Effect of Cost on Load Dispatch of Hybrid Power System aiming Economy

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Abstract - *Load Dispatch is the allocation of the load demand to the various generating units considering their various constraints so as to obtain the most economical operating costs. In a typical power system, several generators are interconnected to provide enough total output to satisfy a given total Load demand. Conventional sources like coal, which is the main source of power generation in India (and of course throughout the world) is fast depleting and also the cost of operation of Thermal power plant is more. Solar energy is freely available and the cost of operation of solar power plant is less. Hence In this paper 6 Thermal units are considered along with 4 solar (PV) units to meet the ever-increasing Load demands.A number of mathematical programming methods, Optimizing techniques and Modern BIA (Biologically Inspired Algorithms)were employed to solve Economic Load Dispatch problems.In this paper I am using solver add-in available in Excel and the results for various loads are compared.*

Since the Load demands are very complex and irregular in nature, this technique is used in solving the Load Dispatch problem by considering the fuel cost coefficients and transmission line losses for Thermal power plants and operating costs for Solar (Photo-voltaic) units. This technique arrives at the most economical solution to the problem. By integrating power obtained by Renewable energy sources to the grid, environmental pollution can be reduced, fossil fuels can be protected and also the freely available sources can be utilized in an optimum way.

Key Words: Load Dispatch, Photo-voltaic, Fuel cost coefficients, Swarm Intelligence, Bio inspired Algorithms Krill -Herd algorithm, solver add-in.

1. INTRODUCTION

Due to massive increase in demand of electricity, energy crisis has reached to its maximum degree all over the world in previous ten years. In today's world the most difficult and important part is the interconnection of large generators in parallel in order to run the load economically and to full fill the load demands. Multiple number of generating units are connected and synchronized in parallel in order to ensure the proper working of large amount of load connected to the system these generators are connected to each other through a common copper bus bar. The primary objective of multiple generating units is to make sure safe and reliable working of the power system while keeping the operating and fuel cost of generating units to the minimum level possible. For this reason, optimized and timely switching of generating units is made possible to ensure maximum cost savings without affecting the load. Also there is a vast scope of the solar power generation in India due to the high solar irradiance index. The problem of economic load dispatch with the inclusion of the renewable power sources will reduce the load of generation on the thermal units and other fossil fuel units. Here in this paper we are including Photo Voltaic System (PVS) in consortium with thermal power generation units.

If the input output characteristic curve of all the connected generators is same and identical to each other, then load can be symmetrically divided on all the generators connected in parallel. However, in most cases this is not the case. All or most of the generators connected are of different brands, having variable efficiency and dissimilar input output characteristics. All these generators will also have different fuel cost curves at different power outputs.. It increases the need of ELD to vary the power of generating units within the desired generating limits of each individual generator to meet output power demand within optimal fuel cost. Economic load dispatch is conducted to compute the operating cost of Hybrid power system through the strategic dispatch of electricity while fulfilling load demand. In this research, economic dispatch is conducted on 6 thermal units in combination with 4photovoltaic units. The basic economic dispatch will only consider real power generation. In this paper ELD problem is solved by ignoring emission, penalty constraint, prohibited operating zone, ramp-rates, and valve-point loading effect on thermal power generators and adding the factor of overestimation and underestimation of available solar power in power estimation section.

Economic load dispatch involves computing the suitable generation level, and the resulting operating cost.

Solar power can be forecasted and integrated into the Grid (e.g., GE Energy, 2008)

According to "A Survey of Bio inspired Optimization Algorithms 'by Binitha S, S Siva Sathya,(IJSCE, May 2012),Swarm intelligence technique is based on collective social behavior of organisms and it deals with the implementation of collective intelligence of groups of simple agents like bees, ants, krills, swarms etc as a problem solving tool. According to "Optimizing Economic Load Dispatch with Renewable Energy Sources via Differential Evolution Immunized Ant Colony Optimization

Technique" by N. A. Rahmat#, N. F. A. Aziz et al(2017),(ELD) is computed to analyse the operating cost of 7Thermal power integrated to 2PV power system and could arrive at a conclusion that by integrating Thermal with PV units decreases the cost of operation as well as the losses. In this paper 6 thermal units are integrated with 2PVunits& 4 PV units for 1000MW load and 1200MW load separately and the cost of economic load dispatch is calculated using solver add-in available in Excel and the results are compared. **Solver** is a Microsoft **Excel add**-in program which can be used for what-if analysis and to find an optimal (maximum or minimum) value for a formula in the objective cell — subject to constraints, or limits, on the values of other formula cells on a worksheet.

1.1 Methodology

Economic Load Dispatch of Thermal Energy interconnected with Solar energy:

Economic load dispatch is calculated to find out the operating cost of power system through the strategic Dispatch (unit commitment) of various generating units while fulfilling load demand. In general, only real power generated and Transmission line losses for thermal power units and operating costs for PV units are considered for solving ELD, while ignoring emission, penalty constraint, prohibited operating zone, ramp-rates, and valve-point loading effect.

A. Operating Cost equation of Thermal power plant:

The equivalent cost of the generator includes mainly the fuel cost, labour cost and maintenance cost etc. The cost depends on the requirement of output power

The quadratic fuel cost function can be given as:

$$Cost_{gen} = \sum_{i=1}^{n} C_i P_i = \sum_{i=1}^{n} a_i P_i^2 + b_i P_i + c_i \text{....(1)}$$

Where Ci is the fuel cost of generating Pi amount of output power. ai, bi and ci is the fuel cost coefficient for Pi.

ai = constant coefficient includes salary and wages, interest and depreciation of the ith generators.

bi = constant coefficient represents the fuel cost in the ith generator.

ci = constant coefficient measure of losses in the ith generator.

$$P_{loss} = \sum_i^n \sum_j^n P_i B_{ij} P_j + \sum_i^n B_{0i} P_i + B_{00} \text{.....(2)}$$

Where B_{ij}, B_{0i}, and $B_{00}$are the elements of loss coefficient matrix.

$$P_{T\,total} = \sum_{i=1}^{N_g} P_i = P_D + P_{loss} \text{......(3)}$$

The total generated power by Thermal units must be equal to the summation of load demand, P_D and power loss, P_{loss}as in Eq. (3)

The inequality constraint of generation limits for each unit is given by Eq.(4)

$$P_{imin} \leq P_i \leq P_{imax} \text{...................... (4)}$$

Where P_{imin} and P_{imax} is the minimum and maximum generation limits of i[th] generator respectively.

B. The operating cost of each PV unit is given by

Cost (PVij) = C_{pvi} (pvij) + $C_{p.pvi}$ (PVi.av – pv_{ij}) + C_{rpvi}(pv_{ij} - PV_{av}) ....(5)

Where $C_{pvi}$is the cost coefficient of PV per unit, $C_{p,pvi}$is the penalty cost coefficient for over estimation of power, and $C_{r,pvi}$ is the reserve cost coefficient for under estimation of PV power. *pvij* is the power committed by *ith* PV unit during *jth* hour. *PVi,av* is the available amount of energy of *ith* PV unit, adding the factor of overestimation and underestimation of available solar power.

The direct cost coefficient of solar power, penalty cost coefficient and reserve cost coefficient for the solar power are 7.86 Rs/KW, 17.80Rs/KWh and 12.28 Rs/KWh respectively. The each PV unit capacity is 30 MW. A proper estimation of solar probability density function should be made to determine actual probability of solar power generation.

The objective function of this study is to minimize the operating cost of power system when PV units are used along with Thermal units for Economic distribution of load among the units.

The total operating cost of conventional generators and PV units is calculated by combining Eq. (1) and eq. (5),

$$\mathbf{Cost_{total}} = \sum_{i=1}^{n} (C_i P_i) + \sum_{i=1}^{m} cost(PV_{ij}) \text{................(6)}$$

The Equation (6) is evaluated considering the fuel co-efficients and minimum and maximum loading capacities for thermal units and the various cost co-efficients and minimum,maximum and average capacities of Solar PV units.

3. Results and Discussions

The cost of dispatch of 1000 MW load and 1200MW load is calculated using 6 thermal units (Table 1& Table 4), 6 Thermal units interlinking with 2 PV units (Table 2 & Table 5) , 6 Thermal units and 4 PV units (Table 3 & Table 6).

Table1- Cost of dispatch1000MW load using 6 Thermal units

Thermal Unit	Fuel cost co-efficients			P G min	P G max		
	a	b	c	MW	MW	Load	Cost
G1	0.15247	38.539	756.79	10	125	125	7956.509
G2	0.10587	46.159	451.32	10	150	150	9757.245
G3	0.02803	40.396	1049.99	35	225	178.1203	9134.643
G4	0.03546	38.305	1243.53	35	210	169.1626	8738.027
G5	0.02111	36.327	1658.56	130	325	175.4583	8682.317
G6	0.01799	38.27	1356.65	125	315	202.2588	9833.039
					Total	**1000**	**54101.78**

Table2- Cost of dispatch of 1000MW load using 6 Thermal units and 2 PV units.

Thermal unit	Fuel cost co-efficients			P G min	P G max			
	a	b	c	MW	MW	Average	Load	cost
G1	0.15247	38.539	756.79	10	125		32.10225	2151.107
G2	0.10587	46.159	451.32	10	150		10.52232	948.7414
G3	0.02803	40.396	1049.99	35	225		143.0042	7400.005
G4	0.03546	38.305	1243.53	35	210		141.6171	7379.339
G5	0.02111	36.327	1658.56	130	325		285.837	13766.91
G6	0.01799	38.27	1356.65	125	315		281.2371	13542.5
PV Unit	Cpvi	Cppvi	Crpvi	Pvi min	Pvi max	Pvi avg.		
PV1	7.86	17.8	12.28	30.38	38.31	31.36	38.31	262.7526
PV2	7.86	17.8	12.28	48.67	67.37	51.45	67.37	441.6498
							1000	45893

Table 3- Cost of dispatch 1000MW load using 6 Thermal units and 4 PV units

Thermal unit	Fuel cost co-efficients			P G min	P G max			
	a	b	c	MW	MW	Average	Load	cost
G1	0.15247	38.539	756.79	10	125		22.52305	1702.152
G2	0.10587	46.159	451.32	10	150		10	923.497
G3	0.02803	40.396	1049.99	35	225		89.38965	4884.948
G4	0.03546	38.305	1243.53	35	210		100.1436	5435.15
G5	0.02111	36.327	1658.56	130	325		215.0683	10447.78
G6	0.01799	38.27	1356.65	125	315		198.3654	9655.978
PV Unit	Cpvi	Cppvi	Crpvi	Pvi min	Pvi max	Pvi avg.		
PV1	7.86	17.8	12.28	30.38	38.31	31.36	38.31	262.7526
PV2	7.86	17.8	12.28	48.67	67.37	51.45	67.37	441.6498
PV3	7.86	17.8	12.28	94.27	115.89	100.7	115.89	827.0466
PV4	7.86	17.8	12.28	120.24	142.94	139.15	142.94	1102.588
							1000	35683.54

Table 4- Cost of dispatch of 1200MW load using 6 Thermal units

Thermal unit	Fuel cost co-efficients			P G min	P G max		
	a	b	c	MW	MW	Load	cost
G1	0.15247	38.539	756.79	10	125	125	7956.509
G2	0.10587	46.159	451.32	10	150	150	9757.245
G3	0.02803	40.396	1049.99	35	225	225	11558.11
G4	0.03546	38.305	1243.53	35	210	210	10851.37
G5	0.02111	36.327	1658.56	130	325	220.4687	10693.61
G6	0.01799	38.27	1356.65	125	315	269.5313	12978.53
						1200	63795.37

Table5 - Cost of dispatch 1200 MW load using 6 Thermal and 2 PV units.

Thermal unit	Fuel cost co-efficients			P G min	P G max			
	a	b	c	MW	MW	Average	Load	cost
G1	0.15247	38.539	756.79	10	125		42.70575	2680.699
G2	0.10587	46.159	451.32	10	150		25.51571	1698.026
G3	0.02803	40.396	1049.99	35	225		199.174	10207.78
G4	0.03546	38.305	1243.53	35	210		186.9246	9642.677
G5	0.02111	36.327	1658.56	130	325		325	15694.58
G6	0.01799	38.27	1356.65	125	315		315	15196.76
PV Unit	Cpvi	Cppvi	Crpvi	Pvi min	Pvi max	Pvi avg.		
PV1	7.86	17.8	12.28	30.38	38.31	31.36	38.31	262.7526
PV2	7.86	17.8	12.28	48.67	67.37	51.45	67.37	441.6498
							1200	55824.92

Table6 - Cost of dispatch of 1200 MW load using 6 Thermal and 4 PV units

Thermal unit	Fuel cost co-efficients			P G min	P G max			
	a	b	c	MW	MW	Average	Load	cost
G1	0.15247	38.539	756.79	10	125		30.08816	2054.388
G2	0.10587	46.159	451.32	10	150		10	923.497
G3	0.02803	40.396	1049.99	35	225		130.5402	6800.946
G4	0.03546	38.305	1243.53	35	210		132.6719	6949.686
G5	0.02111	36.327	1658.56	130	325		269.7082	12991.85
G6	0.01799	38.27	1356.65	125	315		262.4815	12641.27
PV Unit	Cpvi	Cppvi	Crpvi	Pvi min	Pvi max	Pvi avg.		
PV1	7.86	17.8	12.28	30.38	38.31	31.36	38.31	262.7526
PV2	7.86	17.8	12.28	48.67	67.37	51.45	67.37	441.6498
PV3	7.86	17.8	12.28	94.27	115.89	100.7	115.89	827.0466
PV4	7.86	17.8	12.28	120.24	142.94	139.15	142.94	1102.588
							1200	44995.67

Table 7 - Cost comparison chart

Units	G1-G6	G1-G6+Pv1-PV2	G1-G6+Pv1-PV4	% cost saving	
				2PV units	4 PV units
1000 MW Cost	54101.78	45893.0045	35683.53891	15.17284	34.04369
1200 MW cost	63795.37	55824.9197	44995.66577	12.49378	29.46876

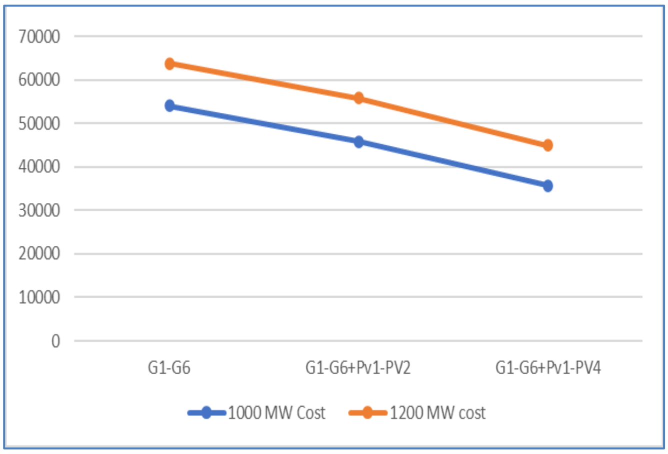

Chart – 1: Cost comparison with respect to Load

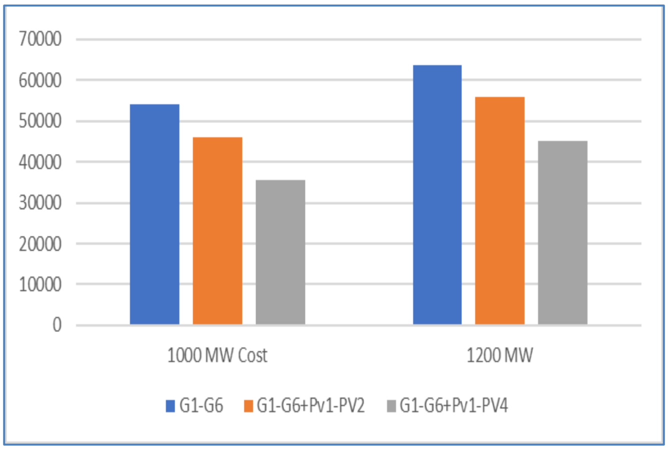

Chart -2: Cost comparison with different combination of units

CONCLUSIONS

It is found from the above charts that as the number of PV units are added to thermal units for various loads, the cost of Load dispatch is reduced. and also the burden on Thermal power units will be reduced. Hence it is required to find out the optimum PV units to be interconnected to Thermal units in order to obtain most economical Load dispatch.

Scope of Work: The ELD can be solved by considering the parameters like emission, penalty constraint, prohibited operating zone, ramp-rates, and valve-point loading effect on thermal power generators to get more appropriate values of cost saving.

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