Introducing a New Method for Multiarea Transmission Networks Loss Allocation

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Abstract: Transmission loss allocation in very large networks with multiple interconnected areas or countries is investigated in this paper. The main contribution is to propose a method to calculate the amount of losses due to activity of each participant in the multi area markets. Pricing of cross-border trades in Multi area systems is often difficult since individual countries may use incompatible internal transmission pricing regimes, and they are usually unwilling to disclose any sensitive information about their own systems.
A new methodology based on the loss formula concept for allocating electric losses to generators and loads is presented in this paper. The only data required are the power flows and characteristics of tie-lines and PV Ward equivalent model of area networks from border nodes point of view. Proposed methodology is tested on the IEEE 118 node network which is divided into three areas, each with a different internal transmission pricing methodology. In the proposed methodology no information is required about individual loads, generations or detailed internal networks. It is also shown to be simple, transparent and very fast and it can deal effectively with multiple pricing policies.

Keywords: Loss Allocation, Multiarea Power Systems, PV Ward Model, Restructured Systems, Tie Line Losses.

1 Introduction

Despite many efforts to fair allocation of transmission system losses, it is yet an open issue in deregulated electric power systems and really needs to be discussed.
As the losses in each circuit are expressed by a nonlinear function of all power injections, it becomes almost impossible to calculate exactly the associate quota that each load or generator causes to the system. Also most of previously proposed algorithms in literature have considered the power market as a limited (single area) or country based power systems [1]. But due to reliability and economic matters, the real power systems have connected to their neighborhood networks through tie lines and shaped a large multi-area power system. So the loss allocation in multiarea systems is more difficult.
One idea to solve this problem is treating the multiarea network as a very large single area including an international operator (IO) [2] with access to detailed information of transmission network and transactions in all areas which runs a single-area loss allocation.
After that the IO assigns inter-area and local network loss costs among all areas and finally each area distributes the combined tie-line, inter-area, and local use charges among its local generators and consumers in a pro rata manner [6]. But implementation of this idea faces to many practical problems such as IO which coordinates the overall loss allocation process needs to have access on detailed data (the cost and impedances of all transmission equipment across the multiarea network) but this information is unlikely to be available because the unwillingness of individual utilities to disclose commercially sensitive information about their networks, customers and transactions.
IO must be kept up to date on multiarea network. In this case for any change in market exchange pattern due to rescheduling of power dispatch (for example in hourly basis markets after each hour rescheduling) and also, changing in network structure, the total system information of all areas (including network structure, all generation and loads) should be transferred to IO through a communication media and should be updated for any change. Because of the large size of real power systems it is obvious that the requirement to share such data is actually cumbersome if not impossible in very large systems with multiple independent transmission organizations.
Various regional markets have different market clearing prices and pricing regimes on the other hand one of the most important features of a loss allocation scheme is the consensus of all market participants about it and also

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in a large multi area network, because of large number of participants with different conditions it is not easy to persuade all GenCos and consumers to accept a unique scheme. Therefore applying a uniquely defined pricing policy by IO is so controversial.

Most of works just solved the loss allocation problem for a limited (single area) or country based power systems [1] and there are a few papers addressing to multiarea network loss allocation.

In [3] Silva and Costa discussed this problem using ITL method following their previous work for a single market system. In this method the total system losses are shared among market participants, according to the sensitivities of the transmission losses in relation to the bus active injections [4]. They considered fictitious buses in multiarea systems for decentralized applying ITL method but finally have done a centralized loss allocation. Bialek, et.al. progressed the well known power tracing method to solve this problem in [5]. They considered each network area as a single node in their study. In this way it was easily possible to allocate the tie lines power losses among participant networks in the basis of proportional shearing principle. The method proposed in [6], has considered the effect of other areas on each area internal losses as well as tie line losses. But, it has used the concept of pro rata method known as a simplest way which can not consider network topology on its calculations. In both methods described in [5], [6] total losses allocated to one area is depend on loss allocation method which adopted by itself and other areas. Reference [7] generalized the Z-bus method to use it in loss allocation of multiarea networks.

This paper proposes an alternative multiarea transmission loss allocation scheme that uses a new loss formula based allocation method [8]. In this strategy first each area implements its own loss allocation method in its local network and importing and exporting buses are treated as virtual generators and loads, respectively. After that to calculate the interchange losses, the PV Ward reduced model of each network is used [9]. Then using proposed method [8] , total losses is allocated to these equivalent networks of each area, which is distributed by the area regional operator (RO) among its generators and loads.

Main advantages of the proposed method are that each regional operator (RO) requires detailed access to its internal technical and cost data only. So each area may uses different internal transmission loss charging methodologies and no information is required about other area transactions, load/generation profiles or internal networks. Also the IO requires access only to data about the tie-line network interconnecting the areas and Ward equivalent network of area. This exchange of data between the ROs and the IO is very limited compared to the complete data exchange.

This approach considers the internal characteristics such as network well-connectivity and power dispatching pattern in interchange loss allocation. Also there is no dependency between allocated losses to the areas and internal loss allocation methods of them.

This paper is organized as follows. Section 2 reviews single area loss allocation methods. In Section 3 the proposed algorithms is described and discussed. Section 4 illustrates and validates the proposed methodology using the IEEE 118 node network. Section 5 concludes that this is a proper technique for allocating losses and charges.

2 Single Area Loss Allocation Method Review

This loss allocation method is a simple and straightforward scheme which can be used by RO of a power market to share the total transmission system losses between market participants. This method directly uses the loss formula and explains it as the sum of separate terms of nodal power injections [8].

Total losses of a typical n -node power system is:

$$P_{loss} = \sum_{i=1}^{n} P_i \tag{1}$$

where P_i is active power injection at each bus i

$$P_{loss} = \Re\left\{\sum_{i=1}^{n} S_i\right\} = \Re\left\{\sum_{i=1}^{n} V_i I_i^*\right\} \tag{2}$$

And easily concluded

$$P_{loss} = \Re\left\{\sum_{i=1}^{n} I_i^*\left(\sum_{j=1}^{n} Z_{ij} I_j\right)\right\} \tag{3}$$

But $Z = R + jX$ and $V_i = E_i\angle\delta_i$ so

$$P_{loss} = \Re\left\{\sum_{i=1}^{n} I_i^*\left(\sum_{j=1}^{n} R_{ij} I_j\right)\right\} + \Re\left\{\sum_{i=1}^{n} I_i^*\left(\sum_{j=1}^{n} JX_{ij} I_j\right)\right\} \tag{4}$$

But it is obvious that the second term is zero because it is equal to $\sum_{i=1}^{n}\sum_{j=1}^{n} X_{ij}\left|I_i\right|\left|I_j\right|\sin\left(\angle I_i - \angle I_j\right)$. So

$$P_{loss} = \Re\left\{\sum_{i=1}^{n}\left(\frac{P_i + jQ_i}{E_i\angle\delta_i}\right)\left(\sum_{j=1}^{n} R_{ij}\left(\frac{P_j - jQ_j}{E_j\angle -\delta_j}\right)\right)\right\} \tag{5}$$

And then

$$P_{loss} = \Re\left\{\sum_{i=1}^{n}\sum_{j=1}^{n} R_{ij}\frac{\left(P_iP_j + Q_iQ_j\right) - j\left(P_iQ_j - P_jQ_i\right)}{E_iE_j\angle\left(\delta_i - \delta_j\right)}\right\} \tag{6}$$

The above equation can be rewritten as

$$P_{Loss} = P_{Loss_{ii}} + P_{Loss_{ij}} \tag{7}$$

where

$$P_{loss_{ii}} = \frac{R_{ii}}{E_i^{\ 2}}\left[P_i^2 + Q_i^2\right] \tag{8}$$

$$\begin{aligned} P_{loss_{ij}} = \frac{R_{ij}}{E_i E_j}[&P_i P_j \cos\delta_{ij} + Q_i Q_j \cos\delta_{ij} \\ &- P_i Q_j \sin\delta_{ij} + P_j Q_i \sin\delta_{ij}] \end{aligned} \tag{9}$$

$P_{Loss_{ii}}$ is a part of total losses that completely depends on power injection on bus i and it is also naturally separated in terms of active and reactive powers. But $P_{Loss_{iij}}$ is a part of total loss that arises from interaction between power injections in bus i with other buses of network. As it is shown in Eq. (9) participant share of each bus in this part is not separated naturally, so it have to be decoupled in the terms of active and reactive power injections at each bus. There is no unique solution to do this problem, but one of most popular methods is to allocate each term on to its two participants regarding to each one absolute value rather to total amount. For example, share of bus i in term $P_i P_j \cos\delta_{ij}$ is $P_i P_j \cos\delta_{ij} \times \left(|P_i| / \left(|P_i| + |P_j|\right)\right)$ and the share of bus j is $P_i P_j \cos\delta_{ij} \times \left(|P_j| / \left(|P_i| + |P_j|\right)\right)$. The same approach can be applied to the other terms. Finally the share of each bus due to its active power injection can be determined from adding its share in all terms. Share of loss due to reactive power injection at each bus also may be calculated.

This method has many inalienable advantages such as covering all losses completely and is based on mathematical formulation of systems without any simplification, additional assumptions or using not proven theories such as proportional sharing. Furthermore this method considers the characteristics of networks as well as active and reactive nodal power injections. It is simple and completely understandable by network participants.

So it seems reasonable to use this method for loss allocation of multiple interconnected networks tie lines between individual power pools that interchange power with each others.

3 Multi Area Loss Allocation Method

Transmission Loss allocation in multiarea power system using the proposed method comprises two main steps.

a) Internal loss allocation

In this stage the RO of each area uses system data to allocate the cost of the local area transmission networks loss among local generators and loads as well as importing and exporting tie lines using a regionally accepted loss allocation method. The system flow data could be acquired from the result of power flow calculation or state estimation.

For this propose each submarket or area may be considered as an independent system, and the corresponding loss allocation can be separately achieved for each area. In this case, the values of virtual generators and loads must be equal to the existing power interchanges. For keeping the internal states unchanged in this part of loss allocation it is needed to model the external networks. Because the boundary buses are usually voltage controlled and also the value of tie lines active power is predefined in contracts it is proposed here to consider boundary buses of the system as the PV buses [7].

The losses allocated to virtual generators and loads in previous stage will not revenue because they are not real entity and just model the tie line power import or exporting. So they must consider as a part of the interchange losses and reallocate to real load and generators of area in next stages.

b) Allocation of interchange losses

Since a portions of the area network losses is due to exports, imports, and wheeling power which pass on to the tie lines, the IO must now refund each area and tie line owners accordingly. For this propose it is necessary to allocate loss share of each area due to wheeling power through other area and tie lines by an independent organization supervised all areas known as international operator (IO).

Proposed method uses PV Ward equivalent model of networks [9] in addition to tie lines and boundary buses data for allocating the tie lines losses to each network.

As it has been shown in Eq. (4), for using proposed method it is needed to have all network complex voltage and also complete Y-bus matrix of total system. But due to previous mentioned reasons, the internal data of each system may be reduced to internal *equivalent* model data. References [5, 6] consider the equivalent of each area as a single node. Although this assumption is helpful for proportional sharing or pro-rata methods (because they don't need network characteristics of systems), it seems that it is not a reasonable assumption because it considers all the buses of internal area as a nodes connected together with some lossless lines.

One of the consequences of this assumption is that it does not allocate any share of tie line losses to an area which transfers power to the other areas and has the same import and export power. But it seems unreasonable because if a power interchange is made between two areas through a third network transmission lines, the two areas have to pay for transition right, so why should not the third network be responsible for its

tie line losses like the two others? In the other words, by this assumption no differences would appear between wheeling power through a well-connected network and a network with weak-connection in spite of their different power losses caused by them due to the same amount of power wheeling. Also wheeling power, by a highly loaded system, has much more losses in comparison with lightly loaded ones, but the above mentioned assumption ignores this fact.
A better solution which proposed in this paper to this problem is to determine the Ward Equivalent [3, 4] for each area. According to this equivalent, a power system can be reduced to a small network with equivalent admittances and power injections.
Therefore network extended Ward equivalent model of each individual area from its boundary buses point of view is substituted with all the networks in IO calculation process. This technique keeps the interaction of internal loading and connectivity of separated networks in IO calculation and it does not need a huge set of information data transferred to IO. For example, a 500 bus system with 4 boundary buses just needs to transfer a 4*4 Y-bus matrix of its equivalent system to IO (also nearly half of this matrix entities are duplicated).
Calculation of equivalent network Y-bus is based on reducing the network size according to

$$YV = I \tag{10}$$

$$\begin{bmatrix} Y_{BB} & Y_{BI} \\ Y_{IB} & Y_{II} \end{bmatrix} \begin{bmatrix} V_B \\ V_I \end{bmatrix} = \begin{bmatrix} I_B \\ I_I \end{bmatrix} \tag{11}$$

where Y is a complete network Y-bus and sub-matrices with subscript B, and I is used for boundary and internal buses respectively.

$$Y_{EQ} V_B = I_{EQ} \tag{12}$$

$$Y_{EQ} = Y_{BB} - Y_{BI} Y_{II}^{-1} Y_{IB} \tag{13}$$

$$I_{EQ} = I_B - Y_{BI} Y_{II}^{-1} I_I \tag{14}$$

Thus Y_{EQ} can easily be calculated by RO and transmitted to IO after each period of bidding or market operation change.
After receiving all the area equivalent Y-bus, boundary bus voltages and phases (calculated by RO of each area) by IO, the Y-bus of fictitious system made by all multi-area network boundary buses can be shaped (boundary lines characteristics already existed in IO database**).**
To implement the proposed method on this equivalent multi-area network, all vector of bus voltages vector (boundary buses) is required. Although voltage magnitude is correct, the reported voltage phase angles of different areas are not synchronous, because they are calculated on the basis of choosing the arbitrary slack bus for each area and it is obvious that reported phase angles of different areas are not synchronous.
As a result IO can synchronize them by using power transfer data from tie lines.
For each tie line with V_i and V_j as sending and receiving end voltages respectively and by considering the pi model for tie lines we have

$$\begin{bmatrix} V_i \\ I_i \end{bmatrix} = \begin{bmatrix} A & B \\ C & A \end{bmatrix} \begin{bmatrix} V_j \\ I_j \end{bmatrix} \tag{15}$$

where A, B and C are the entity of transmission matrix of the tie line.
With complex power S_{ij} sent to the tie line and after some manipulation

$$S_{ij} = V_i \left[\frac{A}{B} V_i + \left(C - \frac{A^2}{B} \right) V_j \right]^* \tag{16}$$

and by some simplification, we get:

$$\delta_{ij} = \text{angle} \left\{ \frac{S_{ij} - \left(A/B\right)^* |V_i|^2}{\left(C - \frac{A^2}{B} \right)^* |V_i||V_j|} \right\} \tag{17}$$

where δ_{ij} is the phase lag of bus j with respect to bus i.
Therefore by using reported data of boundary buses and tie lines power from all areas, IO is able to synchronize these buses according to Eq. (17). Now this system has become ready for dividing its total losses among boundary buses using proposed method and Eq. (4).
But due to power non-conservative nature of Ward equivalent model, total losses allocated to all boundary buses of this equivalent network may not be equal to total losses of the real multiarea system. In fact, in Ward reducing process we miss some complex power at dismissed injection nodes and this may cause changes in total losses of equivalent system. But there is not a serious concern in this issue because IO just needs to know the percent of total multiarea losses caused by each area. Furthermore, compatibility of tie line losses in the presented model to the real system is guaranteed here. However this model can not show the real value of losses in each area but can show the interaction of power interchanges and its impact on total multiarea system losses.
Anyway for finding the total loss share of each area it is just needed to accumulate allocated loss share of all

boundary buses of that area. But this value includes the internal area losses. So for excluding the internal losses to obtain the net share of the area in tie line losses, it is necessary to make a correction according to the following equation

$$\%P_{\text{loss } k} = \%\sum_{b=1}^{m_k} P_{\text{loss } b} - \%R\{\text{Loss}_k\} \quad (18)$$

where m_k is the number of boundary buses b of area k, and $R\{\text{Loss}_k\}$ is the reported real loss of area k to IO.

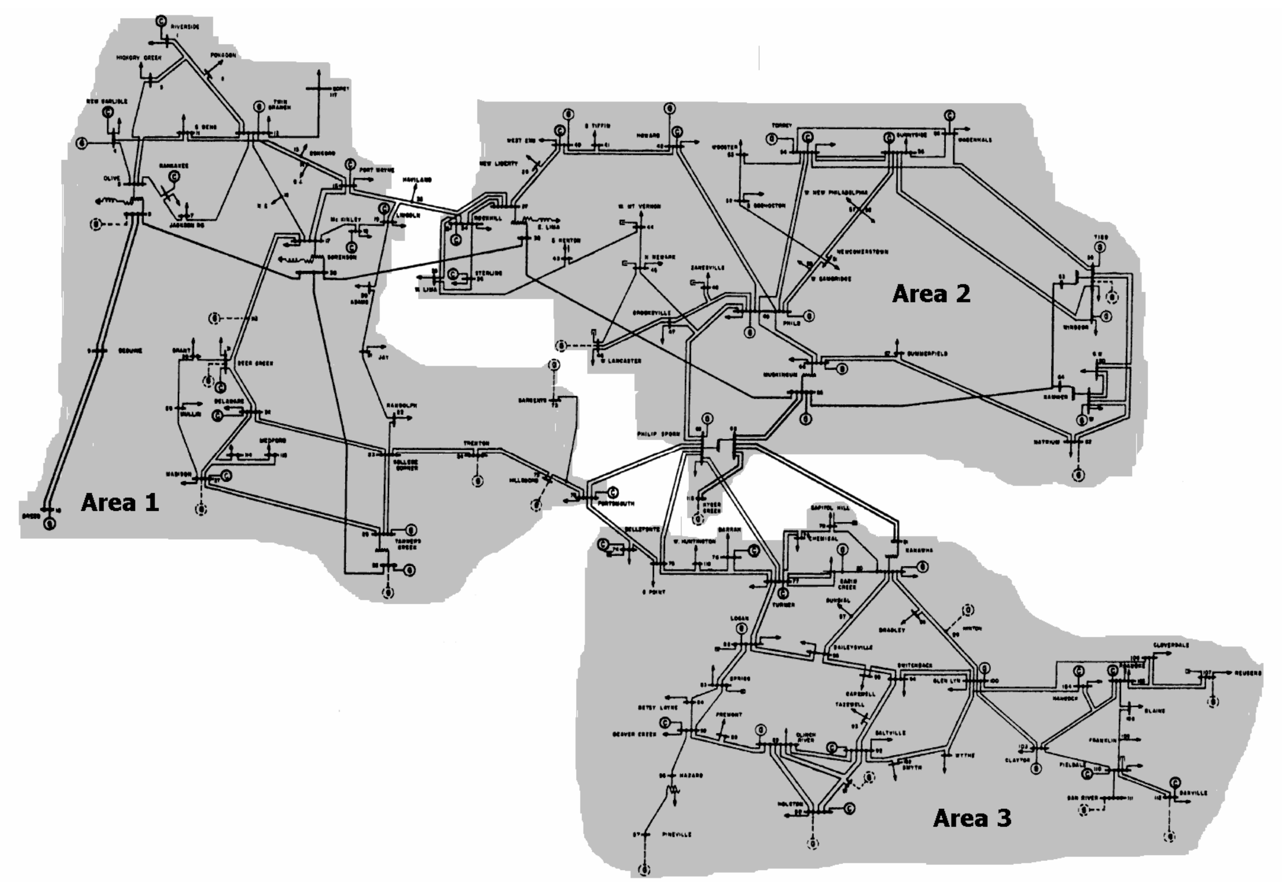

Fig. 1 IEEE 118 bus system divided to 3 areas.

After calculation of exchanging loss and losses allocated to virtual agents for each area in stages 3 and 2 respectively, differences between them must reallocate to area participants The charges for the use of external networks are paid to the IO by the regional operators (ROs) who collect them from the local generators and loads in a pro rata with local loss allocated to each load or generator.

4 Numerical Application

The slightly modified 118-bus IEEE test system [10] is used to illustrate the proposed methodology. It is considered that this system consists of three separate area power markets as shown in Fig.1. There are 9 tie lines in this multi area network that connect 13 boundary buses together in 3 areas.

Figure 2 shows a schematic of the three areas with tie-lines and losses allocated to individual imports/exports within each area are shown next to the associated tie-line.

For example the loss allocated to the export from bus 15 in area #1 is 0.4105 MW.

For implementing the proposed method, each RO needs to compute the updated Y-bus of PV Ward equivalent model of its own system from boundary buses point of view and send it to IO in addition to voltage and phase of boundary buses. These values can easily be calculated using a normal power flow computation or state estimation.

As it was mentioned earlier, internal RO considers the boundary buses as the voltage controlled buses and adds the total power imported or exported from each bus as a generation or load respectively. Now RO can calculate the internal loss share for each market participant according to its loss allocation policy.

The results of this stage are shown in table 1. The bus phases in table 1 just are the results reported from internal RO and they have not been synchronized with other area boundary buses. After collecting all area information by IO, it can synchronize boundary buses using Eq. (17). In this example, bus 15 in area 1 is considered as reference bus and results are presented in table 2. Now using the data of table 2 and previously known tie lines characteristics, IO performs the proposed loss allocation for new 13 buses system that consists of all areas boundary buses.

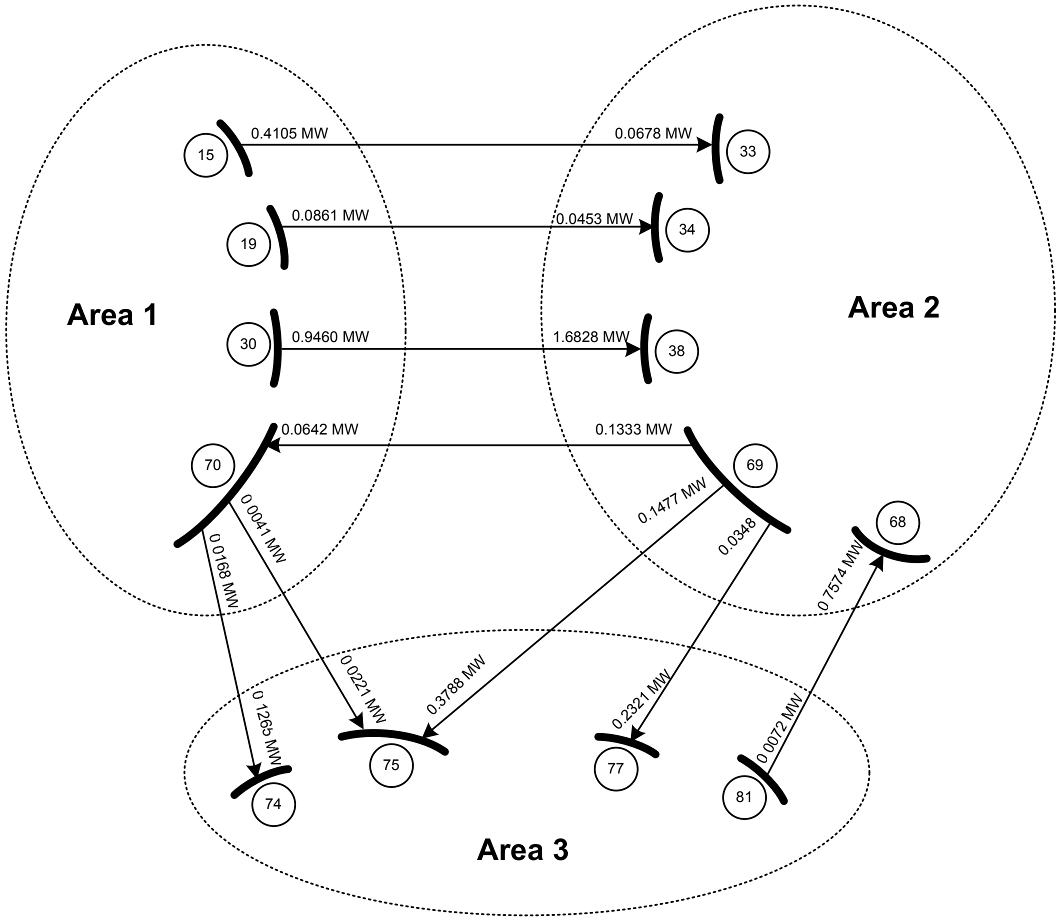

Fig. 2 A schematic of three area system and regional loss allocated to boundary buses.

Table 1 Load flow results for each area performed separately shown for boundary buses.

Area	Bus	Voltage		Total Area Loss		Total Power output [MW]		Total Power Input [MW]	
		Magnitude [pu]	Phase [degree]	In [MW]	In Percent of Total Multiarea Loss	Bus	Area	Bus	Area
1 Slack Bus: 25	15	0.970	-16.528	39.176	%29.221	13.564	129.262	0.0	77.441
	19	0.962	-16.765			2.647		0.0	
	30	1.014	-9.174			87.757		0.0	
	70	0.984	-8.914			25.294		77.441	
2 Slack Bus: 69	33	0.973	-14.023	44.722	%33.357	0	188.121	13.472	142.774
	34	0.984	-13.910			0		2.57	
	38	1.020	-8.169			0		87.398	
	68	1.009	0.890			0		39.334	
	69	1.035	0.0			188.121		0	
3 Slack Bus: 111	74	0.958	-1.823	43.628	%32.541	00	39.557	20.068	130.182
	75	0.970	-0.725			0		89.657	
	81	1.032	5.947			39.557		0	
	77	1.006	3.969			0		20.457	
Sum				127.526	%95.119	356.940			350.396

Table 2 IO analysis of 118 bus multi area power system as a 13 bus synchronous system.

Sending Bus		Voltage		Sending Power		Receiving Bus		Voltage		Receiving Power		Tie Line Loss [MW]	
Bus	Area	Magnitude [pu]	Phase [degree]	Active [MW]	Reactive [Mvar]	Bus	Area	Magnitude [pu]	Phase [degree]	Active [MW]	Reactive [Mvar]		
15	1	0.970	0	13.564	-9.678	33	2	0.973	-1.178	13.472	-3.948	0.092	
19	1	0.962	-0.237	2.647	-15.184	34	2	0.984	-1.065	2.570	-3.467	0.077	
30	1	1.014	7.354	87.757	-59.584	38	2	1.020	4.676	87.398	23.535	0.359	
70	1	0.984	7.614	20.313	10.106	74	3	0.958	6.307	20.068	15.650	0.245	
70	1	0.984	7.614	4.981	4.722	75	3	0.970	7.405	4.941	11.462	0.041	
69	2	1.035	12.854	87.983	16.308	75	3	0.970	7.405	84.716	31.447	3.267	
69	2	1.035	12.854	20.740	12.343	77	3	1.006	12.099	20.457	33.042	0.283	
69	2	1.035	12.854	79.398	13.088	70	1	0.984	7.614	77.441	29.685	1.957	
81	3	1.032	12.099	39.557	23.347	68	2	1.009	13.735	39.334	189.093	0.222	
Total Power Sent				356.940		Total Power Received				350.397		Sum	6.544

Table 3 Result of proposed loss allocation for 13 bus equivalent system.

Area	Bus Number	Boundary Buses		Area			Losses of Equivalent Networks		Each Area Loss Share of Total Multiarea Network Area		
		In MW	In $	In MW	In %	In $	In MW	In %	In MW	In %	In $
1 20 $/MWh	15	12.3566	247.13	-43.3702	-5.807	-867.41	58.802	48.548	-02.17	-4.355	-043.44
	19	4.8020	96.04								
	30	-66.3435	-1326.87								
	70	5.8147	116.29								
2 25 $/MWh	33	0.7588	18.97	106.5945	88.007	2664.86	22.471	18.552	84.123	69.454	2103.07
	34	16.7624	419.06								
	38	0.0955	2.39								
	68	65.4293	1635.73								
	69	23.5485	588.71								
3 30 $/MWh	74	1.2969	38.91	57.8965	47.801	1736.9	33.304	27.496	24.593	20.304	737.79
	75	0.5599	16.8								
	81	11.5721	347.16								
	77	44.4676	1334.03								
Sum		121.1208	3534.35	121.1208	100	3534.35	114.557	94.596	6.544	5.403	797.42

As it is shown in table 3 the total losses shared between 13 boundary buses is much more than total tie line losses and it is just due to equivalent network internal losses of connected areas. It is also different from the total multi area system losses reported on table 2. According to the fact mentioned before, these differences are arisen from power non-conservancy of Ward equivalent models. In the case of area 1 real internal power loss is 39.17 MW but in equivalent model, it is increased up to 58.802 MW that means internal connectivity and loading condition of this area cause its internal losses to increase after transaction with other areas and vise versa for the two other areas. Areas 2 and 3 have decreasing in their equivalent model internal losses against their real system losses around 22.25MW and 10.324MW respectively. So it can be concluded that these two areas internal connectivity and power dispatch cause decreasing in their internal loss after interchanging with other market areas and this is the reason of negative loss allocated to them by proposed method.

To show this fact more clearly, the variations of each area internal losses verses its power interchange to the other areas from twice of normal interchange (%200) to zero are shown in Fig. 3.

Using Eq. (18) the allocated loss to each area is obtained by subtracting internal loss from total loss share of that area. Loss shares computed by proposed method are shown in the last 3 columns of table 3.

To illustrate the ability of the proposed method to deal with cost of loss allocation in a multiarea network with different prices, it is assumed that areas 1,2 and 3 have a market clearing price (MCP) equal to 20, 25 and 30 $/MWh respectively. Computation of losses cost in $ per hour by proposed method is as simple as multiplying the loss share of each node at price of power on that node. As it shown in the last column of table 3 the cost of net interchanging losses is calculated around 140 $/h which means each MW of interchanged loss costs 21.4 $/h. It is obvious that proposed method can also use the local marginal price (LMP) system if it will be necessary. So if buses in the same areas have the different prices, the proposed methodology can work properly.

This allocation of interchange and tie line losses to each area is final goal of this paper and can be used by IO. But in order to show how much reasonable this method works, a numerical comparison with tracing method [5] has been performed.

In tracing method the total loss to be allocated is 11.6965 MW which consists of 6.544 MW of actual losses in tie-lines shown in Fig. 2 and 5.8482MW of compensations for losses due to cross-border trades. Table 4 shows the results of the loss allocation in each area by two methods. As it is shown in table 4 total losses allocated to each area using tracing method depend on losses allocated to tie lines by all areas and consequently depend on other areas loss allocation methods. For example if all three areas in this system use proportional sharing method for their internal loss allocation, the result of tracing methodology for multiarea system will change but the proposed method have no dependency to internal pricing method of individual areas. This comparison which can prove the robustness of proposed scheme was illustrated in table4.

Also to show the accuracy of the proposed method its results has been illustrated against loss shares allocated to buses using a central proposed loss allocation applied on 118 bus system as a unique power system by IO in Fig. 4.

As it is clear in Fig. 4 allocated losses by proposed method are very closed to centralized one and just have a little change in a few buses.

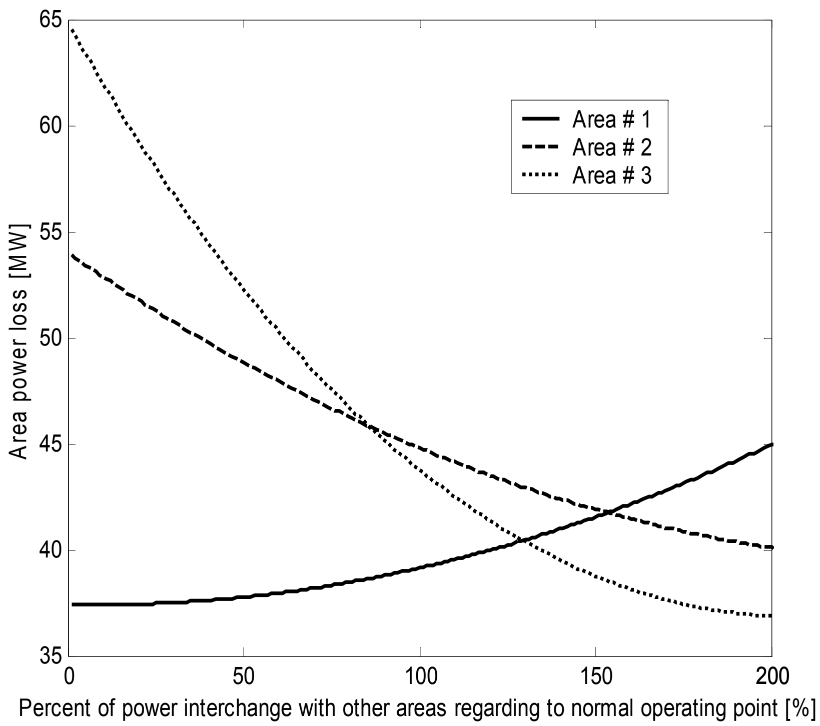

Fig. 3 Internal loss variation of each area versus changing in total power interchange with other areas.

Table 4 Result of loss allocation by proposed method comparing with tracing method.

Area	Losses in Area Caused by itself [MW]	Losses in Area Caused by Other Areas [MW]	Multiarea Losses in other areas and Tie lines Allocated To Area [MW]			
			Case 1: default loss allocation methods		Case 2 : all areas use proportional sharing method	
			Tracing Method	Proposed Method	Tracing Method	Proposed Method
Area1	37.6483	1.5277	3.2752	-102.172	2.8918	-102.172
Area2	41.8639	2.8581	2.5730	84.123	2.396	84.123
Area3	42.8613	0.7667	5.8482	24.593	5.2878	24.593
Sum	122.3735	5.1525	11.6964	6.544	10.5756	6.544

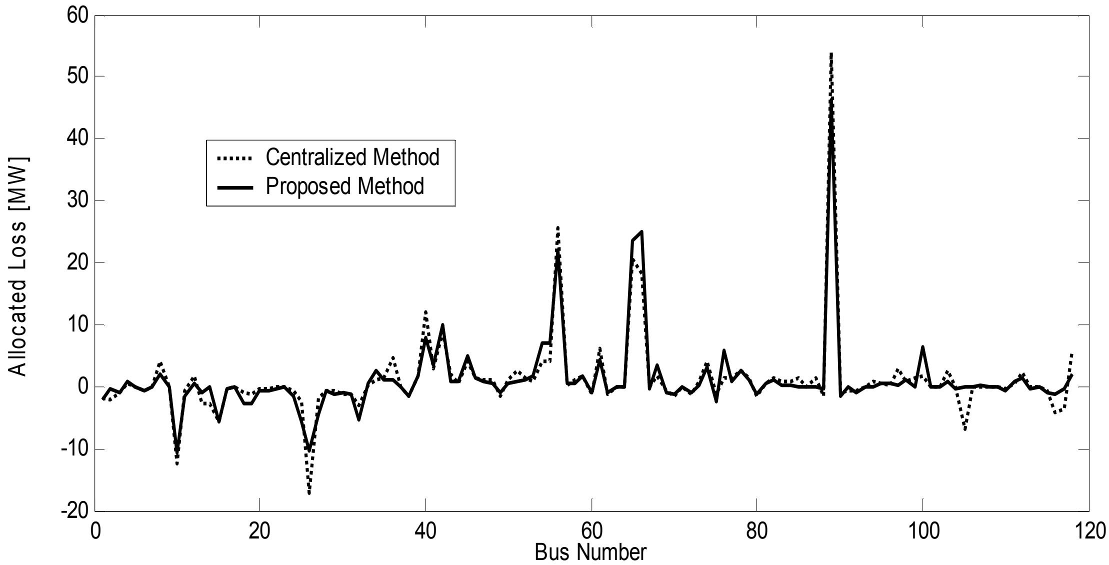

Fig. 4 Comparison of the proposed method with a centralized and decentralized implementation on 118 buses system.

5 Conclusion

In this paper transmission system loss allocation in the multiarea networks has been investigated and a new method based on loss formula has been proposed. This method lets each area to choose its arbitrary internal transmission pricing and allocation scheme. In order to calculate the losses in other networks and tie lines by the regional generators and loads, Ward equivalent of areas are considered to reduce the multiarea network. Therefore IO does not require detailed information about regional networks and avoids disclosing commercially sensitive information about internal networks and generation/load profiles. In this method the only data required are the flows in the tie-lines and the Ward model and boundary buses states of each area. Furthermore it considers internal network's well-connectivity and loading conditions of areas comparing with the other methods which consider all of a network as a node. The numerical study has been performed using the IEEE 118 bus standard network divided into three areas, each with a different internal transmission pricing methodology. Results show that its performance is very close to central loss allocation method. Also comparison of proposed scheme with tracing method shows the independency of its result to changes in internal pricing policy of areas.

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