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Comparative Analysis of Optimal Generation Scheduling in Modern Power Systems Considering Renewable Energy Resources

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Abstract-Majority of electrical power systems are aiming to reduce their dependencies towards fossil fuels in the face of growing concerns for environment, increasing fuel price, energy conservation, and sustainable development. As a result, there has been steady increase in renewable power generation in power systems all over the world and expected to grow further in future. Renewable energy sources (RES) have grown considerably in the last decade.
However, there are still some serious concerns about RES technologies and their implementation into the exiting energy production and distribution systems. The main issue is the intermittent nature of many RES. In particular, wind and solar power plants cannot produce power steadily since wind speed and solar radiation change during the day and the year.The aim of electric supply utility has been identified as to provide the smooth and adequate electric energy to the consumers without any disturbances. Here, one thing should be ensured that electrical power is generated with minimum generation cost. Hence in order to achieve an economic operation, the total demand must be appropriately shared among the all generating units. This research work aims to solve Economic load dispatch Using POWER WORLD AND MAT POWER SIMULATOR Software.This minimize the total generation cost for the system with satisfied all equality and inequality constraints**.**
Keywords-RES, SO, PV, Wind, PSO, ELD, OPF, etc.

I. Introduction

Majority of electrical power systems are aiming to reduce their dependencies towards fossil fuels in the face of growing concerns for environment, increasing fuel price, energy conservation, and sustainable development. As a result, there has been steady increase in renewable power generation in power systems all over the world and expected to grow further in future. Renewable energy sources (RES) have grown considerably in the last decade. However, there are still some serious concerns about RES technologies and their implementation into the exiting energy production and distribution systems.Several operating strategies based on energy, economic or environmental criteria can be adopted to meet the required power demand, which varies over the day and over the year. However, among the others, it is preferable to use an optimum or suboptimum operating strategy based on economic criteria. In other words, an important goal of the energy management strategy is to meet the power demand at minimum operating costs. In order to supply high-quality electric power to customers in a secure and economic manner, an optimization process for rescheduling of the different RES should be adopted.

The operational costs of electrical power system increases, because the system operators are need to secure additional/extra operating flexibility on several time scales to balance the fluctuations and uncertainties in wind/solar PV power output. Therefore, the presence of any renewable source of power, increases balancing requirement and associated costs. Because of wind and solar variability, there has been wide spread interest in determining the increase in ancillary services needed to integrate wind and solar over various time scales.Economic load dispatch is one of the challenging non-convex optimization problems in power system, which is difficult to solve using the conventional methods. The real world input-output characteristics of the generating units are highly non-linear, non-smooth and discontinuous due to valve-point loading effect, prohibited zones, and generating ramp-rate limits.With large interconnection of the electricity networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running costs of electric energy. The main aim of modern electric power utilities is to provide high-quality reliable power supply to the consumers at the lowest possible cost while maintaining all the constraints. ELD is the method of determining the most efficient, low-cost and reliable operation of a power system by dispatching the available generation to supply the load.The main outcomes of restructuring the power system are maximum exploitation of energy resources and flexibility without compromising system security.Optimal power flow (OPF) remains a widely-cultivated topic within power system research community since its inception about half-a-century ago. The prime objective of OPF is minimization of generation cost with optimal settings of control variables which are the generated real power and generator bus voltages of the network. While optimizing the generation cost, system constraints on generator capability, line capacity, bus voltage and power flow balance are to be satisfied.

Economic load dispatch:

Economic load dispatch is one of the challenging non-convex optimization problems in power system, which is difficult to solve using the conventional methods. The real world input-output characteristics of the generating units are highly non-linear, non-smooth and discontinuous due to valve-point loading effect, prohibited zones, and generating ramp-rate limits. With large interconnection of the electricity networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running costs of electric energy. The main aim of modern electric power utilities is to provide high-quality reliable power supply to the consumers at the lowest possible cost while maintaining all the constraints. ELD is the method of determining the most efficient, low-cost and reliable operation of a power system by dispatching the available generation to supply the load.

In Static ELD Problem, minimize the total generation cost in a single time interval (constant load).But in actual power system, with change in load demand,➢ the generation has to be altered to meet the load demand. Hence, static ELD incorporates some difficulties in the system. To avoid this problem, dynamic ELD is implemented. In dynamic ELD, 24➢ connected series static ELD must be solved, covering supply and load demand over a24-hour intervals. In dynamic ELD, costs changing from one generation level to the other generation level. Conventional methods like lambda iteration method, linear programming, non-linear programming, quadratic programming, base point participation factor method, gradient descent technique, equal embedded algorithm and Newton-Raphson method can solve this ELD problems if the cost curves of the generator are piece-wise linear. Practically the input-output characteristics of the generator are highly non-linear and non-convex due to valve-point loading effect, prohibited operating zones, generator ramp rate limits. Thus the resultant ELD becomes a non-convex/non-smooth optimization problem, which is difficult to solve using this type conventional methods. Methods like fuzzy logic, ANN, GA, evolutionary technique, and particle swarm optimization (PSO) can solve non-convex optimization problems efficiently and achieve a fast and near global optimal solution. Among all, PSO was developed through simulation of a simplified social system, and has been found to be robust. The PSO can generate high-quality solutions within shorter computational time and stable convergence characteristics.The objective of ELD is to minimize the total active power generation cost including fuel cost, emission cost, maintenance cost, network losses cost by meeting the following constraints:

- Real power balance
- Network security constraints (maximum MW power flows of transmission lines)
- Downward-and-upward generator ramp-rate limits
- Lower and upper generation limits of each generating unit
- Prohibited operating zones Emission rate (SO_2, CO_2, NO_x)

II. WORK OBJECTIVES

Objectives: To minimize the total active power generation cost of units while satisfying all constraints.

Objective functions:

1. Quadratic (convex) cost function,
2. Valve point loading effect (non-convex).
3. Emission rate.

Constraints:

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1. Real Power balance
2. Generator output limit
3. Generator Ramp-rate limits
4. Prohibited operating zone

- Including transmission line losses minimization.

a. **Simple Economic Load dispatch : Generator Operating Cost Of Thermal Power Plant :**

The fuel cost is meaningful in case of thermal and nuclear stations. The factor influencing power generation at minimum cost are operating efficiency of generator, fuel cost and transmission losses.

Hence the problem is to be determining the generation of different plants such that total operating cost is minimum.

An analytical expression for operating cost can be written as,

$$F(P_{gi}) = a_i P_{gi}^{\ 2} + b_i P_{gi} + c_i \qquad Rs/h$$

……………… (1)

Where,

ai,bi,ci are cost co-efficient for ith plant.

F(Pgi) is the total cost of generation.

Pgi is the generation of ith plant.

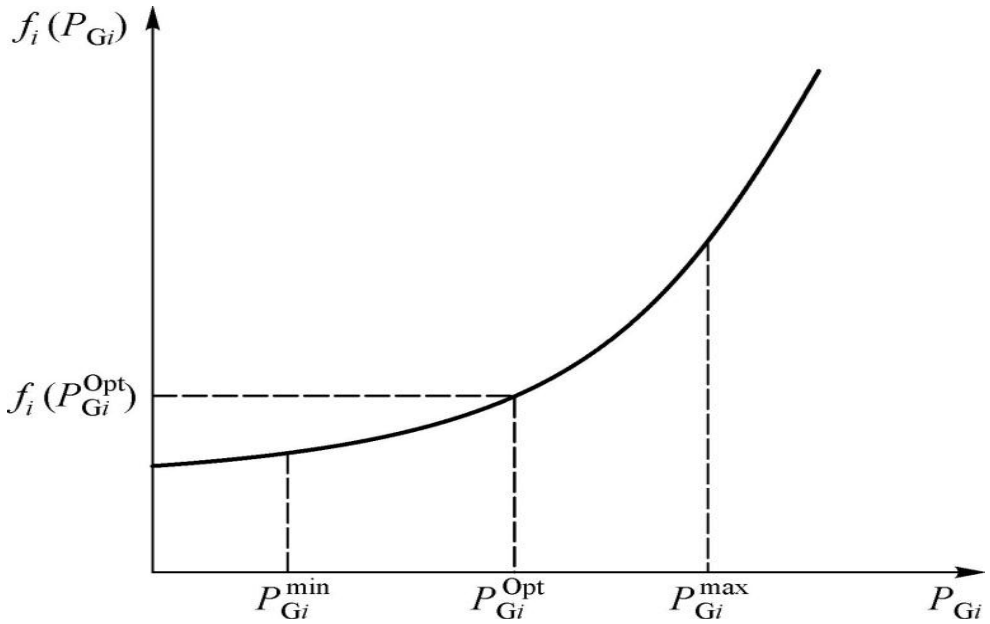

Fig.1 – operating cost of the fossil fired generator

Pgi^{min} and Pgimax are the lower and upper limits on its output.

The Pgi^{min} is the minimum loading limit below which it is uneconomical to operate the unit and Pgimax is the maximum output limit.

Thus, in competitive electricity market, ELD helps in saving a significant amount of revenue and to improve social welfare.

Problem Formulation:

The objective function is:

$$\min F(P_{g_i}) = \sum_{i=1}^{NG} a_i P_{g_i}^{\ 2} + b_i P_{g_i} + c_i$$

……………………………… (2)

Subject to,

1. Equality constraints (energy balance equation),

$$\sum_{i=1}^{NG} P_{g_i} = P_D + P_L$$

……………………………………… (3)

2. Inequality constraints,

$$P_{g_i}^{min} \le P_{g_i} \le P_{g_i}^{max}$$

……………………………………………… (4)

Where,

P_D is the load demand.

P_L is the transmission power loss.

NG is the number of generator units.

Methods to solve economic load dispatch:

There are mainly two types of methods to solve economic load dispatch.

1. Conventional methods.
2. Soft-computing techniques.

1. Conventional methods:

1. Non-linear programming.
2. Linear programming.
3. Quadratic programming.
4. Generalized reduced gradient method.
5. Newton Raphson method.
6. Mixed-integer programming.
7. Interior point methods.
8. Lambda iteration method.
9. Gradient descent method.
10. Lagrange relaxation algorithm.

2. Soft-computing techniques:

1. Artificial neural network (ANN).
2. Evolutionary algorithms.
3. Tabu search (TS).
4. Genetic algorithms (GA).
5. Differential evolution.
6. Particle swarm optimization (PSO).
7. Cuckoo search algorithms.
8. Firefly algorithms.
9. Ant colony search algorithm.
10. Fuzzy logic.
11. Simulated annealing.

III. Simulation Implementation Using Power World

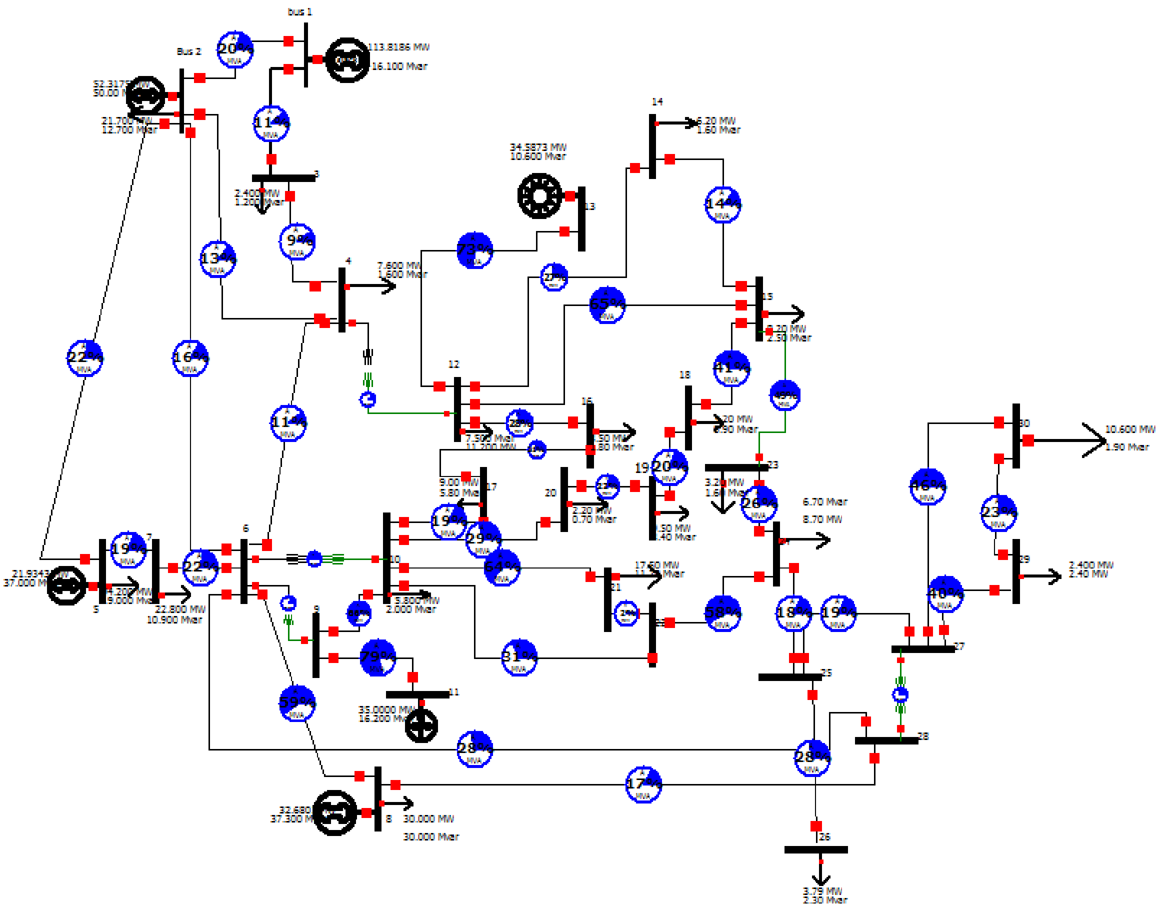

Fig.2- Power World Simulator for IEEE 30-bus systemOPF Load case with RE

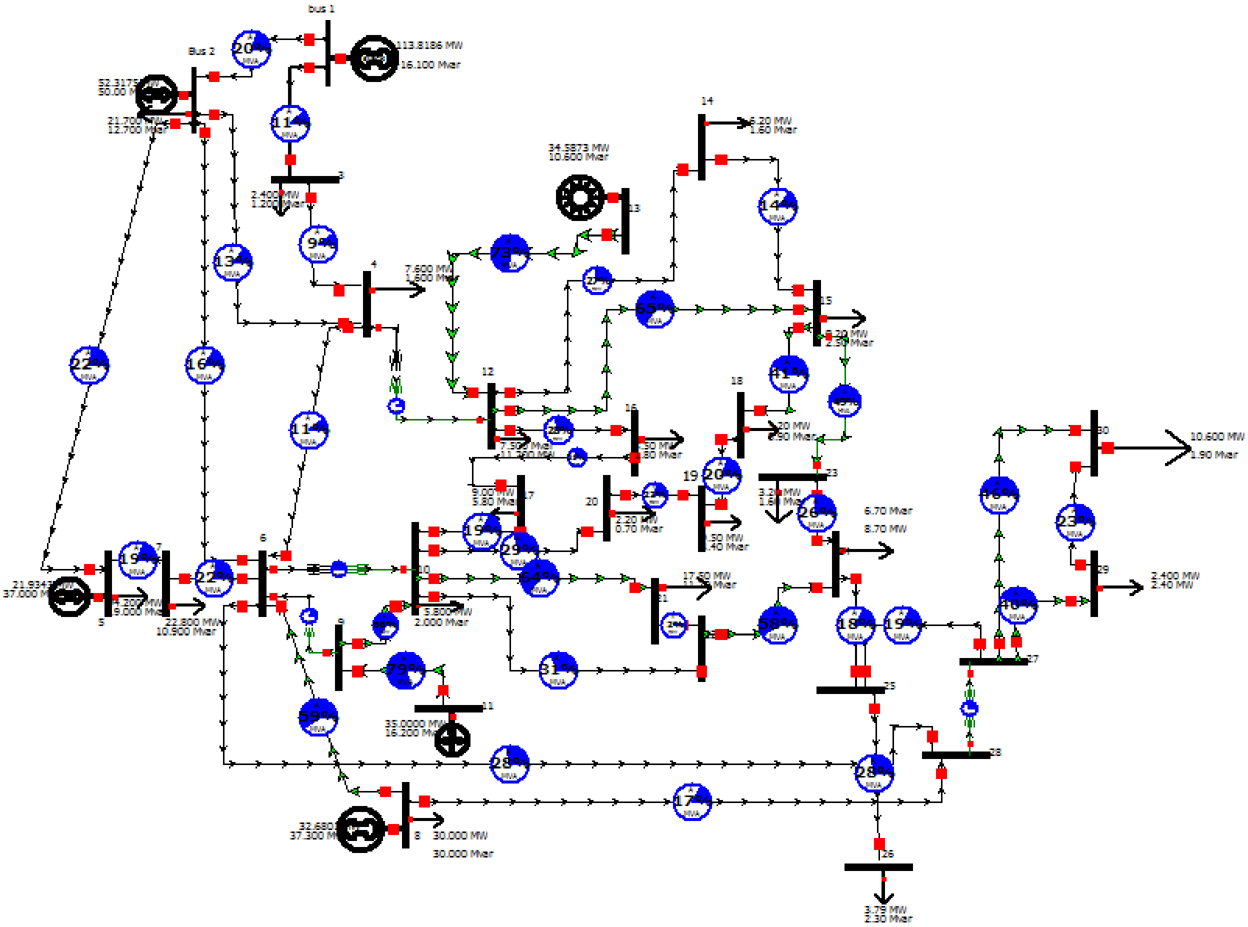

Fig.3- MI Power World Simulator for IEEE 30-bus systemOPF with REfor 283.69MW Load

Table-1OPF Result by POWER WORLD

Total Generation	290.34MW
Total Loss	2.73
Total Load	283.69MW
Constraints	Generator MW limits, Line MVA limit
Model	Cubic cost model

Table-2OPF Line Flow Result

Line No	Line Flow	Line No	Line Flow	Line No	Line Flow
Bus 1-2	24.1	Bus 4-12	3.9	Bus 21-22	-0.3
Bus 1-3	14.8	Bus 12-13	-43.5	Bus 15-23	6.8
Bus 2-4	8.5	Bus12-14	-8.3	Bus 22-24	8.2
Bus 3-4	12.3	Bus 12-15	19.6	Bus 23-24	3.5
Bus 2-5	27.1	Bus 12-16	8.2	Bus 24-25	-2.9
Bus 2-6	10.6	Bus 14-15	-2.0	Bus 25-26	3.9
Bus 4-6	9.3	Bus 16-17	-4.6	Bus 25-27	-1.0

Bus 5-7	-5.9	Bus15-18	-6.3	Bus 28-27	-14.4
Bus 6-7	-28.8	Bus 18-19	-3.0	Bus 27-29	1.7
Bus 6-8	-13.0	Bus19-20	6.4	Bus 27-30	7.1
Bus 6-9	-9.9	Bus 10-20	8.7	Bus 29-30	-3.7
Bus 6-10	4.6	Bus 10-17	4.4	Bus 8-28	5.5
Bus 9-11	-50.1	Bus 10-21	17.3	Bus 6-28	8.9
Bus 9-10	40.2	Bus 10-22	8.6		

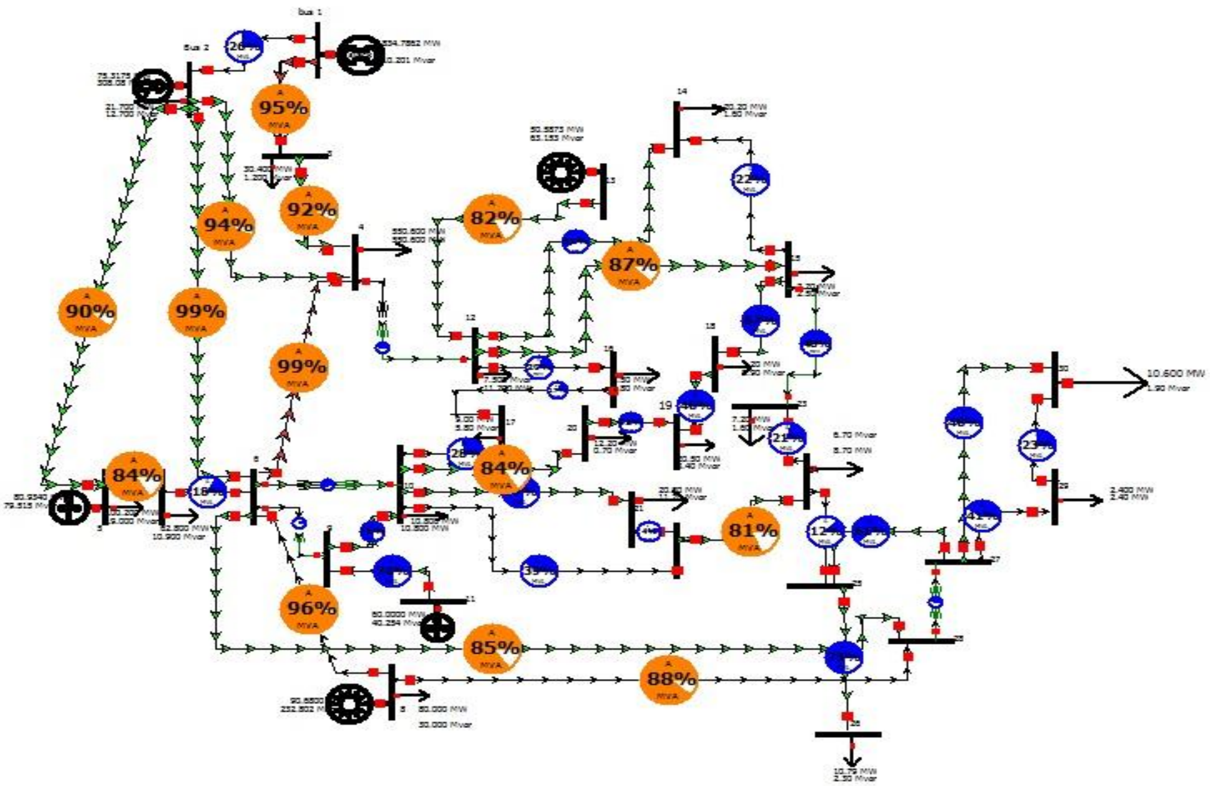

Fig.4-MI Power World Simulator for IEEE 30-bus system OPF with RE for 1003MW Load

Table-3 OPF Result by POWER WORLD

Objective function	Minimum Cost of Generation
Total Generation	1192.31MW
Total load	1003.69 MW
Total cost	64412.82₹/hr
Total loss	188.62MW
Constraints	Generator MW limits, Line MVA limit
Model	Cubic cost model

Iv.Simulation Results Of 9 Bus System With Matpower

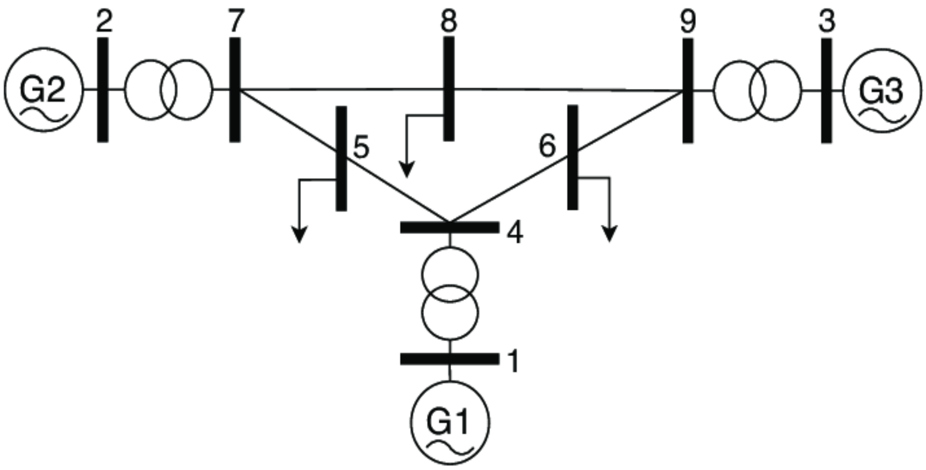

Fig.5- MAT POWER IEEE Standard 9 Bus System

Table-4MAT POWER 9 Bus System Data

Bus No	Bus Type	Bus Voltage	Active Load	Reactive Load
Bus 1	Slack Bus	16.5	0	0
Bus 2	PV Bus	18	0	0
Bus 3	PV Bus	13.8	0	0
Bus 4	PQ Bus	230	0	0
Bus 5	PQ Bus	230	125	50
Bus 6	PQ Bus	230	90	30
Bus 7	PQ Bus	230	0	0
Bus 8	PQ Bus	230	100	35
Bus 9	PQ Bus	230	0	0

Table-5Line Data of 9 Bus System

Line From	Line To	R (pu)	X (pu)	B (pu)
1	4	0	0.0576	0
4	5	0.01	0.085	0.176
4	6	0.017	0.092	0.158
6	9	0.039	0.17	0.358
5	7	0.032	0.161	0.306
9	3	0	0.0586	0

7	2	0	0.0625	0
9	8	0.0119	0.1008	0.209
7	8	0.0085	0.072	0.149

Table-6Generator Cost Data of 9 Bus System

Cost characteristics=aP1^2+bP1+c									
	a	b	c	P max MW	P min MW	Q max Mvar	Q min Mvar	V max (pu)	V min (pu)
Gen-1	0.11	5	150	250	10	300	-300	1.1	0.9
Gen-2	0.085	1.2	600	300	10	300	-300	1.097	0.9
Gen-3	0.1225	1	335	270	10	300	-300	1.087	0.9

Table-7MATPOWER SIMULATION RESULT OF 9 BUS SYSTEM

>> result=runopf('case9');	
Converged in 3.39 seconds	
Objective Function Value = 17503.37 $/hr	
System Summary	
Buses	9
Generators	3
Branches	9
Areas	1
Generation (actual)	654.8MW
Load	645.0MW
Losses (I^2 * Z)	9.82MW
Voltage Magnitude	1.029 p.u.

Table-8 MATPOWER OPF RESULT BUS DATA

Bus Data						
Bus	Voltage		Generation		Load	
	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.100	0.000*	219.24	60.59	-	-
2	1.089	0.913	245.22	48.67	-	-
3	1.100	-0.032	190.36	31.26	-	-
4	1.074	-6.134	-	-	-	-
5	1.060	-8.788	-	-	100.00	40.00
6	1.088	-5.380	-	-	-	-
7	1.046	-12.68	-	-	310.00	45.00
8	1.070	-6.643	-	-	-	-
9	1.029	-12.976	-	-	235.00	60.00
Total:			654.82	140.52	645.00	145.00

Table-9 MATPOWER OPF RESULT BRANCH DATA

Branch Data							
Branch	From	To	From Bus	Injection	To Bus	Injection	Loss (I^2 * Z)

	Bus	Bus	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1	4	219.24	60.59	-219.24	-35.96	0.000	24.63
2	4	5	58.66	-1.95	-58.14	-13.26	0.514	2.78
3	5	6	-41.86	-26.74	42.48	-11.86	0.623	2.72
4	3	6	190.36	31.26	-190.36	-13.24	0.000	18.02
5	6	7	147.89	25.10	-145.55	-29.08	2.339	19.82
6	7	8	-164.45	-15.92	166.56	17.85	2.107	17.85
7	8	2	-245.22	-15.73	245.22	48.67	0.000	32.94
8	8	9	78.66	-1.36	-76.85	-23.30	1.801	9.06
9	9	4	-158.15	-36.70	160.58	37.91	2.434	20.69
Total:							9.819	148.51

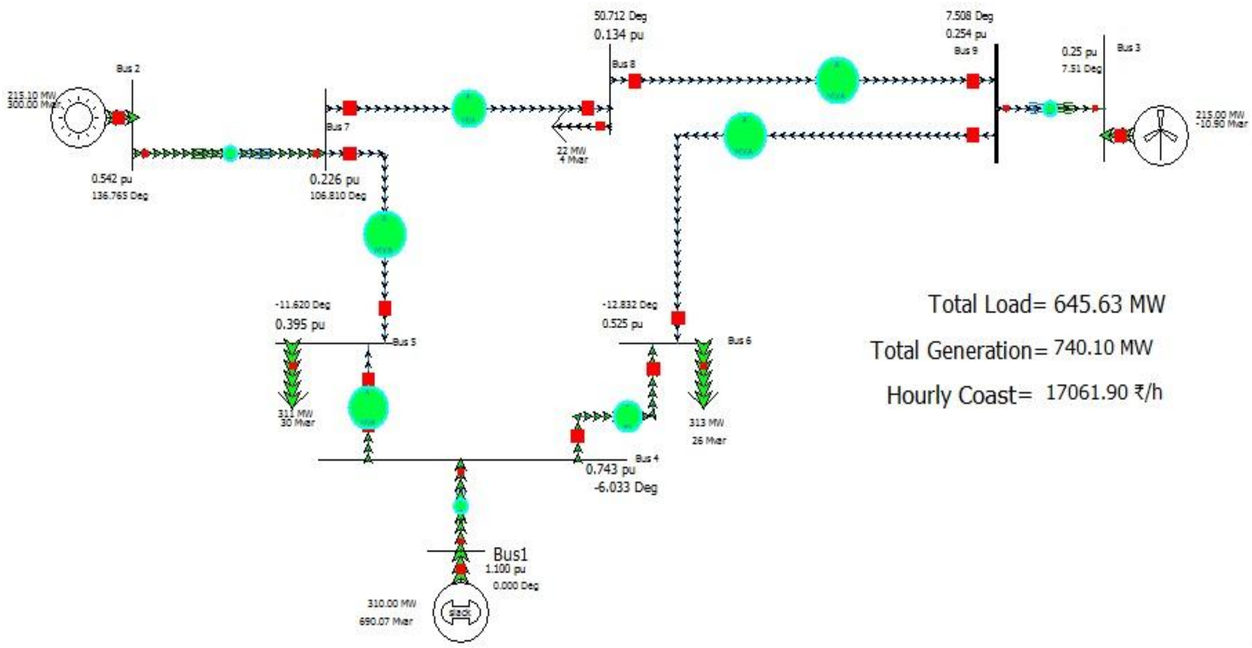

Fig.6-Power World Opf Result

Table-10Comparison of Results (9 Bus System)

Solver/Software	Total cost
Power World	17061.90 ⍰/hr
Mat Power	17503.37 $/hr

V. Conclusion

An important goal of the energy management strategy is to meet the power demand at minimum operating costs. In order to supply high-quality electric power to customers in a secure and economic manner, an optimization process for rescheduling of the different RES should be adopted.A perfect forecast eliminates uncertainty, but there is still variability. Balancing generation and load demand instantaneously and continuously is very difficult task as the loads and generators are fluctuating constantly. As a result of varying wind speed and solar irradiation, wind and solar plants generate varying amounts of electricity. In this paper done MATLAB analysis for IEEE 30-bus and IEEE 9 bus system with Power World Simulator & Mat Power both software.

References

[1] Bounthanh Banhthasit, Chaowanan Jamroen, Sanchai Dechanupaprittha Optimal generation schedulingof power system for maximum renewable energy harvesting and power losses minimization International Journal of Electrical and Computer Engineering August 2018 ISSN: 2088-8708.

[2] Vikash Kumar Saini, Kailash Chand Sharma, Vivek Prakash and Rohit Bhakar, "Impact of Renewable Energy Sources and ElectricVehicle Penetration on Generation Scheduling" IEEE conference paper 2018, 978-1-5386-4996-1/18.

[3] Carlos Roldán-Blay, Vladimiro Miranda, Leonel Carvalho and Carlos Roldán-Porta, Optimal Generation Scheduling with Dynamic Profiles for the Sustainable Development of Electricity Grids" conference paper in Sustainability 2019, 11, 7111; doi:10.3390/su11247111.

[4] Nilesh K Patel, Nitish R Patel and Bhavin K Suthar, "Optimal Generation Scheduling for Wind, Solar and Thermal Power Considering Grid Security Constraints", IEEE conference paper 2018, 978-1-5386-9316-2/18.

[5] Abdul Basit , Tanvir Ahmad, Asfand Yar Ali, Kaleem Ullah and Gussan Mufti and Anca Daniela Hansen,"Flexible Modern Power System: Real-Time Power Balancing through Load and Wind Power" Energies journal paper 2019, 12, 1710.

[6] Abdullah M. Shaheen a, Shimaa R. Spea b, Sobhy M. Farrag c, Mohammed A. Abidod,"A review of meta-heuristic algorithms for reactive power planning problem" Ain Shams Engineering Journal (2018) 9, 215–231.

[7] Tapas Kumar Panigrahi, Arun Cu. Sahoo, Aurobindo Behera, "A review on application of various heuristic techniques to combined economic and emission dispatch in a modern power system scenario"CienceDire, Energy Procedia 138 (2017) 458–463., 2013, 5, 1016-1021.

[8] Pahad parvez Mahdi, et al., 'A holistic review on optimization strategies' for combine economic emission dispatch problem' Elsevier renewable and sustainable energy review,24 June 2017.

[9] G. Yesuratnam and D. Thukaram (2006), "Congestion management in open access based on relative electrical distances using voltage stability criteria", Electric Power Systems Research 77 (2006) 1608–1618.

[10] C. L. Chen, T. Y. Lee, and R. M. Jan, "Optimal wind-thermal coordination dispatch in power systems with large integration of wind capac- ity," Energy Convers. Manisolated age., vol. 47, no. 18–19, pp. 3456–3472, Nov. 2006.

[11] Abarghooee RA, Aghaei J. Stochastic dynamic economic emission dispatch considering wind power. In: IEEE power engineering automation conference; 2011. p. 158–61.

[12] N. Yorino, H.M. HafizY. Sasaki, Y. Zoka, High-speed real-time dynamic eco- nomic load dispatch, IEEE Trans. Power Syst. 27 (2) (May 2012) 621e630.

[13] P. Bansilal, D. Thukaram, Optimal reactive power dispatch algorithm for voltage stability improvement, Electr. Power Energy Syst. 18 (7) (1996) 461e468.

[14] Christie RD, Wollenberg BF, Wangensteen I. Transmission management in the deregulated environment. Proc IEEE 2000;88:170–95.

[15] Soares A, Antunes CH, Oliveira C, Gomes Á. A multi-objective genetic approach to domestic load scheduling in an energy management system. Energy 2014;77:144–52.

[16] Lu Y, Wang S, Sun Y, Yan C. Optimal scheduling of buildings with energy generation and thermal energy storage under dynamic electricity pricing using mixed-integer nonlinear programming. Appl Energy 2015;147: 49–58.

[17] Sood Yog Raj, Singh Randhir. Optimal model of congestion management in deregulated environment of power sector with promotion of renewable energy sources. Renew Energy 2010;35:1828–36.

[18] H. Ren-hui and Z. Li-zi, "Research on green generation scheduling and its efficiency assessment model," in 2009 Fifth International Conference on Natural Computation, 2009, pp. 239-24.