MVA-Km Method and Genetic Algorithm for a Comprehensive Transmission Cost Allocation by AC Power Flow

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Abstract
The charge of electricity has emerge as the focal point of all activities in the power market. It is essential to increase the correct pricing scheme that may offer the beneficial economic information to marketplace members, including technology, transmission companies and customers. Although many methods have already been proposed, however appropriately estimating and allocating the transmission cost within the transmission pricing scheme remains a difficult task. This paper presents a MVA-Km method and Genetic Algorithm to allocate the cost pertaining to the transmission lines of the network to all the generators and demands. A load flow solution is run and, the proposed method determines how line flows depend on nodal currents. This result is then used to allocate network costs to generators and demands.

Keywords— Loadflow, Power market, AC Power Flow, MVA-Km Method,Genetic Alogorithm.

I. INTRODUCTION

In Eighties, almost all electric powered energy utilities all through the world were operated with an organizational model wherein one controlling authority operated the generation, transmission, and distribution systems positioned in a set geographic location and it refers to as vertically incorporated electric utilities(VIEU). Economists for some time had puzzled whether or not this monopoly corporation became efficient. With the instance of the financial advantages to society resulting from the deregulation of different industries including telecommunications and airlines, electric powered utilities also are introducing privatization in their sectors to improve performance. in the course of the Nineteen Nineties many electric utilities and energy network corporations international huge have been pressured to exchange their methods of doing commercial enterprise from vertically integrated mechanism to open marketplace gadget. This kind of system is called as deregulation or restructuring or unbundling.

Deregulation phrase refers to un-bundling of electrical utility or restructuring of electrical utility and allowing non-public companies to take part. The purpose of deregulation is to introduce an detail of opposition into electric energy shipping and thereby allow market forces to price power at low rates for the patron and higher performance for the suppliers and the necessity for deregulation are to offer less expensive energy, to provide greater preference to the patron in purchasing the economic Energy, to give greater choice of generation, to offer higher services with respect to power quality i.e. constant voltage, steady frequency and uninterrupted electricity supply.

In this paper we propose the problem of transmission network cost allocation also presents the solution methodology AC load flow using proportional sharing principle with MVA-Km method and genetic algorithm by generating random real integer apparent power flows and to minimize the total transmission cost. We use the 6 bus test system to validate the methodology.

This paper is organized as follows: Section II presents a short review of the different transmission pricing methods and in Section III we present the proposed methodologies for transmission cost allocation. Section IV presents the results and analysis and finally Section V concludes the discussion.

II. TRANSMISSION PRICING METHODS

The objective of any transmission pricing method is to allocate all or part of the existing and the new cost of transmission system to customers. However, tariffs for transmission services are more often set by government regulations, and are based on its policy directives. The pricing of transmission services should be carried out to achieve the following goals are It recovers the capital and operating costs, It encourages efficiency of use and investment, It provides equal opportunity to all users, It offers a simple and understandable price structure, It is easily implementable. In general, the following three pricing schemes are employed for transmission services:

- Rolled-in (embedded) transmission pricing
- Marginal transmission Pricing
- Composite transmission pricing

The transmission costs may include:

- Running costs, such as costs for operation, maintenance, and ancillary services.
- Past capital investment.
- Ongoing investments for Future expansion

Next, we discuss major transmission cost allocation methods. Some of these methods are used widely by electric utilities, while others are still in developmental stages.

1. Postage Stamp Rate Method
2. Contract Path Method
3. MW-Km Method
4. MVA-Km Method
5. Proportional Sharing Principle (PSP Method)
6. Unused Transmission Capacity Method

III. METHODOLOGY FOR TRANSMISSION COST ALLOCATION

A. MVA-Km Methd

MVA-Km approach can think about both active and reactive power loading of the transmission network due to the transaction and subsequently allocates embedded value of transmission consequently. therefore a transaction causing greater reactive power loading will be allotted extra value than different transactions. normally, the MVA-Km approach is known as flow-mile technique.

PSP method follows the upstream looking algorithm and downstream looking algorithm. In the upstream looking algorithm, the transmission usage or supplement charge is allocated to individual generators and losses are assigned to loads. In the downstream looking algorithm, the transmission usage or supplement charge is allocated to individual loads and losses are assigned to generators.

a. Formation of Branch Incidence Matrix (E) for MVA-Km Method

Consider a network consisting of **n** nodes and **b** branches and define P, SP_G and SP_D as $(n\times 1)$ vectors of nodal apparent power flows, nodal generations and nodal demands respectively, and F as $(b\times 1)$ vector of branch flows, these are calculated from AC PF model. The $(b\times n)$ incidence matrix **E** can be formed by considering '+1' for sending end node and '-1' for receiving end node. If there is any node, that does not belongs to particular branch can be assigned zero. This matrix E can be split into matrix E_u consisting of -1's and E_d consisting of +1's.

b. Formation of Adjacency Matrix (D) and Branch Flow Matrix (F_d)

The adjacency matrix (D) is defined as $(n\times n)$ matrix with $[D]_{ij} = 1$ if there is a flow from node **i** to node **j.** The adjacency matrix can be expressed as follows.

$$D = -E_d^T E_u \qquad (1)$$

The branch flow matrix (F_d) with $(n\times n)$ size, such that its (ij) element is equal to the flow in line i-j towards node j (ie, downstream). F_d can be expressed as follows,

$$F_d = -E_d^T \mathrm{diag}\,(APF) E_u \qquad (2)$$

Where, APF is apparent power flow vector which is taken from AC power flow.

c. Formation of Nodal Powers and Allocation Matrices

The element (i.j) of $\mathbf{F_d^T}$ is equal to the flow in line i-j towards i (ie, upstream). The Kirchhoff Current Law (KCL) can be expressed to nodal powers as,

$$P = SP_D + F_d.1 \qquad (3)$$

or $P = SP_G + F_d^T.1$ (4)

Where, 1 is $(n\times 1)$ vector of ones.

The upstream allocation matrix (A_u) is the sparse and non-symmetric matrix and it can be expressed as,

$A_u = I + E_u^T \mathrm{diag}(F) E_d [\mathrm{diag}(P)]^{-1}$ (5)

Similarly, the downstream allocation matrix (A_d) can be expressed as,

$A_d = I + E_d^T \mathrm{diag}(F) E_u [\mathrm{diag}(P)]^{-1}$ (6)

d. Allocation of Networks to Branch Flows

The proportional sharing principle allows also one to express branch flows as the sum of components supplied from individual generators or to individual loads.

Down Stream

$$P_{bk} = \frac{P_{ij}}{P_i} \sum_{k=1}^{n} [A_{u(i,k)}]^{-1} SP_{Gk} \quad \text{for} \quad j \in \alpha_i^d \qquad (7)$$

where, α_i^d = set of nodes supplied directly from node i

b = Branches

k = Buses (Generator Bus)

P_i = Nodal power

$SP_{G\,k}$ = Apparent power at bus k

P_{ij} = Branch power flow ($i \in$ upstream, $j \in$ downstream)

Up Stream

$$P_{bk} = \frac{P_{ij}}{P_i} \sum_{k=1}^{n} [A_{d(i,k)}]^{-1} SP_{Dk} \quad \text{for} \quad j \in \alpha_i^u \qquad (8)$$

where, SP_{Dk} = Apparent load at bus k

k = Buses (Load bus)

P_{ij} = Branch power flow ($j \in$ upstream, $i \in$ downstream)

α_i^u = Set of nodes supplying node i

e. Algorithm

1. Read the input data LP(k),LQ(k),r(k),x(k), ycp, ycq, vspe, del, Q_{min}, Q_{max}, p_{gen},q_{gen},p_{load},q_{load}
2. Run the AC Power flow and calculate the power flows on each line
3. The Branch Incidence matrixes (E) for the network are formed. The Upstream and Downstream Incidence matrices (E_u and E_d) are also formed.
4. The Adjacency matrix (D) and Branch Apparent power flow matrix (APF_d) using Eqn. 1 and Eqn.2 are computed.
5. The vector of nodal powers P using Eqn. 3 is computed. The upstream and downstream allocation matrices (Au and $A_{d)}$ using Eqn.5 and Eqn. 6 are also computed.
6. Allocations of generation and demand networks to branch flows are evaluated using Eqn. 7 and Eqn. 8.
7. calculate the transmission cost using MVA-Km method take the individual generators and loads flows. This technique develops a set of real power contribution factors and a set of reactive power contribution factors, which uses the result of AC power flow and law of conservation of complex power. The line apparent power flow is multiply with line Length (in Km) and cost per MW (in Rs/hr) and summed over all the network lines as

(Down stream) MVA-Km = ∑ (Ck*Lk*APFtk)

(Up stream) MVA-Km = ∑ (Ck*Lk*APFtk)

APFtk = apparent power flow on line Calculating the transmission cost to individual generators and loads and The total transmission capacity cost is determined to individual generators and loads

(Down Stream)

TOTAL_COST=MVA-Kmg1+ MVA-Kmg2…+ MVA-Kmgn

(Up Stream)

TOTAL_COST=MVA-Kmd1+MVA-Kmd2….+ MVA-Kmdn

B. Genetic Algorithm

A genetic algorithm (or GA) is a search technique used in computing to find true or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. Genetic algorithms are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover.

a. Algorithm

1. Read the input data line length, MVA line limits, sending end and receiving end buses
2. Generate randomly apparent power flows population of n chromosomes. Multiply the random generated apparent power flows with transmission line length and cost
3. Find the total transmission cost (obj(x))
4. Evaluate the fitness f(x) of each chromosome x in the population F(x) = 1/1+ (obj (x))
5. Sorting: sort the population according to the fitness ascending order create a new population by repeating following steps until the new population is complete
6. Convergence check: fitness of first chromosome in the population is equal to the last chromosome in the population
7. Parent selection: using roulette wheel.
8. With a crossover probability crossover the parents to form new offspring by using blend alpha. Cross over Γ=((1+2*alpha)*rand-alpha) Alpha=0.5
9. With a mutation probability mutate new offspring at each locus by using non-uniform mutation.
10. Checking the MVA limits of transmission line
11. With new flows multiply line length and cost. Calculate the total transmission cost.
12. If the end condition is satisfied, stop and return the best solution in current population
13. Go to step 4.

IV. RESULTS AND ANALYSIS

This system consists of 6 buses, 11linesections, 3generator buses. Figure 1 shows the line diagram for the 6-bus system. Bus 1 is assumed to be reference bus.

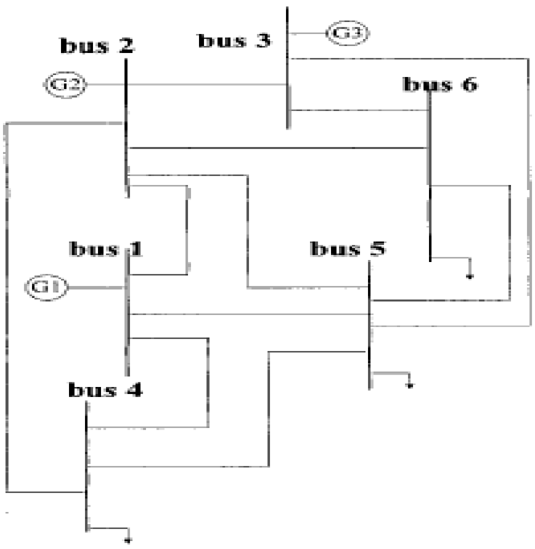

Fig. 1. 6 bus test system

The results for AC power flow with MVA-KM Method Power flow tracing (Down Stream)
Convergence - 0.0001
Cost per MW - 100Rs
RP - Real power, RAP - Reactive power

Table: 1 Power contribution of generators to lines for 6 bus system MVA-Km method (Down Stream)

Transmission Lines LP(k) to LQ(k)	Generator 1 real power flows PG1	Generator 2 real power flows PG2	Generator 3 real power flows PG3
1-2	0.2433	0.0000	0.0000
1-4	0.3696	0.0000	0.0000
1-5	0.3020	0.0000	0.0000
2-3	0.0067	0.0122	0.0000
2-4	0.0760	0.1377	0.0000
2-5	0.0357	0.0646	0.0000
2-6	0.0604	0.1093	0.0000
3-5	0.0053	0.0096	0.1094
3-6	0.0121	0.0219	0.2505
4-5	0.0208	0.0091	0.0000
5-6	0.0061	0.0018	0.0026

Table: 2 Power contribution of generators to lines for 6 bus system MVA-Km method (Down Stream)

Transmission Lines LP(k) to LQ(k)	Generator 1 reactive power flows PG1	Generator 2 reactive power flows PG2	Generator reactive power 3 flows PG3
1-2	-0.1307	0.0000	0.0000
1-4	0.1706	0.0000	0.0000
1-5	0.0955	0.0000	0.0000
2-3	-0.0282	-0.0510	0.0000
2-4	0.1058	0.1915	0.0000
2-5	0.0353	0.0639	0.0000
2-6	0.0285	0.0516	0.0000
3-5	0.0064	0.0116	0.1325
3-6	0.0168	0.0304	0.3473
4-5	-0.0252	-0.0111	0.0000

5-6	-0.0362	-0.0107	-0.0153

Table: 3 Power wheeling pricing using MVA-Km method for 6 bus system (Down Stream)

Transmission Lines LP(k) to LQ(k)	Generator 1 flows Multiple with transmission line length PG1	Generator 2 flows Multiple with transmission line length PG2	Generator 3 flows Multiple with transmission line length PG3
1-2	15962.00	0.0000	0.0000
1-4	11766.00	0.0000	0.0000
1-5	14664.00	0.0000	0.0000
2-3	838.00	1517.00	0.0000
2-4	3765.00	6817.00	0.0000
2-5	2899.00	5249.00	0.0000
2-6	2703.00	4894.00	0.0000
3-5	576.00	1043.00	11924.00
3-6	240.00	434.00	4967.00
4-5	3780.00	1659.00	0.0000
5-6	2123.00	626.00	894.00
Wheeling Price	59316.00	22238.00	17785.00

MVA-Km Total Wheeling Cost of the system
TWC=59316.00+22238.00+17785.00 = 99339.00 Rs/hr

The results for AC power flow with Genetic Algorithm technique Power flow tracing.

The no of buses - 6
The no of lines - 11
No of generators - 3
Cost per MW - 100 Rs/hr
Population Size - 50
Chromosome length - real coded

Table: 4 Apparent power contribution of generators to lines for 6 bus system by GA

Transmission Lines LP(k) to LQ(k)	Generator 1 flows APG1	Generator 2 flows APG2	Generator 3 flows APG3
1-2	0.06533	0.003424	0.00480

1-4	0.16273	0.08602	0.04750
1-5	0.04507	0.09781	0.10495
2-3	0.16649	0.00411	0.00656
2-4	0.09746	0.00622	0.00803
2-5	0.03671	0.05276	0.0588
2-6	0.04223	0.02350	0.0101
3-5	0.20050	0.00183	0.1196
3-6	0.22168	0.07814	0.00538
4-5	0.06597	0.06274	0.02773
5-6	0.05099	0.00984	0.02906

Table: 5 Power Wheeling pricing for 6 bus system GA

Transmission Lines LP(k) to LQ(k)	Generator 1 flows Multiple with transmission line length WC1	Generator 2 flows Multiple with transmission line length WC2	Generator 3 flows Multiple with transmission line length WC3
1-2	3776.52	197.88	277.61
1-4	4703.75	2486.00	1372.82
1-5	2086.75	4528.65	4859.57
2-3	4811.76	119.04	189.69
2-4	2816.77	179.74	232.08
2-5	2121.84	3049.50	3399.86
2-6	1710.29	951.96	412.02
3-5	13915.54	127.17	8303.06
3-6	2571.54	906.43	62.48
4-5	7626.25	7253.20	3206.32
5-6	2947.32	568.75	1679.86
Wheeling Price	49087.39	20368.36	23995.43

Total Transmission Cost using Genetic algorithm
TWC=49087.39+20368.36+23995.43=93451.18Rs/hr

Table: 6 Comparison between AC power flow using MVA-Km Method and Genetic Algorithm for 6 bus test system

Conventional Technique (Downstream)	Genetic Algorithm
99339.00Rs/hr	93451.18Rs/hr

Genetic algorithm is a method which helps us redistribute the flows for proper transmission cost allocation. By the application of MVA-Km method, the results generated have given us a cost.

Further redistribute the power flows, and to ensure that the cost is minimized, the power flows is reworked with genetic algorithm technique. Which has resulted in minimized costs as obtained for 6 bus system (as tabulated above).

V. CONCLUSION

Power system deregulation and transmission open access makes it become more and more important to calculate the contributions of individual generators to individual line flows. The present paper discussed transmission cost allocation in deregulated power system using methods MVA-Km and Genetic algorithm.

New approach for power wheeling pricing called MVA-Km Method applying AC power flow is proposed in this paper. The proposed method has the merit of being able to trace both real and reactive power. It is observed that, this method considering apparent power for wheeling pricing is more reasonable and suitable for real time power system and valid than the commonly used MW-Km method which is based on DC power flow

Genetic algorithm is a method which helps us to redistribute the flows for proper transmission cost allocation. For optimal distribution of power flows to ensure that the transmission cost is minimized, the power flows is reworked the genetic algorithm technique. Studies were carried out on 6bus system. Using genetic algorithm and power flow tracing techniques, it is observed that the minimum transmission cost is obtained using genetic algorithm compared to downstream power flow tracing algorithm. Optimal transmission cost allocation is possible with genetic algorithm because of optimal distribution of power flows throughout the transmission system.

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