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OPTIMAL TCSC PLACEMENT FOR OPTIMAL POWER FLOW

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Very few publications have been focused on the mathematical modeling of Flexible Alternating Current Transmission Systems (FACTS) -devices in optimal power flow analysis. A Thyristor Controlled Series Capacitors (TCSC) model has been proposed, and the model has been implemented in a successive QP. The mathematical models for TCSC have been established, and the Optimal Power Flow (OPF) problem with these FACTS-devices is solved by Newtons method. This article employs the Newton- based OPF-TCSC solver of MATLAB Simulator, thus it is essential to understand the development of OPF and the suitability of Newton-based algorithms for solving OPF-TCSC problem. The proposed concept was tested and validated with TCSC in twenty six-bus test system. Result shows that, when TCSC is used to relieve congestion in the system and the investment on TCSC can be recovered, with a new and original idea of integration.

K e y w o r d s: economic dispatch, power flow, optimal power flow, TCSC device

1 INTRODUCTION

An electrical power system can be seen as the interconnection of generating sources and customer loads through a network of transmission lines, transformers, and ancillary equipment. Its structure has many variations that are the result of a legacy of economic, political, engineering, and environmental decisions. Based on their structure, power systems can be broadly classified into meshed and longitudinal systems. Meshed systems can be found in regions with a high population density and where it is possible to build power stations close to load demand centers. Longitudinal systems are found in regions where large amounts of power have to be transmitted over long distances from power stations to load demand centers. Independent of the structure of a power system, the power flows throughout the network are largely distributed as a function of transmission line impedance; a transmission line with low impedance enables larger power flows through it than does a transmission line with high impedance. This is not always the most desirable outcome because quite often it gives rise to a myriad of operational problems; the job of the system operator is to intervene to try to achieve power flow redistribution, but with limited success. Examples of operating problems to which unregulated active and reactive power flows may give rise are: loss of system stability, power flow loops, high transmission losses, voltage limit violations, an inability to utilize transmission line capability up to the thermal limit, and cascade tripping.

In the long term, such problems have traditionally been solved by building new power plants and transmission lines, a solution that is costly to implement and that involves long construction times and opposition from pressure groups. It is envisaged that a new solution to such operational problems will rely on the upgrading of existing transmission corridors by using the latest power electronic equipment and methods, a new technological thinking that comes under the generic title of FACTS — an acronym for flexible alternating current transmission systems [1].

2 FLEXIBLE ALTERNATING CURRENT TRANSMISSION SYSTEMS

In its most general expression, the FACTS concept is based on the substantial incorporation of power electronic devices and methods into the high-voltage side of the network, to make it electronically controllable (IEEE/CIGRE1995) [1].

2.1 Series Compensation

The world's first Series Compensation on transmission level, counted nowadays by the manufacturers as a FACTS-device, went into operation in 1950. Series Compensation is used in order to decrease the transfer reactance of a power line at rated frequency. A series capacitor installation generates reactive power that in a self- regulating manner balances a fraction of the line's transfer reactance. The result is that the line is electrically shortened, which improves angular stability, voltage stability and power sharing between parallel lines. Series Capacitors are installed in series with a transmission line, which means that all the equipment has to be installed on a fully insulated platform. On this steel platform the main capacitor is located together with the overvoltage protection circuits. The overvoltage protection is a key design factor, as the capacitor bank has to withstand the throughput fault current, even at a severe nearby fault. The primary overvoltage protection typically involves non-linear varistors of metal-oxide type, a spark gap and a fast bypass switch. Secondary protection is achieved with ground

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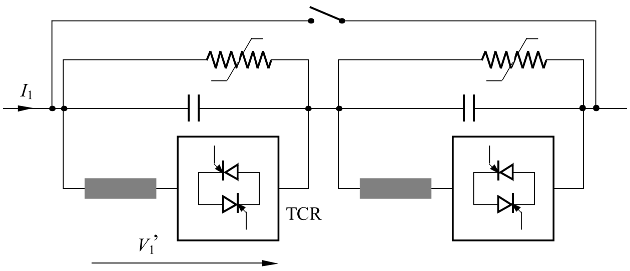

Fig. 1. Principle setup and operational diagram of a Thyristor Controlled Series Compensation (TCSC)

mounted electronics acting on signals from optical current transducers in the high voltage circuit [2].

2.2 TCSC

Thyristor Controlled Series Capacitors (TCSC) address specific dynamical problems in transmission systems. Firstly it increases damping when large electrical systems are interconnected. Secondly it can overcome the problem of Sub-Synchronous Resonance (SSR), a phenomenon that involves an interaction between large thermal generating units and series compensated transmission systems. The TCSC's high speed switching capability provides a mechanism for controlling line power flow, which permits increased loading of existing transmission lines, and allows for rapid readjustment of line power flow in response to various contingencies. The TCSC also can regulate steady-state power flow within its rating limits [2].

3 FORMULATION OF THE ECONOMIC DISPATCH PROBLEM

OPF solutions are carried out to determine the optimum operating state of a power network subjected to physical and operational constraints. An objective function, which may incorporate economic, security, or environmental aspects of the power system, is formulated and solved using a suitable optimization algorithm, such as Newtons method. The constraints are physical laws that govern power generation and transmission system availability, the design limits of the electrical equipment, and operating strategies. This kind of problem is usually expressed as a static, nonlinear programming problem, with the objective function represented as a nonlinear equation and the constraints represented by nonlinear or linear equations.

More often than not, the objective function is taken to be the cost of generation, reflecting the economic aspects of the electrical power system. Hence, the mathematical formulation minimizes active power generation cost by suitable adjustment of the control parameters [3–6].

4 FORMULATION OF THE ECONOMIC DISPATCH PROBLEM

Consider a system with m generators committed and all the loads P_{di} given, find P_{gi} and $|V_i|$, $i = 1, 2, \dots, m$, to minimize the total fuel cost

$$C_T = \sum_{i=1}^{m} C_i(P_{gi}) \,. \tag{1}$$

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

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max},\ i = 1, 2, \dots, m \,, \tag{2}$$

$$|V_i|^{\min} \le |V_i| \le |V_i|^{\max}, i = 1, 2, \dots, m \,, \tag{3}$$

$$|P_{ij}| \le |P_{ij}|^{\max},\ \text{for all lines.} \tag{4}$$

Brief explanation on the problem formulation is given below.

1. The power flow or load flow equations must be satisfied. They are equality constraint in the optimization process.
2. The lower limit on P_{gi} is due to boiler and/or thermodynamic considerations and upper limit is set by thermal limits on the turbine generator unit.
3. The voltage constraint will keep the system voltages near their rated or nominal values. The voltage should be neither too high nor too low and the objective is to help maintain the consumers voltage.
4. Constraints on transmission line powers relate to stability and thermal limits.
5. The minimization of cost function C_T subject to equality and inequality constraints is treated by a branch of applied mathematics called Nonlinear Programming [7].

4.1 Economic Dispatch considering line losses

From the law of conservation of power we can write

$$P_L = \sum_{i=1}^{n} P_i = \sum_{i=1}^{m} P_{gi} - \sum_{i=1}^{n} P_{di} \,, \tag{5}$$

P_i = net injected power at bus i.
P_L = total line loss.
P_{gi} = power generated by i-th generator.
P_{di} = load at bus i.

It is assumed that P_{di} are specified and fixed but the P_{gi} are variables. If P_{di} are fixed, from eqn (5), it can be seen that P_L depends only on the P_{gi}. Bus 1 is a slack bus and the bus power $P_1(P_{g1} = P_1 + P_{d1})$ is a dependent variable and found by solving the load flow equations.

Therefore, only $(m-1)$ of the P_{gi} are independent variables. Thus, for a given power system, and given P_{di}, Q_{di} at all buses and voltage magnitude $|V_i|$, specified at buses $i = 1, 2, \ldots, m$, the functional dependence of P_L may be written as

$$P_L = P_L\big(P_{g2}, P_{g3}, \ldots, P_{gm}\big). \tag{6}$$

Equation (6), depends on the load flow solutions. Expression for total fuel cost is given as

$$C_T = \sum_{i=1}^{m} C_i\big(P_{gi}\big) \tag{7}$$

subject to

$$\sum_{i=1}^{m} P_{gi} - P_L\big(P_{g2}, P_{g3}, \ldots, P_{gm}\big) - P_d = 0 \tag{8}$$

and

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max},\ i = 1, 2, \ldots, m\,. \tag{9}$$

We will first consider the case without the generator limits. The augmented cost function is defined as

$$\tilde{C}_T = \sum_{i=1}^{m} C_i(P_{gi}) - \lambda\Big[\sum_{i-1}^{m} P_{gi} - P_L\big(P_{g2}, P_{g3}, \ldots, P_{gm}\big) - P_D\Big] \tag{10}$$

where λ is the Lagrangian multiplier.

Next, we find a stationary point of $\tilde{C}_T$ with respect to λ and the P_{gi} .

$$\frac{\mathrm{d}\tilde{C}_T}{\mathrm{d}\lambda} = \sum_{i=1}^{m} P_{gi} - P_L - P_D = 0\,, \tag{11}$$

$$\frac{\mathrm{d}\tilde{C}_T}{\mathrm{d}P_{g1}} = \frac{\mathrm{d}C_1}{\mathrm{d}P_{g1}} - \lambda = 0\,, \tag{12}$$

$$\frac{\mathrm{d}\tilde{C}_T}{\mathrm{d}P_{gi}} = \frac{\mathrm{d}C_i}{\mathrm{d}P_{gi}} - \lambda\Big(1 - \frac{\partial P_L}{\partial P_{gi}}\Big) = 0\,,\ i = 2, 3, \ldots, m\,. \tag{13}$$

Equation (13) may be written as

$$L_i \frac{\mathrm{d}C_i}{\mathrm{d}P_{gi}} = \lambda\,,\ i = 2, 3, \ldots, m \tag{14}$$

where

$$L_i = \frac{1}{1 - \frac{\partial P_L}{\partial P_{gi}}}\,, \quad i = 2, 3, \ldots, m\,. \tag{15}$$

L_i is known as penalty factor for the i-th generator. Also note that from equation (12).

$$L_1 = 1\,. \tag{16}$$

Necessary conditions for optimization given in equation (12) and equation (13), may be replaced by

$$L_1 \frac{\mathrm{d}C_1}{\mathrm{d}P_{g1}} = L_2 \frac{\mathrm{d}C_2}{\mathrm{d}P_{g2}} = \cdots = L_m \frac{\mathrm{d}C_m}{\mathrm{d}P_{gm}} = \lambda\,. \tag{17}$$

Equation (17) indicates that for optimal scheduling operate all the generators such that the product $L_i \frac{\mathrm{d}C_i}{\mathrm{d}P_{gi}} = \lambda$ for every generator [7].

5 WORK PLAN

Many researchers have been conducted on determining optimal locations of FACTS devices in a grid. They differ mainly from each other.

Under this section, our goal is to locate the optimum location of FACTS devices. More precisely, we have treated only the series compensation and we have chosen as the series FACTS devices: the TCSC.

Work is determined as follows:

- The methodology adopted is to find the optimal configuration from one or several solutions (depending on the algorithm used) and try to improve over successive iterations. Assessing the quality of a solution is through a calculation of distribution of powers classics. According to the modeling of TCSC, the system modifies the nodal admittance matrix of the network. It is based on evidence that the modified load flow is calculated.
- The optimization method used in between the class of nonlinear programming with constraints method called marginal costs (Lagrange).

5.1 Differential evolution for OPF with TCSC devices

The different types of programming methods for insertion of TCSC in the power network are given in the following stages:
Stage (1) : Insert serial position manual;
Stage (2) : Insert serial position automatic;
Stage (3) : Insert serial position angle.

5.2 Chosen methods

The IEEE26-bus system has been used to show the effectiveness of the proposed method. The used data are in Table 7.

In this work the branches are installed with TCSC. They will be changed and will be given in each simulation proposed in Section 5.1.

The proposed algorithm has been implemented in MATLAB 7. In our case, we chose the strategy to control the transmission angle modulation.

Note that the choice of values of alpha and their operating limits were based on research that has already made the best angle control transits [8].

6 SIMULATION AND RESULTS

6.1 Stage 1

In this first simulation, we shall insert one TCSC in the electric power network guided by our choice (*ie* manually)

Table 1. Total operating losses, Total costs and Lambda factor for IEEE 26-system ($f = 50$ Hz)

Stage 1			
	It = 2 , $T = 2.33783 \times 10^{-5}$ s	It = 2 , $T = 2.33628 \times 10^{-5}$ s	
Results of	Without TCSC	With TCSC manually	Chose's branch (k-m)
Total losses (MW)	12.807	12.7728	(11-25)
Total costs ($/h)	15447.72	15447.26	(11-25)
Lambda λ ($/MWh)	13.538113	13.536783	(11-25)

Table 2. Power generators optimal network for IEEE 26-system ($f = 50$ Hz)

Stage 1			
Generator Optimal (MW)	Without TCSC	With TCSC manually	Chose's branch (k-m)
$P_{G1\ opt}$	447.6919	447.6450	(11-25)
$P_{G2\ opt}$	173.1938	73.1561	(11-25)
$P_{G3\ opt}$	263.4859	63.4174	(11-25)
$P_{G4\ opt}$	138.8142	38.7362	(11-25)
$P_{G5\ opt}$	165.5884	65.5686	(11-25)
$P_{G6\ opt}$	87.0260	87.2427	(11-25)

Table 3. Total operating losses, Total costs and Lambda factor for IEEE 26-system ($f = 50$ Hz)

Stage 2			
	It = 2 , $T = 2.33783 \times 10^{-5}$ s	It = 6 , $T = 4.36523 \times 10^{-10}$ s	
Results of	Without TCSC	With TCSC automatically	Optimsl position
Total losses (MW)	12.807	12.3762	(5-6)
Total costs ($/h)	15447.72	15441.40	(5-6)
Lambda λ ($/MWh)	13.538113	13.520394	(5-6)

Table 4. Power generators optimal network for IEEE 26-system ($f = 50$ Hz)

Stage 2			
Generator Optimal (MW)	Without TCSC	With TCSC automatically	Optimal position
$P_{G1\ opt}$	447.6919	445.3020	(5-6)
$P_{G2\ opt}$	173.1938	171.6583	(5-6)
$P_{G3\ opt}$	263.4859	262.1707	(5-6)
$P_{G4\ opt}$	138.8142	137.6267	(5-6)
$P_{G5\ opt}$	165.5884	173.1344	(5-6)
$P_{G6\ opt}$	87.0260	85.4817	(5-6)

Table 5. Total operating losses, Total costs and Lambda factor for IEEE 26-system ($f = 50$ Hz)

Stage 3			
	It = 2 , $T = 2.33783 \times 10^{-5}$ s	It = 2 , $T = 8.67851 \times 10^{-7}$ s	
Results of	Without TCSC	With TCSC position angle	Optimsl angle
Total losses (MW)	12.807	12.3750	(158.72)
Total costs ($/h)	15447.72	15441.39	(158.72)
Lambda λ ($/MWh)	13.538113	13.520152	158.72)

Table 6. Power generators optimal network for IEEE 26-system ($f = 50$ Hz)

Stage 3			
Generator Optimal (MW)	Without TCSC	With TCSC position angle	Optimal angle
$P_{G1\ opt}$	447.6919	445.2146	158.72
$P_{G2\ opt}$	173.1938	171.6062	158.72
$P_{G3\ opt}$	263.4859	262.1334	158.72
$P_{G4\ opt}$	138.8142	137.5949	158.72
$P_{G5\ opt}$	165.5884	173.3918	158.72
$P_{G6\ opt}$	87.0260	85.4323	158.72

6.1.1 TCSC parameters

1) The basic value is: $S_b = 100$ MVA.
2) The parameters of the controller power transits TCSC are:

- The inductive reactance: $X_{L1} = 0.003$ p.u.
- The capacitive reactance: $X_{C1} = 0.001$ p.u.
- Angle boot alpha α: Effect capacitive: $\alpha_{1\,\min} = 142^\circ$, $\alpha_{1\,\max} = 180^\circ$, $\alpha_1 = 143^\circ$.

And we insert this TCSC for branch (11.25). Result for Stage 1 are in Tabs. 1 and 2.

6.2 Stage 2

In this second simulation, the program inserts one TCSC and chooses the optimal emplacement in the electric power network (*ie* automatically).

6.2.1 TCSC parameters

1) The basic value is: $S_b = 100$ MVA.
2) The parameters of the controller power transits TCSC 1 are:

- The inductive reactance: $X_{L1} = 0.003$ p.u.
- The capacitive reactance: $X_{C1} = 0.001$ p.u.
- Angle boot alpha α: effect capacitive: $\alpha_{1\,\min} = 142^\circ$, $\alpha_{1\,\max} = 80^\circ$, $\alpha_1 = 143^\circ$.

Result for Stage 2 are in Tabs. 3 and 4.

6.3 Stage 3

In this second simulation, the program inserts one TCSC and chooses the optimal emplacement in the electric power network (*ie* automatically).

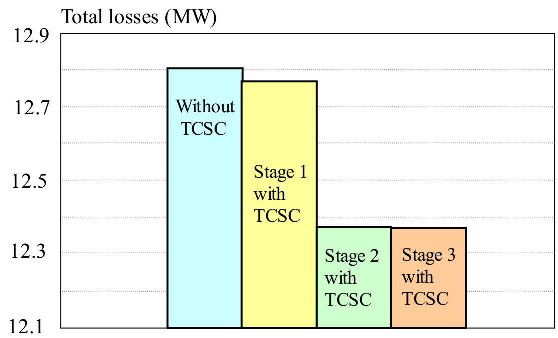

Fig. 2. Total operating losses for IEEE 26-system

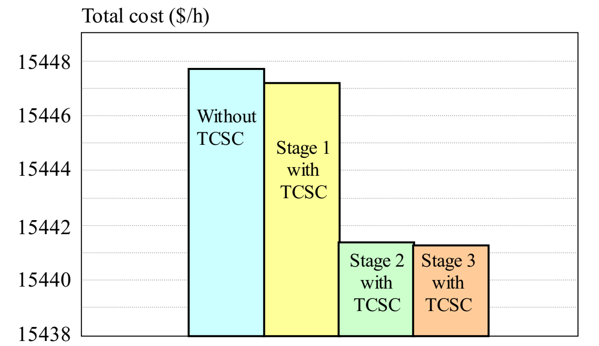

Fig. 3. Total costs for IEEE 26-system

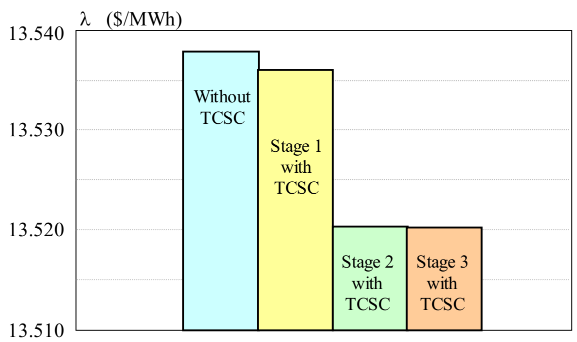

Fig. 4. Lambda factor for IEEE 26-system

6.3.1 TCSC parameters

1) The basic value is: $S_b = 100$ MVA.
2) The parameters of the controller power transits TCSC 1 are:

- The inductive reactance: $X_{L1} = 0.003$ p.u.
- The capacitive reactance: $X_{C1} = 0.001$ p.u.
- Angle boot alpha α: effect capacitive:
$\alpha_{1\,\min} = 142^\circ, \quad \alpha_{1\,\max} = 180^\circ$

And we insert this TCSC for branch (6-21). Result for stage 3 are in Tabs. 5 and 6.

6.4 Interpretation of results

In stage 1: Inserting Series by manual position for the network to 26 nodes, also satisfies the reduced loss in value to 12.8070 MW value 12.7728 for a range of integration and a choice of parameters with TCSC, given manipulator, which is the branch (11-25). It is linked to gather by following the decrease in the cost factor and the lambda.

In stage 2: The algorithm "Insert serial position automatically for a network to 26 nodes and following the introduction of parameters TCSC1, the location of the optimal location is the branch (5-6). The best location has a significant and effective loss of the value of Pt =12.8070 MW value Pt =12.3762 MW, followed by reductions in other factors, cost: value 15447.72 \$/h to value 15441.40 \$/h, the lambda factor: the 13.538113 \$/MWh to value 13.520394 \$/MWh, and the reduction of powers best there is without exceeding the limits imposed by the criterion of optimization.

In stage 3: In the simulation, the program changes its objective. We must insert the TCSC in the network, where we indicated the values of the reactance XL, XC, the limits of the firing angle and location of insertion. The need for the program is to locate the best angle adjustment within the limits imposed. Indeed the results are satisfactory as for the insertion of TCSC in class (5-6), total losses have decreased by 12.8070 MW to 12.3750 MW, the cost of 15447.72 \$/h to 15441.39 \$/h and the lambda factor of 13.538113 \$/MWh at 13.520152 \$/MWh. These are obtained for a setting angle of 158.72 degrees, a larger network than the first test.

7 SUMMARY

In this section, the optimization goal is to make best use of network capacity. TCSC devices are placed in the system to maximize power served to consumers, while observing the constraints of security.

A new and more effective TCSC-OPF model than is currently available in the literature has been presented in this work. The thyristor-controlled series capacitor (TCSC) has introduced a new state variable in OPF formulation, combined with the nodal magnitudes and angles of voltage electricity network in a single frame of reference for iterative solutions via unified Newton method. In the proposed algorithms, the thyristor is set to achieve an optimal level of compensation under the constraints of power through the compensation branch.

The offsets are chosen by the algorithms, leading to more economical solutions in cases where the power is fixed at a specified value.

The extension of the Newton OPF algorithm has proven to be a powerful tool capable to solving insertion of TCSC controller.

The task of finding the best parameters to be introduced to the thyristor-controlled series capacitor (TCSC) was considered a serious problem, therefore, has received much attention and research time.

The effectiveness of the algorithm was illustrated by a numerical example network to 26 nodes. These results clearly show that the algorithms have the flexibility and reliability for convergence.

Finally, we conclude that the improved performance of the system studied is dependent on diversity and freedom of management TCSC device in the system from the proposed programs.

APPENDIX

Table 7. Branch data

Line n^0	Line	R(p.u)	X(p.u)	$B/2$(p.u)	a
1	1–2	0.00055	0.00480	0.03000	1
2	1–18	0.00130	0.01150	0.06000	1
3	2–3	0.00146	0.05130	0.05000	0.96
4	2–7	0.01030	0.05860	0.01800	1
5	2–8	0.00740	0.03210	0.03900	1
6	2–13	0.00357	0.09670	0.02500	0.96
7	2–26	0.03230	0.19670	0.00000	1
8	3–13	0.00070	0.00548	0.00050	1.017
9	4–8	0.00080	0.02400	0.02400	1.050
10	4–12	0.00160	0.02070	0.01500	1.050
11	5–6	0.00690	0.03000	0.09900	1
12	6–7	0.00535	0.03060	0.03060	0.00105
13	6–11	0.00970	0.05700	0.00010	1
14	6–18	0.00374	0.02220	0.00120	1
15	6–19	0.00350	0.06600	0.04500	0.95
16	6–21	0.00500	0.09000	0.02260	1
17	7–8	0.00120	0.00693	0.00693	0.00010
18	7–9	0.00095	0.04290	0.02500	0.95
19	8–12	0.00200	0.01800	0.02000	1
20	9–10	0.00104	0.04930	0.00100	1
21	10–12	0.00247	0.01320	0.01000	1
22	10–19	0.05470	0.23600	0.00000	1
23	10–20	0.00660	0.01600	0.00100	1
24	10–22	0.00690	0.02980	0.00500	1
25	11–25	0.09600	0.27000	0.01000	1
26	11–26	0.01650	0.09700	0.00400	1
27	12–14	0.03270	0.08020	0.00000	1
28	12–15	0.01800	0.05980	0.00000	1
29	13–14	0.00460	0.02710	0.00100	1
30	13–15	0.01160	0.06100	0.00000	1
31	13–16	0.01793	0.08880	0.00100	1
32	14–15	0.00690	0.03820	0.00000	1
33	15–16	0.02090	0.05120	0.00000	1
34	16–17	0.09900	0.06000	0.00000	1
35	16–20	0.02390	0.05850	0.00000	1
36	17–18	0.00320	0.06000	0.03800	1
37	17–21	0.22900	0.44500	0.00000	1

$$\text{Cost} = \begin{bmatrix} 240 & 7.0 & 0.007 \\ 200 & 10.0 & 0.0095 \\ 220 & 8.5 & 0.009 \\ 200 & 11.0 & 0.009 \\ 220 & 10.5 & 0.0080 \\ 190 & 12 & 0.0075 \end{bmatrix} \qquad \text{Mwimits} = \begin{bmatrix} 100 & 500 \\ 50 & 200 \\ 80 & 300 \\ 50 & 150 \\ 50 & 200 \\ 50 & 120 \end{bmatrix}$$

References

[1] ACHA, E.—FUERTE-ESQUIVEL, C. R.—AMBRIZ-PÉREZ, H.—ANGELES-CAMACHO, C.: FACTS, Modelling and Simulation in Power Networks, John Wiley & Sons Ltd, 2004.

[2] ZHANG, S. P.—REHTANZ, C.—PAL, B.: Flexible AC Transmission Systems: Modelling and Control, Springer, Berlin, Heidelberg, New York, 2006.

[3] DOMMEL, H. W.—TINNEY, W. F.: Optimal Power Flow Solutions, IEEE Trans. Power Apparatus and Systems **PAS-87** No. 10 (1968), 1866-1876.

[4] MARIA, G. A.—FINDLAY, J. A.: A Newton Optimal Power Flow Program for Ontario Hydro EMS, IEEE Trans. Power Systems **PWRS-2** No. 3 (1987), 576-584.

[5] MONTICELLI, A.—LIU, W. H. E.: Adaptive Movement Penalty Method for the Newton Optimal Power Flow, IEEE Trans. Power Systems **7** No. 1 (1992), 334-342.

[6] SUN, D. I.—ASHLEY, B.—BREWER, B.—HUGHES, A.—TINNEY, W. F.: Optimal Power Flow By Newton Approach, IEEE Trans. Power Apparatus and Systems **PAS-103** No. 10 (1984), 2864-2880.

[7] DAS, D.: Electrical Power Systems, New Age International (P) Ltd, Publishers.

[8] FUERTE-ESQUIVEL, C. R.—ACHA, E.—AMBRIZ-PÉREZ, H.: A Thyristor Controlled Series Compensator Model for the Power Flow Solution of Practical Power Electronic, IEEE Transactions on Power Systems **15** No. 1 (Feb 2000).

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