Transmission System Congestion Relief Management by Congestion Relief charge in Gaming condition

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***Abstract*- Congestion relief management (CRM) is introduced as one of ancillary services in electricity market. The CRM maintains the system operation within the security limits and defines the revenue transaction for congestion relief. In this paper a mathematical model has been developed for actual congestion relief charge (CRC) in bilateral transaction as a penalty on the generator in the gaming condition. The Market clearing price (MCP) in uncongested system in two area are equal but in future when the load in area A_1 or A_2 varies then MCP in two area will differ. Generators want to do more transaction from low tariff area to high tariff area on the basis of profit maximization objective, resulting in line congestion. CRC, which is liable to be paid by the generator, will be equal to the generators profit in gaming condition. At this stage generator will not have tendency to do more transaction in high tariff area. Therefore, there will be automatic congestion relief management. This particular model will help in system security, encourage system discipline and discourage gaming condition.**

***Key words*- Congestion relief management (CRM), Congestion relief charge (CRC), Congestion relief index (CRI), Generator profit (G_{pro}).**

I. Introduction

In deregulated electricity market, system operator is responsible to maintain the security of the system. When desired transaction is within limit it is called uncongested system. But if transmission requirement is beyond the line limit then the system will be congested. In congested system, it is not possible to fulfill the existing contract resulting in monopolistic price in some region and damage to system component also. Therefore, congestion management is more important in deregulated environment. To solve congestion problem and to maintain the system within security limit is a challenge for the independent system operator (ISO). The congestion relief management (CRM) which is introduced as an ancillary service in market structure maintains the security and defines the revenue transaction in nondiscriminatory method [1-4]. The congestion cost is the cost of congestion relief.

The management of congestion is somewhat more complex in competitive power market and leads to several disputes. Presently, each utility manages the congestion itself by using its own rules and guidelines using physical or financial mechanism. Chao et al [5] proposed an alternative approach that is based on parallel market for link based transmission capacity rights and energy trading under a set of rules defined and administrated by the ISO. Hogan proposed contract path and nodal pricing approach [6] using spot pricing theory[7] for the pool type market. An approach for relieving congestion using minimum shift in the total shift in the transaction is presented in [8]. The curtailment of the transactions can be avoided by willingness to pay premium [9]. Marginal cost signal are used in [10] for generators to manage congestion. With the help of Flexible Available Capacity of Transmission System (FACTS), Transmission network capability is utilized in a better way and congestion can be managed in an efficient manner [11, 12]. Benard etal [13] found congestion cost on the basis of different MCP by changing the generation in two areas with fixed load. Several Optimal Power Flow (OPF) based congestion management schemes is presented by Kumar et al [14]. Dehghan et al [16] proposed congestion relief charges are liable on generator and load both.

Earlier researchers have taken fixed load and variable generation between two areas. But in this case the load has been varied in the two areas, resulting in change in MCP that creates gaming on the basis of profit maximization objective in high tariff area by the generator. For finding out the value of payment, we have to find out the value of line charges, which include line losses and transmission charges. Line charges and line losses has been taken on the basis of Central Electricity Regulatory Commission of India and is taken as 1.6$/MW and 3% respectively [15]. Besides this Researchers in the past have made penalty on generator and load by putting congestion relief charge (CRC) for congestion relief management (CRM). In this paper a new approach has been taken and actual CRC has been imposed on the generator, which has caused congestion in gaming condition. Imposed actual CRC will be equal to generator gaming profit resulting in automatic congestion relief management.

II. System Description

Generator side management for congestion relief is proposed because generators only cause the congestion on the basis of profit maximization objective. A bilateral transaction model of two generators and two loads has been taken for the study as shown in Fig.1. In the figure A & B indicate areas and x indicates the cases. Line congestion is related to available transmission capacity (ATC) of line. In this figure A and B are two areas with different supply, load, and price. With variable load system when load/demand is changed then it is called future load. The load which is connected with supply is called real load.

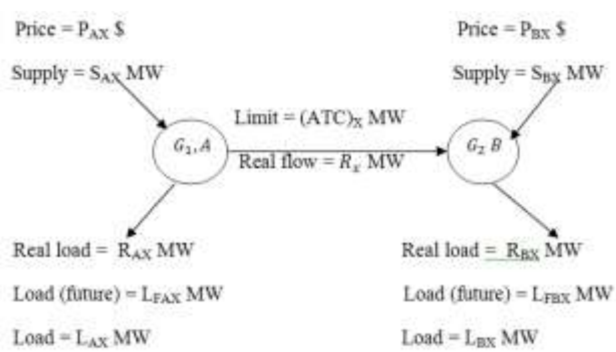

Fig. 1 Bilateral transaction model

A. Proposed mathematical model for actual congestion relief charges

In this approach, when there is some load in area A & B with same market clearing price (MCP) ($P_{AX} = P_{BX}$), then system will be uncongested. But when load will change in future in areas A & B then MCP will change. Now the generators tendency will be to do more transaction in high tariff area by changing the supply or cross the ATC limit. Hence the line will be congested. CRC (δ_c) is calculated by equation (1). Actual profit of the generator within ATC limit $P_{ro,ATC}$ is calculated by equation (2). But Actual CRC ($\delta_{c,act}$) will differ from CRC (δ_c). A mathematical model is proposed for finding out $\delta_{c,act}$ in equation (3), which will be obtained by subtracting equation (2) from equation (1). If MCP changes due to future demand, it may lead to congestion without any fault of generator. The generator can take profit within ATC limit in high tariff area due to change in MCP. So we will subtract the actual profit within ATC limit from the congestion charge for calculating actual congestion relief charge given in equation (3). Gaming profit of the generator G_{pro} is calculated by equation (5) when it crosses the ATC limit of the line on the basis of profit maximization objective in high tariff area. Hence gaming profit will always be equal to actual congestion relief charge or penalty given in equation (6). There will be automatic congestion relief management, which has been proved by the model. Further we will calculate the difference between line charges and actual profit of the generator after transaction named as payment (P_y) given in equation (12). At last, we will calculate the summation of payment and actual congestion relief charge named as payment* (P^*_y) given in equation (13). The Actual CRC can also be obtained on another generator G_2 with same method, when he will do the gaming

Now, we will calculate the congestion charges by using equation (1) given below.

$$\delta_{c=}[(L_{na,act} * price_{na,area}) + (P_{t,act*}price_{other,area}) - (G_{gen} * price_{na,area})] \quad (1)$$

Where, $L_{na,act}$= Actual load in native area

$P_{t,act}$ = Actual power transfer

G_{gen} = Generation of generator G_1

$price_{na,area}$ = price in native area (price of generator area)

$price_{other,area}$ = price in other area (price in another generator area)

The actual profit of generator within ATC limit is given by equation (2)

$$P_{ro,ATC} = P_{t,ATC} *(price_{other,area} - price_{na,area}) \quad (2)$$

Where, $P_{t,ATC}$ = Actual power transfer with ATC limit.

$P_{ro,ATC}$ = Actual profit with ATC limit

$price_{other,area}$ = price in other area

$price_{na,area}$ = price in native area

Actual congestion relief charge $\delta_{c,act}$ is derived by equation (1) & (2) as below

$$\delta_{c,act} = \delta_c - P_{ro,ATC} \quad (3)$$

Where $\delta_c = congestion\ charges$

$P_{ro,ATC}$ = Actual profit within ATC limit

$\delta_{c,act}$ = Actual congestion charge

Mathematically, the congested power P_{con} in the line is given by

$$P_{con} = F_r - F_{ATC} \quad (4)$$

Where, F_r = Real power flow

F_{ATC} = Power flow within ATC limit

Now, we will calculate the gaming profit G_{pro} of the generator by substituting equation (4), in equation (5), which always comes equal to actual congestion relief charge payable by the generator.

$$G_{pro} = (P_{con})*(price_{other,area} - price_{na,area}) \quad (5)$$

Where, $price_{other,area}$ = price in other area $price_{na,area}$ = price in native area.

G_{pro} = Generator profit by gaming

Now, by substitute the equations (1) , (2) & (4) in equations (3) & (5) respectively, we will get the value of gaming profit and actual congestion relief charge that will be equal as in equation (6) given below.

Mathematically, $G_{pro} = \delta_{c,act}$ (6)

Hence automatic congestion relief management takes place in the line.

Mathematically, we will calculate transmission charges and line loss by using equations (7) & (8) respectively as given below.

And $T_{ch} = (j) * (P_{t,act})$ (7)

$$L'_{loss} = [(L) * (P_{t,act})] * price_{other,area} \quad (8)$$

We use j & L for numerical value $\left(\frac{1.6\$}{mw}\right)$ & $\left(\frac{3}{100}\right)$ by using equations (7) & (8) respectively for MATRIX LABORATORY programming.

Where, $\left(\frac{1.6\$}{mw}\right) = j$

$\left(\frac{3}{100}\right) = L$

Now, we will calculate line charges given below in equation (9), by substitute equations (7) & (8).

$$L'_{ch} = L'_{loss} + T_{ch} \quad (9)$$

Where, $L'_{loss} = line\ loss$

$T_{ch} = transmission\ chrges$

Mathematically, the power receiving at end point after losses is given by equation (10)

Where, $P_{t,rec} = P_{t,act} - (L) * (P_{t,act})$ (10)

And, $(L) * (P_{t,act})$ = losses of line

And, $L = \left(\frac{3}{100}\right)$

And, $P_{t,act}$ = Actual power transfer

Actual power transfer which reach at receiving end after losses $P_{t,rec}$ will be less than the power dispatched by the generator. We calculate profit on actual power transaction (at the amount of MW which reaches at receiving end after transmission) by substitute equation (10) in equation (11) given below

$$PRO_A = (P_{t,rec}) * price_{other,area} \quad (11)$$

Where, $P_{t,rec}$ = Actual power transfer which reach at receiving end after losses.

PRO_A = Profit by actual power transfer which reach at receiving end after losses.

$price_{other,area}$ = price in other area.

Now, by substitute the equations (9) & (11) in equation (12), we calculate the value of payment given below in equation (12) (at the amount of MW which reaches at receiving end after transmission).

Payment = $(L'_{ch} - PRO_A)$ (12)

Where, PRO_A = profit on actual power transaction

L'_{ch} = line charges.

Payment* (P^*_y), is the summation of payment and actual congestion relief charge, is obtained by substituting the equations (12) & (3) in equation (13) given below Payment* =Payment+ $\delta_{c,act}$ (13)

Where, Payment* =total payment by including actual congestion charges,

Payment=line charges minus actual profit by transaction

$\delta_{c,act}$ =Actual congestion relief charge

Average actual congestion charge, $\delta_{c,act,avg}$, is given below by equation (14), which is the average summation of actual congestion charges.

$$\delta_{c,act,avg} = \sum_{\delta_{c,act}=1}^{x} = \frac{\delta_{c,act,1}+\delta_{c,act,2}+\delta_{c,act,3}+\delta_{c,act,4}+\delta_{c,act,5}+\cdots}{x} \quad (14)$$

Where, Average actual congestion charges ($\delta_{c,act,avg}$) = 4174 $ (up to five cases)

And, $\delta_{c,act}$ = Actual congestion charge

Now further new models are developed for congestion relief indicator $C_{RI,X}$ and average congestion relief indicator y as in equations (15) and (16) respectively

And, $C_{RI,X} = (\delta_{c,act,X}) / \delta_{c,act,avg}$ (15)

Where $C_{RI,X}$ = congestion relief indicator, and, $\delta_{c,act,X}$ =Actual congestion relief charge for case x where x denotes various cases from 1 to 5.

$\delta_{c,act,avg}$ = Average actual congestion relief charge

The average congestion relief indicator y is given by the average summation of congestion relief indicator given below in equation (16) And,

$$y = \sum_{C_{RI,X}=1}^{x} = \frac{C_{RI,1}+C_{RI,2}+C_{RI,3}+C_{RI,4}+C_{RI,5}+\cdots}{x} \quad (16)$$

Where, Average congestion relief indicator (y) = 1.00 where $C_{RI,x}$ varies between 0.525 to 1.36

Now we will calculate all parameters given in table.1 only for generator G_1 by using the equations from 1 to 16 as given above.

TABLE.1

Parameters ↓ / Cases →	Case-1,(X=1)	Case-2,(X=2)	Case-3,(X=3)	Case-4,(X=4)	Case-5,(X=5)
Supply= S_{AX},(MW)	600	600	600	800	550
Load=L_{AX},(MW)	500	500	500	500	500
Real load=R_{AX},(MW)	450	470	420	450	400
Supply=S_{BX},(MW)	400	400	400	200	450
Load=L_{BX},(MW)	500	500	500	500	500
Real Load=R_{AX},(MW)	550	530	580	550	600
Price=P_{AX},($)	28	29	27	32	35
Price =P_{BX},($)	97	102	98	125	133
Limit=$(ATC)_x$,(MW)	100	100	100	300	100
Real power flow=R_x (MW)	150	130	180	350	150
Act. Congestion Charge= $\delta_{c,act}$ ($)	3450	2190	5680	4650	4900
Gaming profit=G_{pro}($)	3450	2190	5680	4650	4900
Payment= P_y($)	-1677	-2064.40	-2181.60	-13125.50	-6753
Payment*=P_y^* ($)	1773	125.60	3498.40	-8475.50	-1853
Congestion relief indicator = $C_{RI,X}$	0.826	0.525	1.36	1.11	1.17
Actual profit after transaction=(PRO_A)($)	14114	12862	17111	42438	19352

In Table 1 the negative sign in the values of payment indicate the earning money of generator from ISO after transaction. This will indicate by the equation (12), when the value of actual profit after transaction at receiving end is large in compare to line charges, which include line losses and transmission charges. The payment* is also indicate negative values, when the value of payment will be large in compare to actual congestion charge given in equation (13).

III. Result and Discussion

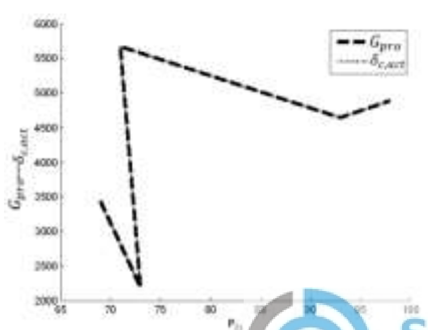

Fig. 1 Gaming profit (G_{pro}), Actual congestion relief charge ($\delta_{c,act,}$) V/S price difference (P_D).

From the fig no-1 shows that the curve of gaming profit and congestion charges will overlap each other, which shows that the value of congestion charges is equal to gaming profit of the generator corresponding to the value of price difference. At each point of the curve it shows that generator profit by gaming is equal to actual congestion charge, which is like a penalty on the generator. Hence the Fig. 1 shows that there is no profit of generator when he will try to do gaming. Therefore automatic congestion relief management due to the imposed charge on the generator.

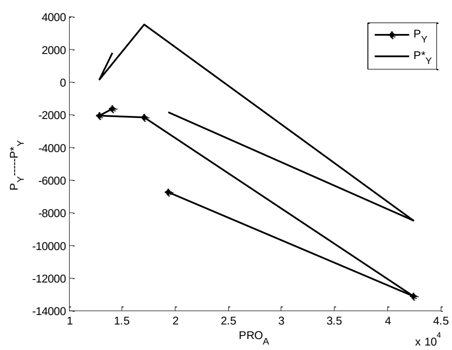

Fig. 2 Payment (P_y), Payment Star (P^*_Y) V/S Actual profit after Transaction at receiving Point (PRO_A)

Fig No-2 shows the variation of payment and payment* with actual profit by transaction at the receiving point. The payment is the difference between line charges and actual profit by transaction. The payment* is the summation of payment and actual congestion charges. Hence the payment and payment* curves shows the amount paid and received by the generator from the independent system operator (ISO).

Average congestion relief indicator y as unity shows that the actual congestion relief charge and average actual congestion relief charge are equal. The value of congestion relief indicator varies from 0.525 to 1.36 for different cases. If y indicates that the value of actual congestion relief charge and average actual congestion relief charge are not equal, converges value in term of fractions and imposed the in-equality condition.

IV. Conclusion

Researchers in the past have made penalty on generator and load by putting CRC for CRM (congestion relief management). In this paper a new approach has been taken and CRC has been imposed on the generator, who has caused congestion in gaming condition. Imposed CRC will be equal to generator gaming profit resulting in automatic congestion relief management.

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