Sreejith Sekharan [1], Karthik Balasubramanian[2]

Vellore Institute of Technology [1], Saipem India Projects Private Limited[2]

doi:10.15199/48.2017.05.06

Estimation of Recovery Cost with TCSC in Dynamic Economic Dispatch

***Abstract**. In this paper, Dynamic Economic Dispatch (DED) problem incorporating TCSC is solved using ABC algorithm. The percentage of cost recovered with the installation if TCSC is estimated. Here dispatch is carried out for a time horizon of 24 hours by considering the ramp up/down constraints along with the prevailing constraints. The percentage gain obtained with TCSC is demonstrated with respected to Equated Monthly Instalment (EMI) paid on the installation cost. The proposed methodology is tested and validated on South Indian 86 bus utility and an IEEE 118 bus test system.*

Streszczenie.** W artykule rozwiązywany jest problem Ekonomicznego Rozsyłu Energii DED w układzie z tyrystorowo sterowanymi kompensatorami TCSC. Oceniany jest procentowy koszt instalacji TCSC a następnie koszt rozsyłu energii w ciągu 24 godzin przy schodkowych zmianach wymuszeń. System przetestowano w układzie IEEE 118 w Południowych Indiach. **Ocena kosztów odzysku w systemie ekonomicznego rozsyłu enegii wyposażżonego w TCSC

Keywords: Dynamic Economic Dispatch, FACTS device, TCSC, ABC algorithm
Słowa kluczowe: Ekonomiczny Rozsył Energii DED, FACTS, TCSC.

Introduction

Static economic dispatch (SED) allocates the load demand economically for the generators such that the cost is minimum. This is carried out for one hour duration [1]. Dynamic economic dispatch (DED) schedules the online generator outputs with the predicted load demands for certain period of time, normally for 24 hours [2]. DED is solved by splitting the total time duration to small sub intervals and employing SED for each interval. Stochastic algorithms have been successfully used to solve power DED problem due to their ability to find the near global solution. Particle Swarm Optimization (PSO) [2,3]. Simulated Annealing (SA) [4], Evolutionary Programming [5] are applied for solving DED problem. These methods suffer with problems like premature convergence, local optimal and more computation time. Traditional methods like Lagrangian relaxation algorithm [6], Linear Programming [7] and Dynamic Programming [8] are used to solve DED problem.

FACTS devices are broadly used for maximizing the loadability and power transfer capability of existing power transmission networks [9]. FACTS devices are used to control the power flow through designated routes and increase the transmission capability to the thermal limit. TCSC (Thyristor Controlled Series Compensation) is a series connected device which is used to control the reactance of the transmission line so as the transmitted power [9]. It is modelled using variable reactance modelling technique [10] and incorporated into DED problem. FACTS devices can be used to improve the power flow controllability thereby to solve DED efficiently. The integration of FACTS devices into the DED problem formulation reduces the burden of generators which are committed to meet the sudden load demand thus making the generation more economical.

Proposed work

In this paper, the following works are carried out.

(a) DED without TCSC in IEEE 118 bus test system
(b) DED with TCSC in IEEE 118 bus test system
(c) DED without TCSC in South Indian 86 bus test system
(d) DED with TCSC in South Indian 86 bus test system
(e) Estimation of recovery cost with TCSC in IEEE 118 bus test system

Problem formulation

Dynamic Economic Dispatch (DED) is implemented which takes into account the dynamic costs involved in changing from one-generation level to the other. For the installation cost of TCSC, EMI is to be paid for a certain period. The term for the calculation of EMI for TCSC is incorporated into the DED problem formulation. The problem is formulated as:

(1) $$F=\sum_{t=1}^{T}\left(\sum_{i=1}^{N}F_{it}(P_{it})+\frac{C_{TCSC}}{720}\left[i*\left(\frac{(1+i)^{L}}{(1+i)^{L}-1}\right)+\frac{M}{12}\right]\right)$$

(2) $$F(P_{i,t})=Min\sum_{t=1}^{T}\sum_{i=1}^{N}a_i+b_iP_{i,t}+c_iP_{i,t}^{2}$$

where, C_{TCSC} is the installation cost of TCSC, $C_{TCSC}=0.0015S^2-0.7130S+153.75 \quad US\$/KVAR$, $S=|Q_2|-|Q_1|$, t = total time horizon (1,2,3,…24), Q2 = reactive power flow after installing TCSC , Q1 = reactive power flow before installing TCSC , N - Total number of generating units, a, b,c - fuel coefficient of thermal generator, Pit - Active power output of i th unit at time t in MW, Fit - cost function of ith unit in $/h at time t, F - total fuel cost in $/h, i= Rate of interest for the installation cost, L= time period for paying EMI (months), M= Maintenance cost of TCSC (Percentge)

This minimization problem is subject to the following constraints:

Real Power balance constraint

To satisfy the load demand, the sum of all the generating units on line must equal to the system load plus the transmission losses. The system power balance constraint is

(3) $$\sum_{i=1}^{N}P_i-P_D-P_L=0$$

Pi- Generation power output of unit i,PD - Total system demand, PL - Total system losses

The most popular approach for finding an approximate value of the losses is by Kron's
loss formula as

(4) $$P_L=\sum_{i=1}^{N}\sum_{i'=1}^{N}P_iB_{ii'}P_{i'}+\sum_{i=1}^{N}B_{io}P_i+B_{oo}$$

where, B00, Bi0 ,Bii' - B loss coefficients

Generation Capacity Limit

The real power output of each generator is constrained by minimum and maximum power limit.

(5) $$P_{i,\min} \le P_i \le P_{i,\max}$$

where, Pi,max and Pi,min - Maximum and minimum power output of unit i,

Unit Ramp Constraints

(6) $$P_{(i,t)} - P_{(i,t-1)} \le UR\,(i)$$

(7) $$P_{(i,t-1)} - P_{(i,t)} \le DR\,(i)$$

where, $UR(i)$- Ramp-up rate limit of i^{th} generator unit, $DR(i)$ - Ramp-down rate limit of i^{th} generator unit.

Modelling of TCSC

The TCSC is a key member in the FACTS family which allows rapid and continuous changes in the transmission line impedance. Thyristor-Controlled Series Compensation (TCSC) is used in power systems to dynamically control the reactance of a transmission line in order to provide sufficient load compensation. The TCSC consists of a capacitor in parallel with a Thyristor Controlled Reactor (TCR) as shown in Fig.1. Actual TCSC system consists of many TCSC modules with a fixed series capacitor. Active power flow through the compensated branch can be maintained at a specified level under a wide range of operating conditions

(8) $$B_{ii} = B_{jj} = \frac{-1}{X_{TCSC}}$$

(9) $$B_{ij} = B_{ji} = \frac{1}{X_{TCSC}}$$

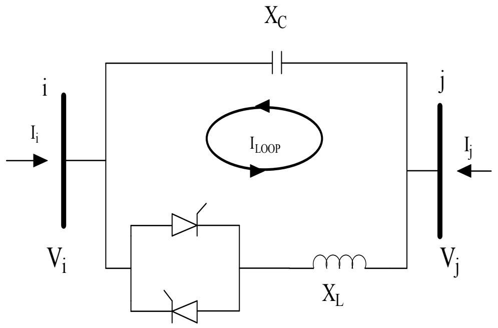

Fig.1 Thyristor Controlled Series Compensator

For capacitive mode of operation the signs are reversed.
The active and reactive power equations at bus "i"are

(10) $$P_i = V_i V_j B_{ij} \sin\left(\theta_i - \theta_j\right)$$

(11) $$Q_i = -V_i^2 B_{ii} - V_i V_j B_{ij} \cos\left(\theta_i - \theta_j\right)$$

The active and reactive power equations at bus "j" are

(12) $$P_j = V_j V_i B_{ji} \sin\left(\theta_j - \theta_i\right)$$

(13) $$Q_j = -V_j^2 B_{jj} - V_j V_i B_{ji}\; cos\left(\theta_j - \theta_i\right)$$

ABC Algorithm

The Artificial Bee Colony (ABC) algorithm is used as the optimization tool here. It is a swarm-based meta-heuristic algorithm, introduced by D. Karaboga [12] for optimizing numerical problems. ABC algorithm performs efficiently in finding optimal solution in various engineering and research problems. This algorithm has been efficiently tested on various benchmark test functions and the results are found to be encouraging [12,13]. Therefore, in this research work, ABC algorithm is used as the optimization tool. The step by step procedure for the proposed method is as follows:

Step 1: Initialize the parameters

Specify generator cost coefficients, generation power limits and ramp rate limits for each unit and B-loss coefficients. Specify a load profile for 24 hour time period. Initialize the control parameters of the ABC algorithm and maximum cycle for the termination process. Initialize the parameters of FACTS devices . Set time count, t as one and repeat the following steps for the scheduled time horizon.

Step 2: Create initial population

Initialization of population with random solutions $M = \left[X_1, X_2, ..., X_m\right]^T$ of *m* solutions or food source positions in the multidimensional solution space, where *m* represents the size of population. Each solution $Xi = \left\lfloor P_{i1}\; P_{i2} ... P_{ij} ... P_{iD} \right\rfloor$, i=1, 2,…, m and j=1, 2,…D, where *D* is the number of parameters to be optimized. In this work, for the DED problem *D* is equal to the number of generators, *N*. The elements of each solution vector denoted as x_{ij} is the real power output of generating units and they are distributed uniformly between their minimum and maximum generation limits. For each interval in the scheduling horizon and with *N* generating units an initial population can be generated:

(14) $$M = \begin{bmatrix} P_{11} & P_{12} & ...P_{1N} \\ P_{21} & P_{22} & ...P_{2N} \\ . & . & . \\ . & . & . \\ . & . & . \\ P_{m1} & P_{m2} & ...P_{mN} \end{bmatrix}$$

where P_{ij} is the real power output of the j^{th} generating unit for the i^{th} individual. Half of the colony size forms the employed bees

Step: 3 Evaluation of Fitness of the population

Evaluate the fitness value of each food source positions corresponding to the employed bees in the colony. A fitness function as in (1) is used:

(15) Fitness = A [1 − %Cost] + B [1 − %Error]

(16) $$Error = \left| \sum_{i=1}^{N} P_i - P_L - P_D \right|$$

(17) $$\%Error = \frac{String\cos t - Min\cos t}{Max\cos t - Min\cos t}$$

(18) $$\%\,Error = \frac{String\;error - Min\;error}{Max\;error - Min\;error}$$

where, A and B are positive weighting coefficients. *Stringcost* is the individual string's cost of generation, *Mincost* is the minimum objective function value within the population, *Maxcost* is the maximum objective function value within the population, *Stringerror* is the individual string's error in meeting the power balance constraint, *Minerror* is the minimum constraint error within the population and *Maxerror* is the maximum constraint error within the population. Determine the best fitness among the individuals and the corresponding minimum cost and the parameters responsible for the minimum cost. Set the cycle count as one and repeat the following steps till the maximum cycle number (MCN) which is the termination criteria, is reached.

Step: 4 Modification of position of the employed bees

An employed bee produces a modification on the position (solution) in its memory for finding a new food source. The new food source is determined by altering the value of any one of the *D* parameters (old food source position), selected randomly and keeping other parameters unchanged. For the ED and DED problem this can be represented as in (19):

$$P_{ij} = P_{ij} + \phi_{ij} * \left(P_{ij} - P_{kj}\right) \quad (19)$$

where, *j* is the index of the selected parameter that is generated randomly. The modified position is then checked for constraints .If the resulting value violates the constraint, they are set to the extreme limits. Then, the fitness value of the new food source position (new solution) is evaluated Here, a greedy selection mechanism is employed as the selection operation between the old and new position. In case, if fitness value of the new position is less than the old one then a limit count is set.

Step : 5 Recruit onlooker bees for selected sites and evaluate fitness

Once all the employed bees complete the search process, they share the information regarding the food sources and positions to the onlooker bee. The onlooker bee selects a food position based on the probability. Onlookers are placed onto the food source sites by using a fitness-based selection technique (roulette wheel selection).

Step 6: Modification of position by onlookers

As in the case of the employed bee discussed in step: 4, the onlookers produces a modification on the position in its memory, and checks the nector amount of the candidate source. If the new food has equal or better nectar than the old source, it is replaced with the old one in the memory. Otherwise, the old one is retained in the memory. Greedy selection mechanism is employed to select a position between the new and the old one.

Step : 7 Abandon sources exploited by bees

If the solution for a food source is not improved after a number of trials, the food source is abandoned and the scout bee discovers a new food source with Xi. Memorize the best solution achieved so far and increment the cycle count.

Step 8 : Memorize the result and Termination

Stop the process if the termination criterion is satisfied. Termination criteria used in this work is the specified maximum number of cycles. Otherwise, go to step : 4. The best fitness and the corresponding position of the food source retained in the memory at the end of the termination criteria is selected as the optimum output powers of generating units involved in the economic dispatch process for that time interval. Increment the time counter and repeat steps 2 to 8 for the time intervals for which the scheduling is specified. Compute the total cost for all the subintervals in the *T* time interval.

Results and Discussions

A. DED without TCSC in IEEE 118 bus system

Here, DED is carried out without incorporating TCSC in the IEEE 118 test system. In this case, the transmission losses are also included. The dispatch is run for a time horizon of 24 hours considering the network, system ,Ramp constrains and the total generation cost is calculated. The generation cost for a time horizon of 24 hours is 1548203.00 $.

B. DED with TCSC in IEEE 118 bus system

In this case, the DED is carried out incorporating TCSC in an IEEE 118-bus system. TCSC is placed in their optimal location and its performance in DED problem is analyzed. The parameters of TCSC are chosen depending on the network parameters. Since the selected line is compensated, this will lead to the reduction in total generation cost of electric power and investment on the compensating devices TCSC has been placed optimally (Line 68-81). The generation cost with TCSC for a time horizon of 24 hours is 1547616.00 $, which is less than the cost incurred without the incorporation of TCSC in the network. TCSC enables active power flow in the transmission line. Although it is not meant for voltage profile improvement, the voltage profile is improved to a certain extend with the incorporation of TCSC in the network. The dispatch obtained for a time horizon of 24 hours is furnished in Table 1

Table 1 DED incorporating FACTS devices in IEEE 118 bus system

Generator\ Location	TCSC -Real Power Dispatch (MW) Line 68-81						
G4 (MW)	360.76	G34(MW)	458.42	G69(MW)	5386.05	G92(MW)	4828.30
G6(MW)	295.70	G36(MW)	1484.20	G71(MW)	1113.71	G99(MW)	4282.76
G8(MW)	395.85	G40(MW)	407.938	G72(MW)	450.24	G10(MW)	4248.51
G10(MW)	6254.07	G42(MW)	380.44	G73(MW)	331.139	G103(MW)	357.09
G12(MW)	4700.30	G46(MW)	1356.55	G74(MW)	233.71	G104(MW)	1445.56
G15(MW)	482.48	G49(MW)	3914.05	G76(MW)	1428.14	G105(MW)	1384.17
G18(MW)	1332.49	G54(MW)	3428.01	G77(MW)	1291.60	G107(MW)	332.91
G19(MW)	352.82	G55(MW)	1296.35	G80(MW)	6073.09	G110(MW)	962.95
G24(MW)	441.83	G56(MW)	1880.28	G82(MW)	1816.05	G111(MW)	1213.86
G25(MW)	5938.93	G59(MW)	3047.57	G85(MW)	456.88	G112(MW)	1858.95
G26(MW)	5491.17	G61(MW)	3243.24	G87(MW)	4745.34	G113(MW)	1693.74
G27(MW)	391.22	G62(MW)	1562.66	G89(MW)	3115.36	G116(MW)	1153.89
G31(MW)	473.83	G65(MW)	6623.49	G90(MW)	330.30	Loss(MW)	2910.7
G32(MW)	1321.12	G66(MW)	7912.02	G91(MW)	788.38	Cost($)	1547200.78

C. DED without TCSC in IEEE South Indian 86 bus utility

In this case, the DED is carried out without incorporating FACTS devices in a practical South Indian 86 bus utility. The real power generation cost obtained for a time horizon of 24 hours is ` 8600586.00. In this case, the ramp constraints are not playing a vital role since all the generators are running to its maximum capacity. There is no significance reduction or increase of power beyond the ramp limits of individual generators.

D. DED with TCSC in 86 bus South Indian Utility

In this case, the DED is carried out incorporating FACTS devices in a practical South Indian 86 bus utility. The parameters of FACTS devices are chosen depending on the network parameters. DED is carried out by placing FACTS devices for 24 hours time horizon. TCSC is placed in various locations in the test system and the best performance is obtained in line 83-84. So, DED is carried out with TCSC placed in line 83-84.

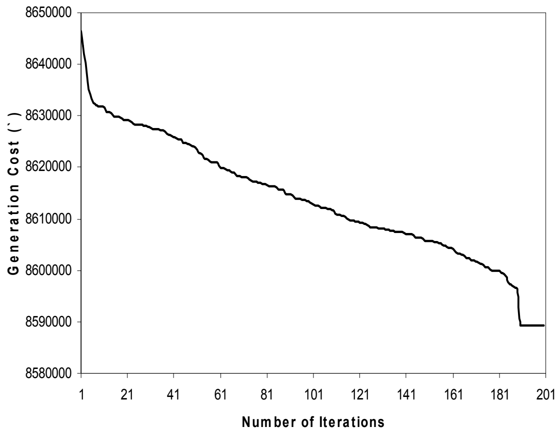

Fig 2 Best cost convergence graph for South Indian 86 bus utility with TCSC

Table 2 DED (MW) with TCSC in South Indian 86 bus utility

GenNo / Hours	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17
1	127.3	128.9	85.79	97.85	156.97	157.0	156.73	47.00	47.00	81.91	81.92	79.57	141.4	119.6	139.7	138.6	138.1
2	102.3	102.2	75.05	90.53	162.03	157.8	163.08	58.97	58.74	95.27	95.78	83.27	115.4	111.3	114.6	117.9	120.3
3	96.69	95.26	73.31	85.45	151.2	148.2	153.26	59.91	59.99	92.41	91.80	78.08	108.8	103.3	111.3	114.2	110.9
4	97.03	95.57	71.24	85.38	149.64	151.8	146.34	59.79	59.86	92.68	91.95	78.93	105.9	106.9	108.4	110.5	108.3
5	89.26	88.86	65.16	77.14	132.56	133.3	132.89	59.55	59.73	79.81	77.10	73.52	99.11	97.25	97.7	96.57	101.4
6	93.15	93.6	66.57	81.72	138.19	139.9	143.91	59.87	59.97	85.93	86.04	75.16	107.2	102.4	102.2	106.2	107.6
7	96.23	96.15	72.97	86.59	150.48	153.5	156.66	60.00	60.00	94.36	92.75	79.19	113.2	113.0	109.8	110.6	110.5
8	100.1	98.62	75.52	86.85	159.39	156.6	158.46	59.82	60.00	98.31	96.19	86.54	113.6	111.5	112.6	119.3	115.4
9	96.69	99.14	74.09	84.27	152.39	158.2	155.46	59.93	59.98	97.89	95.83	83.53	113.8	111.2	112.7	114.2	112.3
10	95.84	97.15	72.43	86.5	150.29	152.8	154.88	59.96	59.76	95.43	95.51	78.68	111.1	107.4	109.8	114.4	112.9
11	84.19	86.27	60.89	76.65	124.24	127.3	130.7	59.93	59.94	75.00	75.61	71.59	96.55	97.63	97.2	95.50	98.24
12	94.04	93.76	66.47	80.86	139.65	138.9	137.64	59.83	59.81	84.56	85.33	74.62	102.4	100.2	98.6	101.9	104.7
13	105.0	99.89	78.47	90.52	161.42	158.5	163.97	60.0	59.91	98.65	100.0	85.77	118.6	113.3	116.2	118.0	116.9
14	118.8	118.0	86.65	94.76	177.23	180.5	181.57	59.95	59.98	109.2	109.2	98.62	135.4	134.9	131.7	139.3	135.8
15	120.6	122.4	86.62	94.93	183.73	180.3	181.47	59.95	59.93	109.3	108.1	101.2	138.0	130.7	133.0	140.0	135.8
16	114.9	117.4	83.04	96.48	177.27	175.2	177.25	59.94	59.86	108.1	108.1	96.78	136.4	131.3	130.7	136.6	136.9
17	85.98	87.50	63.14	67.92	128.07	127.8	125.73	59.93	59.72	83.24	82.43	75.03	96.76	95.80	95.59	97.74	95.74
18	96.36	94.83	71.02	85.12	149.65	149.6	148.01	59.7	59.90	92.53	89.69	79.08	107.1	105.9	105.9	111.5	109.7
19	121.0	117.5	84.17	97.83	182.26	180.8	178.04	59.93	59.89	107.5	108.1	98.73	136.3	135.1	132.2	137.5	136.7
20	96.11	95.98	68.77	87.76	149.24	144.9	149.05	59.81	59.94	90.62	89.13	77.68	107.0	106.8	106.1	109.7	112.2
21	101.2	101.5	76.94	88.12	157.62	161.8	160.7	59.95	60.00	100.4	97.3	84.31	117.4	113.7	112.9	119.0	120.3
22	103.2	103.8	75.73	90.77	164.25	164.2	162.73	59.84	59.78	102.0	101.2	85.35	121.8	118.1	117.9	120.8	121.8
23	129.2	130.0	86.94	99.53	194.5	199.7	194.02	59.79	59.86	109.6	109.7	105.9	149.4	142.6	141.9	151.2	147.0
24	126.4	125.5	84.62	98.71	189.39	188.9	190.51	59.88	59.89	109.3	109.2	101.3	142.7	138.6	137.9	137.7	143.3

The real power dispatch with TCSC for a period of 24 hours is given in Table 2. The total generation cost obtained is `8587379.00. The convergence graph of the best generation cost incorporating TCSC is shown in Fig 2.

E. Estimation of recovery cost with TCSC in IEEE 118 bus test system

The number of real world applications of advanced FACTS devices is still limited. There can be various reasons for few installations and one of the main reason is the high investment cost. The cost, however, has to be compared against the anticipated benefits. There are many benefits with the installation of FACTS devices, most of which are difficult to quantify or put in terms of monetary values. The high cost and unquantifiable benefits are big hurdles in showing the viability of such devices. Hence, analyzing the benefits of FACTS devices in terms of monetary value and ways to recover investment on FACTS devices is much necessary in the present restructured power system scenario. It may be noted that this recovery is calculated duly upon the gain in the operating cost obtained with TCSC. The investigations on cost recovery and payback period are illustrated based on 2 approaches namely EMI and Non-EMI scheme. In the EMI scheme, the total amount to be paid back is calculated for a fixed number of years with an interest and the amount is equally divided on a monthly installment basis. However in the Non-EMI Scheme, the profit obtained during the scheduling operation (i.e. profitable difference of the operating costs with and without TCSC) is paid back on the same day. Hence the money is paid back without any delay once the profit is obtained. Here the installation cost of TCSC devices along with the rate of interest is used for calculating the profits. The formula for calculating the EMI is given as,

$$R = \frac{P * r * (1+r)^n}{(1+r)^n - 1} \tag{20}$$

Where: P = Installation cost of TCSC, r = Annual rate of interest, n = Number of payments

The series connected device TCSC has an installation cost of M$ 4.63 for IEEE 118-bus test system. Assuming that this amount is acquired as a loan with an interest of 8% per annum. The EMI paid for the amount will be M$ 0.0443 and for a span of 10 years, the total amount paid will be M$ 5.322.

Table: 3 Recovery Cost with TCSC in IEEE 118 bus test system

Particulars	TCSC (M$)
Device installation cost	4.63
Rate of Interest per annum	8.00
Total Period (months)	120
Monthly EMI	0.04435
Annual Gain with SVC	0.214255
Total Gain for 10 years with 8 % interest	2.1395
Total EMI for 10 years	5.3226
Total Profit in 10 years (after payback)	0.43
Profit in percentage of EMI after payback	49.98
Percentage profit, if initial investment is made without loan facility	53.38
Non-EMI scheme with out maintenance cost(after payback)	23.80
Non-EMI scheme with 3 % maintenance cost(after payback)	4.63

The annual gain with TCSC will be M$ 0.214, which will be M$ 0.43 after 10 years with an interest of 8% per annum. 49.98 % of the installation cost can be taken back based on the EMI scheme and 27.20 % of the initial installation cost is obtained as profit. In the non EMI scheme, approximately 51.7% of the installation cost can be recovered solely considering the profit obtained based on the operating cost. Considering a maintenance charge of 3% per annum of the initial installation cost, the profit obtained will be 4.63 % of the total installation cost. The advantages related to congestion management, building or new substations and transmission lines are not considered.

Conclusion

Dynamic Economic Dispatch (DED) problem incorporating TCSC is solved using ABC algorithm. The case studies are carried out in a standard IEEE 118 bus system and a practical South Indian 86 bus utility. Incorporation of TCSC into the test system improves the power flow in in lines and reduces the transmission losses.

Here dispatch is carried out for a time horizon of 24 hours by considering the ramp up/down constraints along with the prevailing constraints. Analysis is done by placing TCSC in its optimal position in the test system. The cost benefit analysis with TCSC in DED problem is also discussed. The analysis is done with and without EMI scheme. It is clear that, the profit with the installation of TCSC in the system can be obtained in reasonable time. This can be extended to other FACTS devices also.

Authors

Author 1*: Dr. Sreejith.Sekharan, Associate Professor, Energy and Power Electronics Department, School of Electrical Engineering, Vellore Institute of Technology, Vellore -14, Tamil Nadu , India. Email:sreejith.s@vit.ac.in*

Author 2: *Karthik Balasubramanian, Engineer, Saipem India Projects Private Limited,Chennai-34, India*

Email : karthik.balasubramanian@saipem.com

REFERENCES

[1] J. Jasper , Albert Aruldoss , Differential evolution with random scale factor for economic dispatch considering prohibited operating zones, Przegląd Elektrotechniczny ,05, (2003), 187-191

X.S. Han, H.B. Gooi, D.S. Kirschen, Dynamic economic dispatch: feasible and optimal solutions, IEEE Transaction on Power systems, 16 (2001) , 22–28.

[2] T.A.A. Victoire, A.E. Jeyakumar, Deterministically guided PSO for dynamic dispatch considering valve-point effect, Electric Power System Research, 73,(2005), 313–322.

[3] Chaturvedi KT, Pandit M, Srivastava L, Particle swarm optimization with time varying acceleration coefficients for non-convex economic power dispatch. International Journal of Electric Power and Energy Systems 31(6), (2009), 249–57.

[4] Wong KP, Fung CC, Simulated annealing based economic dispatch algorithm ,IEE Proceedings on Generation Transmission and Distribution, 140(6), (1993), 509–515.

[5] P. Attaviriyanupap, H. Kita, E. Tanaka, J. Hasegawa, A hybrid EP and SQP for dynamic economic dispatch with nonsmooth fuel cost function, IEEE Transaction on Power systems, 17(2002). 411–416.

[6] Hindi, K., & Ghani, M, Dynamic economic dispatch for large-scale power systems: A Lagrangian relaxation approach" Electric Power System Research, 13(1),(1991) 51–56.

[7] Jabr, R., Coonick, A., & Cory, B, A homogeneous linear programming algorithm for the security constrained economic dispatch problem, IEEE Transactions on Power System, 15(3),(2000), 930–937.

[8] Travers, D., & Kaye, R, Dynamic dispatch by constructive dynamic programming. " IEEE Transactions on Power System, 13(1),(1998),72–78.

[9]Narain G. Hingorani, Laszlo Gyugyi Understanding FACTS: concepts and technology of flexible AC transmission systems, IEEE Press, 2000

[10]Enrique Acha, FACTS : Modelling and Simulation in Power Networks ' Wiley publishers

[11]D. Karaboga, B. Basturk, On the performance of artificial bee colony (ABC) algorithm, Applied. Soft Computing. 8,(2000), 687–697

[12]Dervis Karaboga *, Bahriye Akay ,A comparative study of Artificial Bee Colony algorithm, Applied Mathematics and Computation, 214, (2009),108–132.

[13]K. Chandrasekaran, S. Hemamalini, Sishaj P. Simon, Narayana Prasad Padhy, Thermal unit commitment using binary/real coded artificial bee colony algorithm , Electric Power Systems Research 84 ,(2012),109–119.