number of optimized parameters. At time t, the i^{th} particle Xi(t) can be described as $X_i(t) = [X_{i1}(t), X_{i2}(t), \cdots X_{in}(t)]$. Where Xs are the optimized parameters and X ik (t) is the position of the i^{th} particle with respect to the k^{th} dimension; i.e. the value of the k^{th} optimized parameter in the i^{th} candidate solution.

Population, Pop (t): It is a set of n particle at time t, i.e.

$$Pop(t) = [X_1(t), X_2(t), \cdots X_n(t)]$$

Swarm: It is an apparently disorganized population of moving particles that tend to cluster together towards a common optimum while each particle seems to be moving in a random direction.

Personal best (Pbest): The personal best position associated with i^{th} particle is the best position that the particle has visited yielding the highest fitness value for that particle.

Global best (Gbest): The best position associated with i^{th} particle is the best position particle that any particle in the swarm has visited yielding the highest fitness value for that particle. This represents the best fitness of all the particles of a swarm at any point of time.

The optimization process uses a number of particles constituting a swarm that moves around a pre-defined search space looking for the best solution. Each particle is treated as a point in the D-dimensional space in which the particle adjusts its "flying" according to its own flying experience as well as the flying experience of other neighbouring particles of the swarm. Each particle keeps track of its coordinates in the pre-defined space which are associated with the best solution (fitness) that it has achieved so far. This value is called pbest. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the whole swarm. This value is called gbest. The concept consists of changing the velocity of each particle toward its pbest and the gbest position at the end of every iteration. Each particle tries to modify its current position and velocity according to the distance between its current position and pbest, and the distance between its current position and gbest.[6]

FORMULATION OF PSO:

PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called g-best. After finding the two best values, the particle updates its velocity and positions according to the following equations.[2]

$$v_i^{(u+1)} = w * v_i^{(u)} + C_1 * rand() * (pbest_i - p_i^{(u)}) + C_2 * rand() * (gbest_i - p_i^{(u)})$$

$$p_i^{(u+1)} = p_i^{(u)} + v_i^{(u+1)}$$

In the above equation, The term rand ( )* $(pbest_i - p_i^{(u)})$ is called particle mempry influence.

The term rand ( )* $(gbest_i - p_i^{(u)})$ is called swam influence.

In the above equation, C1 generally has a range (1.5,2) which is called as the self-confidence range and C2 generally has a range (2, 2.5) which is known as the swarm range. V velocity of the ith particle at iteration 'i' should lie in the pre-specified range (Vmin,Vmax). The parameter Vmax determines the resolution with which regions are to be searched between the present position and the target position. If Vmax is too high, particles may fly past good solutions. If Vmax is too small particles may not explore sufficiently beyond local solutions. Vmax is often set at 10-20% of the dynamic range on each dimension.

The constants C1 and C2 pull each particle towards pbest and gbest positions. Low values allow particles to roam far from the target regions before being tugged back. On the other hand, high values result in abrupt movement towards, or past, target regions. Hence the acceleration constants C1 and C2 are often set to be 2.0 according to past experiences.

The inertia constant can be either implemented as a fixed value or can be dynamically changing. This parameter controls the exploration of the search space. Suitable selection of inertia weight 'ω' provides a balance between global and local explorations, thus requiring less iteration on
average to find a sufficiently optimal solution. As originally developed, ω often decreases linearly from about 0.9 to 0.4 during a run. In general, the inertia weight *w* is set according to the following equation,

$$w = w_{max} - \left[\frac{w_{max} - w_{min}}{ITER_{max}}\right] * ITER$$

Where W -is the inertia weighting factor
Wmax- maximum value of weighting factor
Wmin - minimum value of weighting factor
ITER – Current iteration number
ITERmax-Maximum iteration number.

STEPS OF IMPLEMENTATION:

1. Initialize the Fitness Function ie. Total cost function from the individual cost function of the various generating stations.
2. Initialize the PSO parameters Population size, C1, C2, Wmax,Wmin,, error gradient etc.
3. Input the Fuel cost Functions, MW limits of the generating stations along with the B-coefficient matrix and the total power demand.
4. At the first step of the execution of the program a large no(equal to the population size) of vectors of active power satisfying the MW limits are randomly allocated.
5. For each vector of active power the value of the fitness function is calculated. All values obtained in an iteration are compared to obtain Pbest. At each iteration all values of the whole population till then are compared to obtain the Gbest. At each step these values are updated.
6. At each step error gradient is checked and the value of Gbest is plotted till it comes within the pre-specified range.
7. This final value of Gbest is the minimum cost and the active power vector represents the economic load dispatch solution

III. RESULT ANALYSIS

To verify the feasibility and effectiveness of the proposed PSO algorithm, two different power systems were tested one is three generating units [15] and other is six generating units [16, 17]. Results of proposed particle swarm optimization (PSO) are compared with quadratic programming methods. A reasonable B-loss coefficients matrix of power system network has been employed to calculate the transmission loss. The software has been written in the MATLAB-7 language.

Case Study-1: 3-units system

In this case, a simple power system consists of three-unit thermal power plant is used to demonstrate how the work of the proposed approach. Characteristics of thermal units are given in Table 1, the following coefficient matrixB_{ij} losses.

Table1: Generating unit capacity and coefficients

Unit	Pmax (MW)	Pmin (MW)	a ($/MW^2)	b ($/MW)	C (MW)
1	600	100	0.00156	7.92	561
2	400	100	0.00194	7.85	310
3	200	50	0.00482	7.97	78

$$B_{ij} = \begin{bmatrix} 0.75 & 0.05 & 0.075 \\ 0.05 & 0.15 & 0.10 \\ 0.075 & 0.10 & 0.45 \end{bmatrix} * 1e^{-4}$$

For the above system considering loads of 585MW, 700MW & 800MW, conventional Lagrange multiplier method is applied to obtain the economic load dispatch. Table 2 shows the economic load dispatch of the above mentioned loads neglecting the transmission line losses.

Table2: lambda iteration method neglecting losses for three unit system.

S.No	Load (MW)	P1 (MW)	P2 (MW)	P3 (MW)	Lambda	Total fuel cost (Rs/hr)
1	585	268.8938	234.2651	81.8411	8.758949	5821.44
2	700	322.9408	277.7256	99.335	8.927575	6838.41
3	800	369.9383	315.5174	114.5443	9.074207	7738.50

Table 3 shows the economic load dispatch result of the system including the transmission line losses. The transmission line losses are calculated with the help of the B-Coefficient matrix

S.No	Load (MW)	PLoss (MW)	Lambda	Total fuel cost (Rs/hr)
1	585	6.9574	8.998969	5886.94
2	700	10.02	9.225003	6934.79
3	800	13.1415	9.424247	7867.23

PARTICLE SWARM OPTIMIZATION METHOD:

PSO was applied to the above system for obtaining economic load dispatch of similar load requirements. PSO was implemented according to the flow chart shown. For each sample load, under the same objective function and individual definition, 20 trials were performed to observe the evolutionary process and to compare their solution quality, convergence characteristic and computation efficiency. [7]

PSO METHOD PARAMETERS:

POPULATION SIZE: 100
MAXIMUM NO OF ITERATION: 100000
INERTIA WEIGHT FACTOR (w): Wmax=0.9 & Wmin=0.4
ACCELERATION CONSTANT: C1=2 & C2=2
ERROR GRADIENT: 1e-06

Table 4: Comparison of results between Conventional method and PSO method for three unit system (Loss Neglected Case).

S.No	Load (MW)	Lamda method (Rs/hr)	PSO method (Rs/hr)
1	585	5821.44	5821.439522
2	700	6838.41	6838.404351
3	800	7738.50	7738.494671

Table 5: Comparison of results between Conventional method and PSO method for three unit system (Loss included Case).

S.No	Load (MW)	Lamda method (Rs/hr)	PSO method (Rs/hr)
1	585	5886.94	5886.911604
2	700	6934.79	6934.78119
3	800	7867.23	7867.202213

Case Study-2: 6-units system

Characteristics of thermal units are given in Table 6, the following coefficient matrixB_{ij} losses.

Table6: Generating unit capacity and coefficients

Unit	Pmax (MW)	Pmin (MW)	a ($/MW^2)	b ($/MW)	C (MW)
1	125	10	0.15240	38.53973	756.79886
2	150	10	0.10587	46.15916	451.32513
3	225	35	0.02803	40.39655	1049.9977
4	210	35	0.0354	38.30553	1243.5311
5	325	130	0.02111	36.32782	1658.5596
6	315	125	0.01799	38.27041	1356.6592

$$B_{ij} = \begin{bmatrix} 0.000140 & 0.000017 & 0.000015 & 0.000019 & 0.000026 & 0.000022 \\ 0.000017 & 0.000060 & 0.000013 & 0.000016 & 0.000015 & 0.000020 \\ 0.000015 & 0.000013 & 0.000065 & 0.000017 & 0.000024 & 0.000019 \\ 0.000019 & 0.000016 & 0.000017 & 0.000071 & 0.000030 & 0.000025 \\ 0.000026 & 0.000015 & 0.000024 & 0.000030 & 0.000069 & 0.000032 \\ 0.000022 & 0.000020 & 0.000019 & 0.000025 & 0.000032 & 0.000085 \end{bmatrix}$$

For the above system considering loads of 585MW, 700MW & 800MW conventional Lagrange multiplier method is applied to obtain the economic load dispatch. Table 2 shows the economic load dispatch of the above mentioned loads neglecting the transmission line losses.

Table 7: Comparison of results between Conventional method and PSO method for Six-unit system (Loss Neglected Case).

S.No	Load (MW)	Lambda method(Rs/hr)	PSO method(Rs/hr)
1	800	40675.97	40675.9682
2	900	45464.08	45464.08097
3	1000	50363.69	50363.69128

Table 8: Comparison of results between Classical Method and PSO method of a Six- unit system (Loss included Case).

S.No	Load (MW)	Lambda method(Rs/hr)	PSO method(Rs/hr)
1	800	41896.63	41896.62871
2	900	47045.16	47045.15634
3	1000	57871.60	57870.36512

IV. CONCLUSIONS

In this paper, PSO method was employed to solve the ELD problem for two cases one three unit system and another six unit system. The PSO algorithm showed superior features including high quality solution, stable convergence characteristics. The solution was close to that of the conventional method but tends to give better solution in case of higher order systems. The comparison of results for the test cases of three unit and six unit system clearly shows that the proposed method is indeed capable of obtaining higher quality solution efficiently for higher degree ELD problems. The convergence characteristic of the proposed algorithm for the three unit system and six unit system is plotted. The convergence tends to be improving as the system complexity increases. Thus solution for higher order systems can be obtained in much less time duration than the conventional method. The reliability of the proposed algorithm for different runs of the program is pretty good, which shows that irrespective of the run of the program it is capable of obtaining same result for the problem. Many non-linear characteristics of the generators can be handled efficiently by the method.

REFERENCES

[1] Saadat, H. (2010). Power system Analysis. Tata Mcgraw hill.

[2] Swarup K.S. , Rohit Kumar P., “A new evolutionary computation technique for economic dispatch with security constraints” ;Electrical Power and Energy Systems 28 (2006) pp 273–283

[3] Wadhwa, C.L (2009). Electrical Power System. New Age publishers.

[4] Zhu Jizhong (IEEE) 2008, OPTIMIZATION OF POWER SYSTEM OPERATION.

[5] Sudhakaran M., D - Vimal Raj P. Ajay and Palanivelu T.G, “Application of Particle Swarm Optimization for Economic Load Dispatch Problems” The 14th International Conference on Intelligent System Applications to Power Systems, ISAP 2007.

[6] Lee K.Y. and Park J., Application of particle swarm optimization to economic dispatch problem: Advantages and disadvantages, in Proc IEEE PES Power Syst. Conf. Expo. Oct 2006, pp 188-192

[7] Birge, B.,” PSOt, A Particle Swarm Optimization Toolbox for Matlab”, IEEE Swarm Intelligence Symposium Proceedings, April 24-26,2003.

[8] Gaing Zwe-Lee, “Particle Swarm Optimization to solving the Economic Dispatch Considering the Generator Constraints”, IEEE Trans. On Power Systems, Vol.18, No.3, pp. 1187-1195, August 2003.

[9] D. N. Jeyakumar, T. Jayabarathi, and T. Raghunathan, “Particle swarm optimization for various types of economic dispatch problems,” Int. J. Elect. Power Energy Syst., vol. 28, no. 1, pp. 36–42, 2006.

[10] Park, J.-B., Lee K.-S, Shin J.-R, and Lee K. Y, “A Particle Swarm Optimization for Economic Dispatch with Non-Smooth Cost Functions,” IEEE Transactions on Power Systems, Vol. 20, No. 1, pp. 34-42, February 2005.

[11] R. C. Eberhart and Y. Shi, “Comparing inertia weights and constriction factors in particle swarm optimization,” in Proc. Congr.Evolutionary Computation, 2000, vol. 1, pp. 84–88.

[12] A. Jiang and S. Ertem, “Economic dispatch with non-monotonically increasing incremental cost units and transmission system losses”,IEEE Transactions on Power Systems, vol. 10, no. 2, pp. 891-897, May 1995.

[13] Tabassum, Saleha, and B. Mouli Chandra. "Power Quality improvement by UPQC using ANN Controller." *International Journal of Engineering Research and Applications* 2.4 (2012): 2019-2024.

[14] Chandra, B. Mouli, and Dr S. Tara Kalyani. "FPGA controlled stator resistance estimation in IVC of IM using FLC." *Global Journal of Researches in Engineering Electrical and Electronics Engineering* 13.13 (2013).

[15] Chandra, B. Mouli, and S. Tara Kalyani. "Online identification and adaptation of rotor resistance in feedforward vector controlled induction motor drive." *Power Electronics (IICPE), 2012 IEEE 5th India International Conference on*. IEEE, 2012.

[16] Chandra, B. Mouli, and S. Tara Kalyani. "Online estimation of Stator resistance in vector control of Induction motor drive." *Power India Conference, 2012 IEEE Fifth*. IEEE, 2012.

[17] MURALI, S., and B. MOULI CHANDRA. "THREE PHASE 11-LEVEL INVERTER WITH REDUCED NUMBER OF SWITCHES FOR GRID CONNECTED PV SYSTEMS USING VARIOUS PWM TECHNIQUES."

[18] BABU, GANDI SUNIL, and B. MOULI CHANDRA. "POWER QUALITY IMPROVEMENT WITH NINE LEVEL MULTILEVEL INVERTER FOR SINGLE PHASE GRID CONNECTED SYSTEM."

[19] NAVEENKUMAR, K., and B. MOULI CHANDRA. "Performance Evaluation of HVDC Transmission system with the Combination of VSC and H-Bridge cells." *Performance Evaluation* 3.02 (2016).

[20] Vijayalakshmi, R., G. Naga Mahesh, and B. Mouli Chandra. "Seven Level Shunt Active Power Filter for Induction Motor Drive System." *International Journal of Research* 2.12 (2015): 578-583.

[21] BAI, RM DEEPTHI, and B. MOULI CHANDRA. "Speed Sensorless Control Scheme of Induction Motor against Rotor Resistance Variation." (2013).
[22] Chandra, B. Mouli, and S. Tara Kalyani. "Online Rotor Time Constant Tuning in Indirect Vector Control of Induction Motor Drive." *International Journal on Engineering Applications (IREA)* 1.1 (2013): 10-15.
[23] Rajesh, P., Shajin, F. H., Mouli Chandra, B., & Kommula, B. N. (2021). Diminishing Energy Consumption Cost and Optimal Energy Management of Photovoltaic Aided Electric Vehicle (PV-EV) By GFO-VITG Approach. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 1-19.
[24] Reddy C, Narukullapati BK, Uma Maheswara Rao M, Ravindra S, Venkatesh PM, Kumar A, Ch T, Chandra BM, Berhanu AA. Nonisolated DC to DC Converters for High-Voltage Gain Applications Using the MPPT Approach. Mathematical Problems in Engineering. 2022 Aug 22;2022.
[25] Sravani, B., C. Moulika, and M. Prudhvi. "Touchless door bell for post-covid." *South Asian Journal of Engineering and Technology* 12.2 (2022): 54-56.
[26] Mounika, P., V. Rani, and P. Sushma. "Embedded solar tracking system using arduino." *South Asian Journal of Engineering and Technology* 12.2 (2022): 1-4.
[27] Prakash, A., Srikanth, T., Moulichandra, B., & Krishnakumar, R. (2022, February). Search and Rescue Optimization to solve Economic Emission Dispatch. In *2022 First International Conference on Electrical, Electronics, Information and Communication Technologies (ICEEICT)* (pp. 1-5). IEEE.
[28] Kannan, A. S., Srikanth Thummala, and B. Mouli Chandra. "Cost Optimization Of Micro-Grid Of Renewable Energy Resources Connected With And Without Utility Grid." *Materials Today: Proceedings* (2021).
[29] Chandra, B. M., Sonia, D., Roopa Devi, A., Yamini Saraswathi, C., Mighty Rathan, K., & Bharghavi, K. (2021). Recognition of vehicle number plate using Matlab. *J. Univ. Shanghai Sci. Technol*, *23*(2), 363-370.
[30] Noushin, S. K., and Daka Prasad2 Dr B. Mouli Chandra. "A Hybrid AC/DC Micro grid for Improving the Grid current and Capacitor Voltage Balancing by Three-Phase AC Current and DC Rail Voltage Balancing Method."
[31] Deepika, M., Kavitha, M., Chakravarthy, N. K., Rao, J. S., Reddy, D. M., & Chandra, B. M. (2021, January). A Critical Study on Campus Energy Monitoring System and Role of IoT. In *2021 International Conference on Sustainable Energy and Future Electric Transportation (SEFET)* (pp. 1-6). IEEE.
[32] ANITHA, CH, and B. MOULI CHANDRA. "A SINGLE-PHASE GRID-CONNECTED PHOTOVOLTAIC INVERTER BASED ON A THREE-SWITCH THREE-PORT FLYBACK WITH SERIES POWER DECOUPLING CIRCUIT."
[33] Sai, V. N. V., Kumar, V. B. C., Kumar, P. A., Pranav, I. S., Venkatesh, R., Srinivasulu, T. S., ... & Chandra, B. M. Performance Analysis of a DC Grid-Based Wind Power Generation System in a Microgrid.
[34] Prakash, A., R. Anand, and B. Mouli Chandra. "Forward Search Approach using Power Search Algorithm (FSA-PSA) to solve Dynamic Economic Load Dispatch problems." *2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS)*. IEEE, 2019.
[35] Balasamy, K., Krishnaraj, N. & Vijayalakshmi, K. Improving the security of medical image through neuro-fuzzy based ROI selection for reliable transmission. *Multimed Tools Appl* **81**, 14321–14337 (2022). https://doi.org/10.1007/s11042-022-12367-4
[36] M. Jeyaselvi, C. Jayakumar, M. Sathya, S. J. A. Ibrahim and N. S. Kalyan Chakravarthy, "Cyber security-based Multikey Management System in Cloud Environment," 2022 International Conference

on Engineering and Emerging Technologies (ICEET), Kuala Lumpur, Malaysia, 2022, pp. 1-6, doi:10.1109/ICEET56468.2022.10007104, https://ieeexplore.ieee.org/abstract/document/10007104

[37] S. Jafar Ali Ibrahim et al., "Rough set based on least dissimilarity normalized index for handling uncertainty during E-learners learning pattern recognition", International Journal of Intelligent Networks, Volume 3, 2022, Pages 133-137, ISSN 2666-6030, https://doi.org/10.1016/j.ijin.2022.09.001.(https://www.sciencedirect.com/science/article/pii/S2666603022000148)

[38] Ibrahim,S. Jafar Ali, Rajasekar S. Chakravarthy N. S. Kalyan, Varsha, Singh Maninder Pal , Kumar Vaneet and Saruchi Synthesis, Characterization of Ag/Tio2 Nanocomposite: Its Anticancer and Anti-Bacterial and Activities, Global Nest, Volume 24, Issue 2, June 2022, Pages:262-266, Issn No: 1790-7632, DOI: https://doi.org/10.30955/gnj.0042505

[39] Linjiang Xie, Feilu Hang, Wei Guo, Yao Lv, Wei Ou, and C. Chandru Vignesh "Machine learning-based security active defence model - security active defence technology in the communication network "International Journal of Internet Protocol Technology 2022 15:3-4, 169-181 https://doi.org/10.1504/IJIPT.2022.125955

[40] KexuWu, Chaolin Li, Chandru Vignesh C, Alfred Daniel J "Digital teaching in the context of Chinese universities and their impact on students for Ubiquitous Applications" Computers and Electrical Engineering, Volume 100, May 2022, 107951, https://doi.org/10.1016/j.compeleceng.2022.107951

[41] Huiyi Zang, C Chandru Vignesh and J Alfred Daniel "Influence of Social and Environmental Responsibility in Energy Efficiency Management for Smart City"Journal of Interconnection Networks, Vol. 22, No. Supp01, 2141002 (2022), https://doi.org/10.1142/S0219265921410024.

[42] R Menaha, VE Jayanthi, N Krishnaraj," A Cluster-based Approach for Finding Domain wise Experts in Community Question Answering System", Journal of Physics: Conference Series, Volume: 1767, IOP Publishing, 2021. DOI 10.1088/1742-6596/1767/1/012035.

[43] J Ramprasath, M Aswin Yegappan, Dinesh Ravi, N Balakrishnan and S Kaarthi, Assigning Static Ip Using DHCP In Accordance With MAC, INTERNATIONAL JOURNAL FOR TRENDS IN ENGINEERING & TECHNOLOGY, Vol 20, Issue 1, 2017.

[44] J Ramprasath, Dr S Ramakrishnan, P Saravana Perumal, M Sivaprakasam, U Manokaran Vishnuraj, Secure network implementation using VLAN and ACL, International Journal of Advanced Engineering Research and Science, Vol 3, Issue 1, PP. 2349-6495, 2016

[45] J Ramprasath, V Seethalakshmi, Secure access of resources in software-defined networks using dynamic access control list, International Journal of Communication Systems, Vol 34, Issue 1, PP. e4607, 2020.

[46] Balasamy, K., Krishnaraj, N. & Vijayalakshmi, K. An Adaptive Neuro-Fuzzy Based Region Selection and Authenticating Medical Image Through Watermarking for Secure Communication. Wireless Pers Commun 122, 2817–2837 (2022). https://doi.org/10.1007/s11277-021-09031-9