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Transmission Pricing Methodology based on Particle Swarm Optimization

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ABSTRACT: In deregulated power market analysis and management of wheeling prices across each producer and customer is one of the most crucial and challenging task. Wheeling prices management is carried out to calculate, reduce price and share profit between users (producer and customer) and transmission owner. The better way to manage wheeling prices and make profit can be adjustment of power flow control and share profit between all trading parties. Mostly transmission owners adopted absolute approach for price calculation due to efficient use and counter flow charges are to be paid by users. But if transmission owner and users will share the benefits of the counter flow by using profit sharing factor decided by regulatory body and power flows optimize during process then all trading parties can take benefit. Total price of transmission in power flow based methods is depend on power flow and therefore wheeling prices analysis is a complex combinational optimization problem in which involve non linear functions having multiple local minima and nonlinear discontinues constraints. Here wheeling prices management is formulated based on non linear constraints multi objective optimization problem of optimal power flow. In this paper wheeling price analysis to calculate counter flow and optimize power using genetic algorithm and particle swarm optimizations which are population based algorithms. Here effectiveness of PSO and GA has been demonstrated on IEEE-30 bus system and is found to be superior PSO algorithm.

I. INTRODUCTION

The main objective of wheeling prices management in power market is to accurately determine transmission usage in order to implement usage based cost allocation across each producer and customer. Wheeling price management is depend on several variables as line length, cost across each transmission line, power flow etc. [1].

Wheeling price calculation method mostly classified into embedded cost and incremental cost or marginal cost [2-5] categories. In above cost methods embedded cost methods are used mostly in power industry because of fairness to all producers and customers, easily measurable electrical cost etc.. There are several types of embedded cost method based on real power flow as postage stamp, contract path, MW-mile [2-7] and real and reactive power flow based MVA mile method [8] used commonly in power industry.

Postage stamp method is popular due to simplicity but not frequently used due to ignore actual power flow and in contract path method actual path taken by transaction does not flow only specified contract path therefore of transmission outside the contracted path [k.l.lo]. So in real Power flow MW-mile method and with real and reactive power flow MVA-mile method is more widely used. This is because in transmission system determining an accurate transmission usage could be difficult due to the non linear nature of Power flow [1].therefore power flow based methods are suitable for practical power system. There are three different MW-mile and MVA-mile approaches used to determine wheeling prices [8-9] as absolute, reserve and dominant or positive or zero counter flow approach. Among all absolute approach is most popular because provide more revenue to the Transco's. Somewhere zero counter flow and reserve method are also used but they are not easily acceptable by Transco's [10-11].

In this scenario, if price of counter flow or difference of used absolute cost and used dominant or positive or zero counter flow approach will divide between users and transmission owner using profit sharing factor decided by regulatory body and users profit also divide between producer and customer according to their participation then this approach can be decide all trading parties benefits [12]. In this paper two approaches used absolute and zero counter flow method with MW-mile and MVA –mile to calculate counter flow price and best possible solution can be find to use better optimization technique. Here we used Genetic algorithm and particle swarm optimization for optimize power flow and finally calculate price difference between absolute and zero counter flow (difference is called negative flow or counter flow price) are divide between users and transmission owner using profit sharing factor decided by regulatory body and users profit also divide between producer and customer according to their participation. Due to counter flow available transfer capability are also increased across transmission line [13]. Here distribution factor based tracing [14-15] is used to trace the system.

Genetic algorithms are adaptive heuristic search based on the evolutionary ideas of natural selection and genetics [16]. It's start with generation of initial population and then selection, crossover and mutation are performed until the best population is found [17].

Particle swarm optimization is a population based stochastic optimization techniques inspired by social behavior of bird flocking or fish schooling [18].here each potential solution is regarded as a particle and a set which is composed of particles is called a swarm [19].In GAs chromosomes share information with each other so the whole population likes a one group toward an optimal area and in PSO only gBest(or IBest) gives out the information to others. Then in PSO all the particles tend to converge to the best solution quickly even in the local in most cases [18].

II. WHEELING PRICE ASSESSMENT

For assessment of wheeling different methodologies MW mile for active power flow and MVA mile for active and reactive power flow are to be used. The discussion about both methods and their sub methods as follows:

A. MW-mile method

Power flow based MW-mile methodology allocates the Charges for each transmission facility to [14, 28-29] transmission Transactions based **on** the extent of use of that facility by these transactions. As can be seen the dimension of power (MW) and distance (mile).

$$TC_t = TC * \frac{\sum_{k\in K} C_k L_k P_{t,k}}{\sum_{t\in T} * \sum_{k\in K} C_k L_k P_{t,k}} \tag{1}$$

Where TC_t price allocation of network user t, TC is the total transmission cost, C_k is cost per mw per unit length of line k, L_k is line length, P is power flow in line k due to user t, T is user set and K is transmission line set.

a. Used absolute MW-mile method

In used method users are pay based on actual power flow only. With this in absolute approach counter flows are also pay by users. This method show efficient use and not guarantee to recovery of fixed transmission price [3]. Transmission owner prefer this absolute method for more profit. As can be seen that the dimension of power in MW.

$$TC_t = \sum_{k\in K} C_k \frac{|F_{t,k}|}{F_{k,\max}} \tag{2}$$

For where TC_t price allocation of network user t, C_k is cost per mw per unit length of line k, $F_{t,k}$ is the power flow on line k by user t, $F_{k,max}$ is the capacity of line k and K is transmission line set.

b. Used zero counter flow or positive flow method

In zero counter flow or positive flow users pay only for positive flow and nothing for the counter flow [3]. As can be seen that the dimension of power in MW.

$$TC_t = \sum_{k\in K} C_k \frac{F_{t,k}}{F_{k,\max}}\ ,\quad F_{t,k} > 0 \tag{3}$$

For where TC_t price allocation of network user t, C_k is cost per mw per unit length of line k, $F_{t,k}$ is the power flow on line k by user t, $F_{k,max}$ is the capacity of line k and K is transmission line set.

B. MVA-Mile method

MVA mile is an extended version of MW mile method .the extension is additional reactive power flow charges with active flow charges. All the methods and sub methods as absolute, reserve and zero counter flow can be implementing with MVA mile method as an extension.

III. PROBLEM FORMULATION

Optimal power flow and distribution factor have to be calculate for calculation of price. Descriptions of problem areas under:

A. optimal power flow calculation

Calculation of power flow come from result of an optimal power flow calculation using fixed generation input data. Optimal power dispatch problem including transmission losses function as [9, 10]:

$$MinF_T = \sum_{n=1}^{n} F_n \tag{4}$$

$$F_n = a_n P_{gg}^{\;2} + b_n P_{gg} + \sum C_n + [\sum P_{gg} - (baseMVA * \sum P) - P_{dt}] \tag{5}$$

Where a_n,b_n,c_n are generator cost, P_{gg} generator power P_{dt} distribution power in transmission line.

B. Profit sharing factor

To determine power flow impact in transmission lines we can explain power flow as follows [7]

$$\Delta P_i = \left|\pm P_{t,i}\right| - \left|\pm P_{b,i}\right| \tag{6}$$

Where ΔP_i is power flow impact in line ‘I’, $P_{t,I}$ the power flow in line ‘I’ during transaction and $P_{b,I}$ the power flow in line ‘I’ for base case.

ΔP Is the negative power flow impact if $\left|\pm P_t\right| < \left|\pm P_b\right|$.

The submission of the negative power flow impact incurred the line which was negative and taken as an absolute value and then using profit sharing factor ‘r’. For ‘n’ lines it can be written as:

$$\frac{1}{r}\sum_{i}^{n}\left|\Delta P_i\right| = \frac{\Delta P_{neg}}{r} \quad \text{For all } \Delta P_i < 0 \tag{7}$$

Where ‘r’ is the profit sharing factor used to determine sharing of profit due to negative or counter flow between transmission owner and users. The profit sharing factor is determined practically by regulatory body. If factor is set 4 the transmission owner will receive 25% of benefit and remaining 75% is awarded to transmission users (Producers and customers). For calculation assume r=4 in this paper.

IV. EVOLUTIONARY ALGORITHMS

In artificial intelligence, an evolutionary algorithm is a subset of evolutionary computation, a generic population based Meta heuristic optimization algorithm. EA is mechanism inspired by biological evolution, such as reproduction, mutation, recombination and selection. In this paper we use two population based algorithm as genetic algorithm and particle swarm optimization [16].

A. Genetic algorithm

Genetic algorithm proceed to initialize a population of solutions and then to improve it through repetitive application of the mutation, crossover, inversion and selection operator [16].

a. initialization

In initialization, population size depends on the nature of problem. Initially population is generated randomly and in this paper population size and considered ‘50’ with ‘200’ generation limit.

b. Selection

During each successive generation, a proportion of the existive population is selected to breed a new generation. Certain selection method rate the fitness of each solutions select the best solutions. With random population size time limit consider as '300' in this paper.

c. crossover and mutation

For each new solution to be produced a pair of parent solution is selected for breeding from the pool selected previously. By producing a child solution using the method of crossover and mutation [17].

d. Termination

Process will be terminated on fixed number of generation reached which set '200' in this paper.

e. Particle swarm optimization

Particle swarm optimization is population based technique and here use PSO in following computational steps:

f. Computational steps of particle swarm optimization

1. Generate size of swarm "no. of birds" randomly. In this paper no. of birds considers'50' for calculation.
2. Set dimension of problem and here consider '5' for calculation.
3. Set PSO parameter c_1=1.2 and c_2= 0.12
4. Set PSO momentum or inertia w=0.9
5. Initialize the parameter and swarm, velocities and position, evaluate initial position, velocity update, swarm update, evaluate a new swarm and after this run main loop function.

V. RESULTS AND DISCUSSION

After execution of Postage stamp and mw-mile method with verification of Garver 6-bus and IEEE-RTS 24 bus system price contribution can be calculate across each load and generator. In this total annualized cost of transmission across Garver 6 bus test system is 0.340M€ and in IEEE-RTS 24 bus system is 139.105K€ [9]. After analysis with different level contributions of generator and load following results were found which describe as follows. Graphical representation of generator and load with cost in M€ determine in 6 bus and generator and load with % of total cost in M€ in IEEE-RTS 24 bus test system results. Results of both buses are as under:

A. Garver 6 bus test system results

a. Generator test:- Generator test perform with 6 buses and 3 generators. Total peak load is 760 MW while total installed generation capacity is 1100 MW. Postage stamp method is independent to power flow and transmission distance. So after increasing distance mw-mile is more efficient as compare to postage stamp method. Here generator contributes 0-50% contribution in total transmission cost.

TABLE 1 Postage stamp GGDF method for 6 bus test system in M€

Method	Producer	contribution 0%	contribution 10%	contribution 20%	contribution 30%	contribution 40%	contribution 50%
Postage stamp method	G1	0	0.0067	0.0134	0.0201	0.0268	0.0335
	G3	0	0.0149	0.0298	0.0447	0.0596	0.0745
	G6	0	0.0123	0.0247	0.0371	0.0495	0.0619
Total price of generator contribution		0	0.034	0.0679	0.1019	0.1359	0.1699

TABLE 2 Mega watt mile GGDF method for 6 bus test system in M€

Method	Producer	contribution 0%	contribution 10%	contribution 20%	contribution 30%	contribution 40%	contribution 50%
Mega watt mile method	G1	0	0.0041	0.0083	0.0125	0.0167	0.0209
	G3	0	0.0119	0.0238	0.0357	0.0477	0.0596
	G6	0	0.0178	0.0357	0.0536	0.0715	0.0894
Total price of generator contribution		0	0.0338	0.0678	0.1018	0.1359	0.1699

b. Load test

TABLE 3 Postage stamp GLDF method for 6 bus test system in M€

Method	Customer	contribution 100%	contribution 90%	contribution 80%	contribution 70%	contribution 60%	contribution 50%
Postage stamp method	L1	0.0357	0.0322	0.0286	0.025	0.0214	0.0178
	L2	0.1073	0.0966	0.0858	0.0751	0.0644	0.0536
	L3	0.0178	0.0161	0.0143	0.0125	0.0107	0.0089
	L4	0.0715	0.0644	0.0572	0.0501	0.0429	0.0357
	L5	0.1073	0.0966	0.0858	0.0751	0.0644	0.0536
Total price of load contribution		0.3396	0.3059	0.2717	0.2378	0.2038	0.1696

TABLE 4 Mega watt mile GLDF method for 6 bus test system in M€

Method	Customer	contribution 100%	contribution 90%	contribution 80%	contribution 70%	contribution 60%	contribution 50%
Mega watt mile method	L1	0.0378	0.0341	0.0302	0.0265	0.0227	0.0189
	L2	0.079	0.0711	0.0632	0.0553	0.0474	0.0395
	L3	0.0134	0.0121	0.0107	0.0094	0.008	0.0067
	L4	0.0922	0.0829	0.0737	0.0645	0.0553	0.0461
	L5	0.1173	0.1056	0.0938	0.0821	0.0704	0.0586
Total price of load contribution		0.3397	0.3058	0.2716	0.2378	0.2038	0.1698

B. IEEE-RTS 24 bus test system results

a. Generator test

Generator test perform with 24 buses, 38 lines and transformers, 10 committed generators. Total peak load is 2850MW and total installed generation capacity is 3405MW. Here show the results of generator to contributes 0-50% of total transmission pricing.

TABLE 5 Postage stamp GGDF method for 24 bus test system in K€

Method	Producer	contribution 0%	contribution 10%	contribution 20%	contribution 30%	contribution 40%	contribution 50%
Postage stamp method	G1	0	0.5648	1.1297	1.6945	2.2594	2.8243
	G2	0	0.5648	1.1297	1.6945	2.2594	2.8243
	G7	0	1.0261	2.0523	3.0784	4.1046	5.1307
	G13	0	1.6549	3.3099	4.9649	6.6199	8.2749
	G15	0	0.492	0.0984	1.4761	1.9682	2.4602

	G16	0	1.3918	2.7836	4.1754	5.5672	6.9591
	G18	0	3.0529	6.1058	9.1587	12.2116	15.2645
	G21	0	3.0529	6.1058	9.1587	12.2116	15.2645
	G22	0	0.7181	1.4362	2.1543	2.8724	3.5906
	G23	0	1.3918	2.7836	4.1754	5.5672	6.9591
Total price of generator contribution		0	13.9101	26.935	41.7309	55.6415	69.5522

TABLE 6 Mega watt mile GGDF method for 24 bus test system in K€

Method	Producer	contribution 0%	contribution 10%	contribution 20%	contribution 30%	contribution 40%	contribution 50%
Mega watt mile method	G1	0	1.1984	2.3969	3.5953	4.7938	5.9923
	G2	0	1.2098	2.4196	3.6294	4.8392	6.049
	G7	0	1.5638	3.1276	4.6915	6.2553	7.8191
	G13	0	0.8987	1.7975	2.6963	3.5951	4.4939
	G15	0	0.6325	1.2651	1.8976	2.5302	3.1627
	G16	0	0.5302	1.0605	1.5908	2.1211	2.6514
	G18	0	1.7256	3.4513	5.177	6.9027	8.6284
	G21	0	1.8084	3.6168	5.4253	7.2337	9.0421
	G22	0	1.7263	3.4526	5.1789	6.9052	8.6315
	G23	0	2.6163	5.2326	7.8489	10.4652	13.0815
Total price of generator contribution		0	13.91	27.8205	41.731	55.6415	69.5519

b. Load test:- In this test perform with 17 loads. Loads contributions are 50-100%.

TABLE 7 Postage stamp GLDF method for 24 bus test system in K€

Method	Customer	contribution 100%	contribution 90%	contribution 80%	contribution 70%	contribution 60%	contribution 50%
Postage stamp method	L1	5.2713	4.7442	4.217	3.6899	3.1628	2.6356
	L2	4.7344	4.261	3.7875	3.3141	2.8406	2.3672
	L3	8.7855	7.907	7.0284	6.1499	5.2713	4.3927
	L4	3.6118	3.2506	2.8894	2.5282	2.1671	1.8059
	L5	3.4654	3.1188	2.7723	2.4257	2.0792	1.7327
	L6	6.6379	5.9741	5.3103	4.6465	3.9827	3.3189
	L7	6.101	5.4909	4.8808	4.2707	3.6606	3.0505
	L8	8.3463	7.5116	6.677	5.8424	5.0078	4.1731
	L9	8.5415	7.6873	6.8332	5.979	5.1249	4.2707
	L10	9.5177	8.5659	7.6141	6.6623	5.7106	4.7588
	L13	12.9343	11.6408	10.3474	9.054	7.7605	6.4671
	L14	9.4689	8.522	7.5751	6.6282	5.6813	4.7344

	L15	15.4723	13.9251	12.3779	10.8306	9.2834	7.7361
	L16	4.8808	4.3927	3.9047	3.4166	2.9285	2.4404
	L18	16.2533	14.6279	13.0026	11.3773	9.7519	8.1266
	L19	8.8343	7.9509	7.0675	6.184	5.3006	4.4171
	L20	6.2475	5.6227	4.998	4.3732	3.7485	3.1237
Total price of load contribution		139.1042	125.1935	111.2832	97.3726	83.4623	69.5515

TABLE 8 Mega watt mile GLDF method for 24 bus test system in K€

Method	Customer	contribution 100%	contribution 90%	contribution 80%	contribution 70%	contribution 60%	contribution 50%
Mega watt mile method	L1	8.0175	7.2157	6.414	5.6122	4.8105	4.0087
	L2	7.2635	6.5371	5.8108	5.0844	4.3581	3.6317
	L3	9.2995	8.3696	7.4396	6.5096	5.5797	4.6497
	L4	5.3832	4.8449	4.3066	3.7682	3.2299	2.6916
	L5	4.8318	4.3486	3.8654	3.3822	2.8991	2.4159
	L6	8.9566	8.061	7.1653	6.2696	5.374	4.4783
	L7	10.5031	9.4528	8.4025	7.3522	6.3019	5.2515
	L8	12.3984	11.1586	9.9187	8.6789	7.439	6.1992
	L9	8.202	7.3818	6.5616	5.7414	4.9212	4.101
	L10	10.2204	9.1983	8.1763	7.1542	6.1322	5.1102
	L13	11.248	10.1232	8.9984	7.8736	6.7488	5.624
	L14	5.9957	5.3961	4.7965	4.1969	3.5974	2.9978
	L15	10.4308	9.3877	8.3446	7.3015	6.2584	5.2154
	L16	3.1045	2.794	2.4836	2.1731	1.8627	1.5522
	L18	12.2794	11.0515	9.8235	8.5956	7.3676	6.1397
	L19	6.1892	5.5703	4.9514	4.3324	3.7135	3.0946
	L20	4.7805	4.3025	3.8244	3.3464	2.8683	2.3902
Total price of load contribution		139.1041	125.1937	111.2832	97.3724	83.4623	69.5517

VI. CONCLUSION

Wheeling price calculation is become a challenging task due to deregulation. Every step price calculation for each unit of generator and load is very necessary for fair and straightforward competition. Wheeling pricing calculation at different level is also a necessary task due to know availability status and consumption of power because it cannot be constant ever. This approach has been implemented on Garver 6 bus and IEEE-RTS 24 bus test system and helpful to know every step calculation of wheeling prices. With this comparison and verification of postage stamp and mw-mile method shows the superiority of mw-mile approach in presence of power flow and with increase in distance.

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