Embedded Cost Allocation Method: Comparison and Discussion Of Used Methods

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Abstract— This paper presents and analyses several methods for embedded cost allocation in deregulated electricity market environment. In this paper six embedded cost methods (postage stamp method, contract path method, MW-Mile, MW-cost, MVA-Mile, MVA-cost) are evaluated and tested on 6-Bus test system subjected to two bilateral wheeling transaction. The charges obtained from the different embedded cost methods are then compared.

Keywords— Embedded cost methods, postage stamp method, contract path method, MW methods, MVA methods.

I.   Introduction

In the deregulated electricity structure transmission pricing of services places an important role. The cost of transmission network can be interpreted as the cost of operation, maintenance and planning of the transmission services. Several methodologies have been proposed for all or part of the existing network cost to the users of the transmission system. Some of the methods such as postage stamp, contract path, MW-Mile are based on the actual network usage of a transaction and can be addressed as embedded cost method [1]. Fundamental principle of any transmission pricing scheme is to allocate all or part of the existing and new cost of transmission system to the consumers. Embedded cost of the network is allocated to the users in proportion to their 'extent of use' of the transmission resources.

Embedded cost is defined as the revenue requirement needed to pay for all existing facility plus any new facility added to the power system during the life of the contract for transmission service[2]. Of all embedded cost methods postage stamp method is the simplest one. In its simplest form this method is independent of the distance wheeled. In general, the postage stamp method does not give correct incentives to suppliers or users of electrical energy for sitting future investment or for an efficient use of the grid in the short term. Contract path method is used when a path is specified for each transaction; this method is also simple in calculation but ignores the actual system operation. MW-Mile method is based on the idea that the power flow kilometer

on the transmission due to transaction is calculated by multiplying the power flow and length of the line. MW-Mile method only considers the active power flow on line due to transaction and does not consider the reactive power flow this problem is overcome in the MVA-Mile method. MVA-Mile method considers both active and reactive power flows on the transmission lines due to particular transaction.

II.   Embedded Cost Methods

This paper evaluates the following eight embedded methods:
   A. Postage stamp method.
   B. Contract path method.
   C. MW-Mile method.
   D. MW-Cost method.
   E. MVA-Mile method.
   F. MVA-Cost method.
   G. Modulus method
   H. Zero-counter flow method

A. Postage stamp method

This method is traditional method and also called as rolled-in embedded method. In this method total cost are allocated proportionally to transaction amount of each party. This method is simplest among all embedded cost methods and also easy in implementation. This method is independent of the actual system operation and does not give correct incentives to suppliers or users of electrical energy system for future investment. For any transaction T cost of transmission transaction is given by the following equation;

$$Cat = (T.C)*Pt/Ppeak \qquad (1)$$

Where;
T.C = Total cost (sum of all facility cost)
Pt   = Transacted power
Ppeak = sum of all active load of the transmission system including transaction.

B. Contract path method

This is the second traditional embedded cost method. This method also ignores the actual system operation. This method is based on the concept that the power due to a

particular transaction is confined to flow along specified electrical continuous path. Changes in flows of facilities that are not along the specified path are not considered in the calculation. For any transaction T cost of transaction in contract path method is given by the following equation;

$$C_{at} = P_t * \frac{\sum_{path} C_f}{P_{min.path}} \tag{2}$$

Where:

P_t = transacted power

$\sum_{path} C_f$ =cost of facilities along the specified path

$P_{min.path}$ = maximum long term rating of the transmission line along the specified path

C. MW-Mile method

This method is based on the idea that transaction cost is proportional to the change in MW flows in the facilities multiplied by length of the facilities. MW- mile method is based on DC load flow. Drawback of this method is that it only considers active power flow on transmission line due to a transaction and not considers the reactive power flow. For any transaction T cost (€/hr) due to MW-Mile method is given by the following equation;

$$C_{at} = \frac{C * \sum_f (\Delta MWf) T * Lf}{8760 * \sum_T \sum_f (\Delta MWf) T * Lf} \tag{3}$$

Where;

(ΔMW) = MWf (with T) – MWf (without T)

Lf= Length of transmission facility f

(MWf)T= MW flow in facility f due to transaction T.

D. MW-Cost method

In this method transaction cost is proportional to the change in MW flows in facilities multiplied by cost of the facilities. For any transaction T cost (€/hr) due to MW-Cost method is given by the following equation;

$$C_{at} = \frac{C * \sum_f (\Delta MWf) T * Cf}{8760 * \sum_T \sum_f (\Delta MWf) T * Cf} \tag{4}$$

Where;

(ΔMW) = MWf (with T) – MWf (without T)

Cf= Cost of transmission facility f

(MWf)T= MW flow in facility f due to transaction T.

E. MVA-Mile method

MVA-Mile method is based on the AC load flow solution. Therefore this method consider both active and reactive power flows in facility due to a transaction. In this method transaction cost is proportional to the change in MVA flows in facilities multiplied by length of the facilities. For any transaction T cost (€/hr) due to MVA-Mile method is given by the following equation;

$$C_{at} = \frac{C * \sum_f (\Delta MVAf) T * Lf}{8760 * \sum_T \sum_f (\Delta MVAf) T * Lf} \tag{5}$$

Where;

(ΔMVA) = MVAf (with T) – MVAf (without T)

Lf= Cost of transmission facility f

(MVAf)T= MVA flow in facility f due to transaction T

F. MVA-Cost method

In this method transaction cost is proportional to the change in MVA flows in facilities multiplied by cost of the facilities. For any transaction T cost (€/hr) due to MVA-Mile method is given by the following equation;

$$C_{at} = \frac{C * \sum_f (\Delta MVAf) T * Cf}{8760 * \sum_T \sum_f (\Delta MVAf) T * Cf} \tag{6}$$

Where;

(ΔMVA) = MVAf (with T) – MVAf (without T)

Cf= Cost of transmission facility f

(MVAf)T= MVA flow in facility f due to transaction T

G. Modulus method

Modulus method only considers the absolute values of change in MW flows in facilities due to a particular transaction. . For any transaction T cost (/hr) due to Modulus method is given by the following equation;

$$C_{at} = \frac{C * |\sum_f (\Delta MWf) T|}{|\sum_T \sum_f (\Delta MWf) T|} \tag{7}$$

Where;

$|\sum_f (\Delta MWf) T|$ =absolute values of change in Mw flows in facilities due to a particular transaction (MWf (with T) – MWf (without T))

$|\sum_T \sum_f (\Delta MWf) T|$ absolute values of change in facilities due to all transaction including base load flow

C=sum of all facility cost

H. Zero-counter flow method

The Zero Counter flow method only taxes the positive flows. This method assumes that the negative flows are beneficial for the network, therefore in these cases the transactions are not paid but also they do not have credit. It is given by the following equation;

$$C_{at} = \frac{C * \sum_f (\Delta MWf) T}{\sum_T \sum_f (\Delta MWf) T} \tag{8}$$

$$C_{at} = \begin{cases} \frac{C * \sum_f (\Delta MWf) T}{\sum_T \sum_f (\Delta MVAf) T} & \text{for } \sum_f (\Delta MWf) T > 0 \\ 0 & \text{for } \sum_f (\Delta MWf) T < 0 \end{cases}$$

Where;

(ΔMW) = MWf (with T) – MWf (without T)

(MWf)T= MW flow in facility f due to transaction T.

C=sum of all facility cost

III.   Case Study: 6-Bus Test System

In this paper eight embedded cost methods (postage stamp method, contract path method, MW-Mile, MW-cost, MVA-Mile, MVA-cost, Modulus and Zero-counter flow) are evaluated and tested on 6-Bus test system subjected to two bilateral wheeling transaction.6-bus test system consists of three generators of 100MW, 50MW and 60 MW at bus no.1, 2,3 respectively and three loads of 70MW each at bus no 4,5,6 respectively.
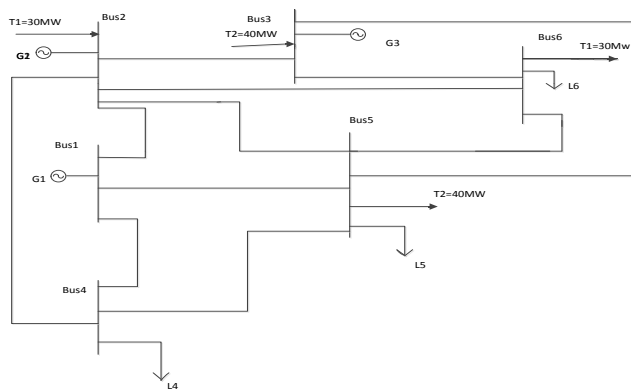
Figure 1: 6 Bus Test System

TABLE IV.   RESULTS AND DISSCUSION OF EMBEDDED COST METHODS

Cases	Postage stamp (€/hr)	Contract path (€/hr)	MW-Mile (€/hr)	MW- Cost (€/hr)
Transaction T1	111.113	33.02	-404.40	-497.6189
Transaction T2	148.15	75.45	173.5512	116.366
Pool	777.825	-	1361.1	1325.1
Cases	MVA-Mile (€/hr)	MVA-Cost (€/hr)	Zero counter (€/hr)	Modulus (€/hr)
Transaction T1	630.727	625.6474	124.8757	293.1995
Transaction T2	-35.2167	-23.5184	154.5811	179.9635
Pool	441.54	434.9258	757.598	563.8918

TABLE I.   TRANSACTION

Transactions	From Bus No.	To Bus No.	Value of transaction in MW
T1	2	6	30
T2	3	5	40

TABLE II.   LINE DATA OF 6-BUS SYSTEM

Line bus-bus	R(p.u)	X(p.u)	B/2 (p.u)	Length(k.m) Lf	Annual cost (K€/yr) Cf
1-2	0.1	0.2	0.02	578	1101
1-4	0.05	0.2	0.02	289	550.5
1-5	0.08	0.3	0.03	463	882
2-3	0.05	0.25	0.03	289	550.5
2-4	0.05	0.1	0.01	289	550.5
2-5	0.1	0.3	0.02	578	1101
2-6	0.07	0.2	0.025	405	885
3-5	0.12	0.26	0.025	694	1171.95
3-6	0.02	0.1	0.01	116	220.95
4-5	0.2	0.4	0.04	1156	970.2
5-6	0.1	0.3	0.03	578	1101

TABLE III.   BUS DATA OF 6-BUS SYSTEM

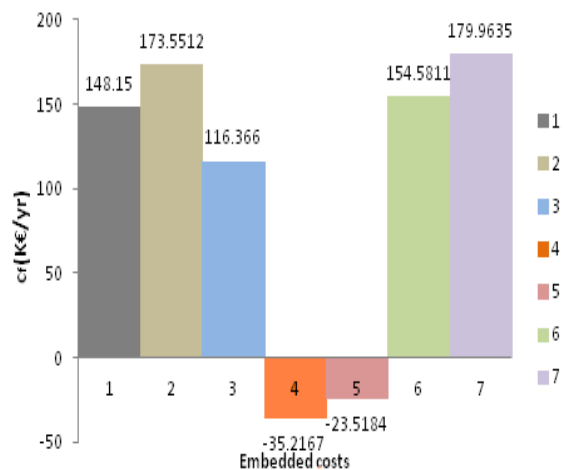| Bus no	Bus mode	V p.u	An-gle	P gen p.u	Q gen p.u	P load (p.u)	Q load (p.u)	Q max (p.u)	Q min (p.u)
1	Swing	1.05	0	0	0	0	0	100	-100
2	PV	1.05	0	0.5	0	0	0	100	-100
3	PV	1.07	0	0.6	0	0	0	60	-100
4	PQ	1	0	0	0	0.7	0.7	0	0
5	PQ	1	0	0	0	0.7	0.7	0	0
6	PQ	1	0	0	0	0.7	0.7	0	0

Figure 2: Embedded cost allocation of different methods using transaction1
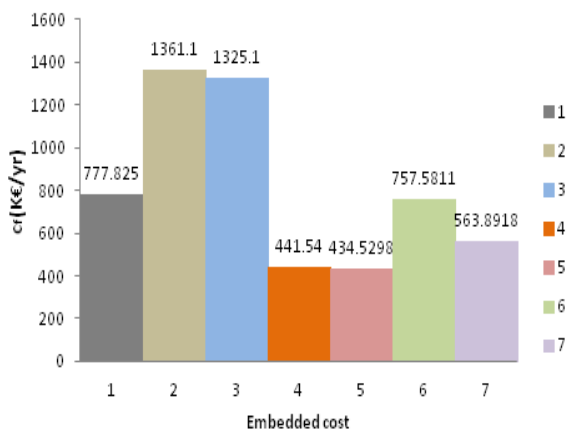

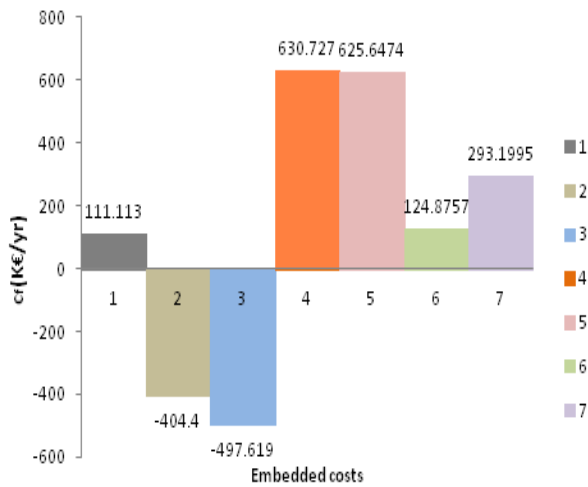Figure 3: Embedded cost allocation of different methods using transaction2

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Figure 4: Embedded cost allocation of different methods for the base case

IV.   Discussion

Out of the 8 methods, best method is the MVA-cost method, since it considers both active and reactive power flows on the lines and also cost in this method is less than the MW-mile and MW-cost methods. Table1 shows the two transactions of values 30Mw and 40 MW, table 2 shows the line data of 6-Bus test system, table 3 is the bus data of 6-Bus test system and table-4 shows the comparison of eight embedded cost methods

V.   Conclusion

This paper explains eight embedded cost methods (postage stamp method, contract path method, MW-Mile, MW-cost, MVA-Mile, MVA-cost, modulus, Zero counter flow). These methods are evaluated and tested on 6-Bus test system subjected to two bilateral wheeling transaction. The charges obtained from the different embedded cost methods are compared. Out of the eight embedded cost methods MVA-cost method is the best.

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