ACTA Press

Determination of Tariff for Wheeling Contracts Considering Fairness Congestion Cost Allocation

Amir Bashian, Toktam Sharifian Attar, Mohammad Hossein Javidi, and Mehrdad Hojat

Keywords

Congestion Cost, Transmission Tariff, Wheeling Contract

Abstract

Fair transmission cost allocation, among network users, is very important in restructured power system. On the other hand, transmission pricing is the basis issues for transmission cost allocation. In this paper, a fair method for specifying transmission tariffs especially for wheeling contracts during peak and off-peak periods is proposed. Calculating congestion cost, when the wheeling contract leads to transmission congestion, is the main objective of our proposed method. In this method, the congestion cost is allocated to all users whose transactions contribute in congestion. The cost is allocated according to their contribution in network congestion. The method utilizes power transfer distribution factors. Then, Fairness of the method is analyzed. The proposed method has been implemented on 9-bus IEEE test system. Simulation results confirm the advantages of the method. The results also show that by using the method, the cost related to congestion will completely be recovered.

Important Links:

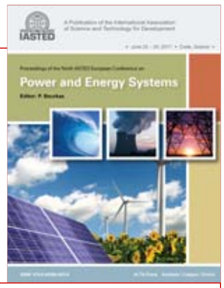
- DOI: 10.2316/P.2011.714-084
- *From Proceeding* (714) Power and Energy Systems - 2011

Add Paper to Cart

Go Back

ACTA Press

Power and Energy Systems (EuroPES 2011)



June 22 – 24, 2011
Crete, Greece

Editor(s): P. Bourkas

Other Years: 2011

Abstracts may contain minor errors and formatting inconsistencies.
Please contact us if you have any concerns or questions.

Add Checked Papers to Cart

Track	Power System Operation	Free	Subscription
714-028	**Experimental Study of Steam Turbine Blade Performance Operating in Partial Admission** Hyong-Jun Choi, Young-Ha Park, and Soo-Yong Cho	Abstract	Buy now
714-082	**Investment Perspectives on the Interconnection of Isolated Systems with the Mainland Grid: Crete Case Study** Emmanouil Loukarakis, Konstantinos Kalaitzakis, Eftichios Koutroulis, and Georgios Stavrakakis	Abstract	Buy now
714-115	**Experimental Investigation of EHD Flow in Wire to Cylinder Electrode Configuration** Konstantinos N. Kiousis and Antonios X. Moronis	Abstract	Buy now
714-126	**Urban Power Supply System's Development in Conditions of Uncertain Information** Svetlana Guseva, Nataly Skobeleva, Oleg Borscevskis, and Lubov Petrichenko	Abstract	Buy now
714-192	**Risk Management Methods for Service Oriented Architecture Implementation in Electric Power System** Nevenka Kiteva Rogleva, Vangel Fustik, and Vladimir Trajkovic	Abstract	Buy now
714-029	**DC Ring Topology – A Comprehensive Solution to Mega City Power Grids** Mohamed Y. Haj-Maharsi	Abstract	Buy now
714-141	**Overview of Voltage Control and Potential Applications of Secondary Voltage Regulations in Malaysia Tenaga Nasional Berhad Grid System** Sheikh Kamar B. Sheikh Abdullah, Nik Sofizan B. Nik Yusuf, Danial B. Mohd Nor, Ismail B. Musirin, and Izham B. Zainal Abidin	Abstract	Buy now

Track	Renewable Energy	Free	Subscription
714-026	**Case Study: Hydroelectric Generation Employing the Water Distribution Network in Pato Branco, Brazil** Bruno Leonardo Alves da Silva, Jean-Marc S. Lafay, Fernando L. Tofoli, and Luiz Sílvio Scartazzini	Abstract	Buy now
714-009	**A Grid-Connected PV System based on the Buck Converter** Joyce O. Gaio, Filipe R. Motta, João P.A. Grastiquini, Fernando L. Tofoli, and Carlos A. Gallo	Abstract	Buy now
714-021	**TejWell Dam** Tejinder Singh	Abstract	Buy now
714-073	**The Contribution of a PV Inverter in a Microgrid** Anastasia Adamopoulou, Wolf G. Früh, and Maria Samarakou	Abstract	Buy now
714-083	**Geo-Spatial Planning and Optimal Placement of Renewable Energy Systems** Sergey Malinchik	Abstract	Buy now
714-198	**Air Conditioning Load Control in Residential Feeders under the Presence of Distributed PV Systems** Yahia Baghzouz and Mehdi Etezadi-Amoli	Abstract	Buy now
714-061	**Developmental and Grid-Parity Analysis of the Photovoltaic Industry of Taiwan** Yenhaw Chen, Eve Hoadley, Chunto Tso, and Yen-Lin Chen	Abstract	Buy now
714-147	**Wind Farm Placement in Order to Congestion Management using Generation Shift Distribution Factors** Seyyed Zeinolabedin Moussavi, Ali Badri, and Fazlolah Rastegar Kashkooli	Abstract	Buy now
714-052	**Floating Solar Chimney Technology Scale Analysis** Christos D. Papageorgiou, Michael Psalidas, and Sotiris Sotiriou	Abstract	Buy now
714-064	**Floating Solar Chimney Technology with Multi-Pole Generators** Christos D. Papageorgiou, Sotiris Sotiriou, and Michael Psalidas	Abstract	Buy now
714-167	**A Preliminary Study of Oil Palm Fronds for Gasification Process** Shaharin A. Sulaiman, Samson M. Atnaw, and Mohamad N.Z. Moni	Abstract	Buy now
714-181	**The Main Features of Treska Cascade Control Center** Vangel V. Fustik and Nevenka Kiteva Rogleva	Abstract	Buy now
714-166	**A Framework for Analyzing Load-Carrying-Capacity of Plug-In Electric Vehicles and Impact on Solar Generators** Soumyo V. Chakraborty, Sandeep K. Shukla, and James Thorp	Abstract	Buy now
714-008	**Small Scale Photovoltaic-Wind Hybrid Systems in D.R. Congo: Status and Sustainability** Kanzumba Kusakana and Herman Vermaak	Abstract	Buy now

714-146	**Development of a DC-DC Converter with Symmetrical Output Applied in Renewable Energy Sources** Humberto T. Coelho, Vanessa C. de Sá, Carlos A. Gallo, and Roberto M. Finzi Neto	Abstract	Buy now
714-098	**Isolated Small Wind Power System** Pieter Ehlers, Coneth G. Richards, and Dan V. Nicolae	Abstract	Buy now
714-120	**Evaluation of Industrial Wastes and Effluents for Biomass Production under a New Process** João C.A.R. Claro and Darinka Costa-Gonzalez	Abstract	Buy now

Track	Distribution Systems	Free	Subscription
714-045	**Considerations about a New Type of High Breaking Capacity Fuses** Adrian Plesca and Alina Scintee	Abstract	Buy now
714-068	**Reasearch and Practise of Intelligent Service Restoration on County Distribution System** Huajian Hu, Huan Qi, and Xuncheng Huang	Abstract	Buy now
714-071	**Review of Magnetic Ballast Discharge Lamp Models** Julio Molina, Juan Jose Mesas, and Luis Sainz	Abstract	Buy now
714-072	**Experimental Measurements of Fluorescent Lamp Harmonic Current Emissions and Their Impact on Neutral Current** Jordi Cunill-Solà, Juan Jose Mesas, and Luis Sainz	Abstract	Buy now
714-034	**A New BPSO based Approach for Locating of Fault Indicators in Distribution Networks** Vahid Rashtchi, Ahmad Ashouri, and Amir Bagheri	Abstract	Buy now
714-003	**Fuzzy Modeled Load Flow Solution for Unbalanced Radial Power Distribution System** Mini S. Thomas, Rakesh Ranjan, and Roma Raina	Abstract	Buy now
714-056	**The Economical PQMS Construction Case in the Distribution Power System** Yong-Up Park, Byung-Sung Lee, and Won-Suk Choi	Abstract	Buy now
714-200	**The Inclusion of a Fuel Cell Model in a Power Flow Algorithm** Gladis G. Suarez-Velazquez, Jazmín Ortiz-Guerrero, and César Angeles-Camacho	Abstract	Buy now

Track	Power Electronics	Free	Subscription
714-012	**Study of a Three-Phase Shunt Active Power Filter Controlled using the Method of "Equivalent Sinusoid"** Mihail H. Antchev, Vanjo T. Gourgoulitsov, Mariya P. Petkova, and Hristo M. Antchev	Abstract	Buy now
714-179	**A Decaying DC-Offset Filtering Scheme based on the Stationary Wavelet Transform** Adedayo A. Yusuff, Adisa A. Jimoh, and Josiah L. Munda	Abstract	Buy now
714-175	**A Marine Electric Propulsion System with Poly-Phase Permanent Magnet Synchronous Motor under Full and Partial-Phase Operation** Mikhail V. Pronin, Aleksey G. Vorontsov, Grigorii A. Gogolev, and Lidia I. Osipova	Abstract	Buy now
714-145	**Consumption of the Electric Energy at Tramway with Resistors and Transistors Control** Jiri Kubín	Abstract	Buy now
714-156	**Study, Design and Implementation of a High Efficiency AC-DC-AC SMPS with Soft Switching Characteristics** Fernando L. Tofoli and Carlos A. Gallo	Abstract	Buy now
714-116	**Application of Wavelet Packets in Power Line Communications** Ehsan Sheybani and Nasser Rashidi	Abstract	Buy now

Track	Energy Storage	Free	Subscription
714-024	**Modelling and Simulation of SOFC System** Jabulisile S. Mavundla, Akshay K. Saha, Nelson M. Ijumba, Leon Chetty, and Edward Chikuni	Abstract	Buy now
714-088	**Improvement of Stability of Large Scale Wind Power Plant by Grading Energy Storage System** Yuanyuan Xu, Huan Qi, and Suqin Sun	Abstract	Buy now
714-089	**Effects on Grid Usage and Sizing of a Battery Model using Persistence Estimation Optimization** Filip Andrén, Matthias Stifter, and Johannes Kathan	Abstract	Buy now
714-128	**Long-Term Hydrogen Storage Approach for 5MW Micro-Power Generator using Wind Turbines** Shuang Yu, Tim J. Mays, and Roderick W. Dunn	Abstract	Buy now
714-085	**Effect of Round Trip Efficiency (RTE) on the Economic Performance of Energy Storage Systems** Basem R. Alamri	Abstract	Buy now

Track	Electrical Safety	Free	Subscription
714-063	**Causes of Conductor Abruption during Normal Weather Conditions** Constantinos D. Halevidis, Constantinos G. Karagiannopoulos, and Perikles D. Bourkas	Abstract	Buy now
714-062	**Protection from the Abruption of the Concentric Supply Cable** Constantinos D. Halevidis, Aikaterini D. Polykrati, Constantinos G. Karagiannopoulos, and Perikles D. Bourkas	Abstract	Buy now
714-193	**Feasibility of Fire Ignition from Molten Particles of Electrical Appliances** Panagiotis I. Mouzakitis, Constantinos D. Halevidis, George K. Soulinaris, John D. Koustellis, and Emmanuel I. Koufakis	Abstract	Buy now
714-118	**Causes of the Melting Image of a Conductor of Low Voltage Power Line Network** Aikaterini D. Polykrati, Constantinos D. Halevidis, Eleftherios G. Psarros, Emmanuel I. Koufakis, and Perikles D. Bourkas	Abstract	Buy now
714-190	**Protective Measures against Electrical Hazards of Consumer Installations** John D. Koustellis, Aikaterini D. Polykrati, John S. Katsanis, Peris G. Halaris, and Perikles D. Bourkas	Abstract	Buy now
714-114	**Protection of Technical Personnel from Electromagnetic Field during the Electrical Devices Overheating Test** John D. Koustellis, Fotini S. Karagrigoriou, Panagiotis I. Mouzakitis, Aikaterini D. Polykrati, and Perikles D. Bourkas	Abstract	Buy now

Track	Energy Efficiency	Free	Subscription

714-055	**Energy Management System for Smart Grid Consumers with Advanced Usage Information** Tongdan Jin, Yijuan Lu, and Chongqing Kang	Abstract	Buy now
714-174	**The Natural Radioactivity of Waste Materials and their Use as Building Materials: An Italian Case Study** Massimo Zucchetti and Hysen Mankolli	Abstract	Buy now
714-187	**Electrical Energy Consumptions in Hospitals - The Case of Lifts** John S. Katsanis, George N. Malahias, John D. Koustellis, and Peris G. Halaris	Abstract	Buy now
714-016	**Energy Gain in a Cold Season using Gunny Insulation in Concrete Buildings** Jahangir Payamara	Abstract	Buy now

Track	Reliability, Modelling, and Simulation	Free	Subscription
714-044	**Procedure for Investigating the Planned and Operational Reliability of Transmission Networks with GICs** Ron Herman, Charles T. Gaunt, and Milton Edimu	Abstract	Buy now
714-129	**Development of Methodology for Assessment of Reliability of Pipeline Networks** Sigitas Rimkevicius, Algirdas Kaliatka, Mindaugas Valincius, Gintautas Dundulis, Albertas Grybenas, and Inga Žutautaite-Šeputiene	Abstract	Buy now
714-050	**Appropriate Statistical Load Models for Light Industrial Electrification** Pierre van Rhyn, Jan-Harm Pretorius, and Ronald Herman	Abstract	Buy now
714-051	**Derivation of Electrical Design Algorithms for Light Industrial Parks** Pierre van Rhyn, Jan-Harm Pretorius, and Ronald Herman	Abstract	Buy now
714-178	**Modelling and Simulation of Combined Cycle Power Plants Participating in Network Frequency Control** Mohammad Hadi Mazhab Jafari, Ali Mazhab Jafari, and Kamal Saidabadi	Abstract	Buy now
714-087	**Physical Modeling and Laboratory Testing of Cairo-Aswan 3-Phase High Voltage Transmission Line** Rania M. Sharkawy	Abstract	Buy now
714-191	**Model Structure of Generalized Load and Combined Method for Parameter Determination** Yuqing Jin, Changpei Gao, Bin Sun, Guosong Wang, Ping Ju, and Xiaowen Gu	Abstract	Buy now
714-197	**Numeric Oscillations Decreasing in Electromagnetic Transient Simulations due to the Variation of the Circuit Quantity used for the Transmission Line Representation** Leonardo S. Lessa, Afonso J. Prado, Sérgio Kurokawa, José Pissolato Filho, and Luiz F. Bovolato	Abstract	Buy now

Track	FACTS	Free	Subscription
714-125	**Description of the Internal State of TCSC** Amos O. Anele, John T. Agee, and Adisa A. Jimoh	Abstract	Buy now
714-031	**Improving Power System Stability by the Use of SSSC-Static Synchronous Series Compensator** Ali Rahnamaei, Payam Farhadi, Davoud Mostafa, Mohammad Karimi, and Mina Vajdi	Abstract	Buy now
714-030	**Novel Designs for a DC Breaker** Mohamed Y. Haj-Maharsi	Abstract	Buy now
714-103	**The Enhancement of Industrial Power System Operation using STATCOM Equipment with Fuzzy Logic and Genetic Algorithm** Javad Khodabakhsh and Ehsan S. Parizy	Abstract	Buy now

Track	Strategies and Electricity Markets	Free	Subscription
714-101	**Environmental/Economic Load Dispatch under Carbon Reduction Policies with Particle Swarm Optimization** Jae-Kun Lyu, Wook-Won Kim, Yong-Tae Yoon, and Jong-Keun Park	Abstract	Buy now
714-161	**Co-Benefits of Internalizing Local Air Pollution Costs in India's Power Sector** Ryo Eto, Akinobu Murata, Yohji Uchiyama, and Keiichi Okajima	Abstract	Buy now
714-013	**A Fuzzy Controller based Demand-Side Management System Design for Optimization of Induction Furnaces** Lungile Nyanga and Samson Mhlanga	Abstract	Buy now
714-084	**Determination of Tariff for Wheeling Contracts Considering Fairness Congestion Cost Allocation** Amir Bashian, Toktam Sharifian Attar, Mohammad Hossein Javidi, and Mehrdad Hojat	Abstract	Buy now
714-077	**A Statistical Approach in Determining the Electrical Short Term Demand in a Rapid Railway System** Grant Manuel and Jan-Harm C. Pretorius	Abstract	Buy now
714-159	**An Investigation of Strategic Behavior by a Reserve Provider in the Joint Energy and Reserve Market** Kai Liu, Jin Zhong, David P. Camara, and Yunhe Hou	Abstract	Buy now

Track	Testing of Electrotechnical Apparatus	Free	Subscription
714-017	**Determination of Overvoltages in High Voltage Networks at Single Phase Faults by Numerical Simulation and Experiments** Curcanu George, Toader Dumitru, and Toaxen Vasile	Abstract	Buy now
714-169	**The Average Value of Electronic Energy during Dielectric Ageing of Polymeric Solid Insulators under HVAC Stress** Peris G. Halaris, John S. Katsanis, George K. Soulinaris, John D. Koustellis, and Aikaterini D. Polykrati	Abstract	Buy now
714-086	**Application of Modified Sequential Floating Forward Feature Selection to Partial Discharge Patterns** Rania M. Sharkawy and Karim I. Mohamedeen	Abstract	Buy now
714-162	**Partial Discharges Measurements on Coated and Non-Coated Solid Dielectric in Air** George K. Soulinaris, Constantinos D. Halevidis, Fotini S. Karagrigoriou, Peris G. Halaris, and Perikles D. Bourkas	Abstract	Buy now
714-109	**Consumed Electrical Power in Fuse Cases of Low Voltage Electrical Boards** Fotini S. Karagrigoriou, Panagiotis I. Mouzakitis, John D. Koustellis, Emmanuel I. Koufakis, and Constantinos G. Karagiannopoulos	Abstract	Buy now

Track	Applications	Free	Subscription
714-158	**Conversion of Glycerol to Gasoline Additive** Michio Ikura	Abstract	Buy now ☐
714-067	**H_2S Removal Capacity and Structural Properties of Iron-based Composite Sorbent** Ailing Ren, Junyan Sun, Bin Guo, Yuhui Zhao, and Miaomiao Zhang	Abstract	Buy now ☐
714-076	**Nano-Pt(Ni)/TiO_2-NTs Electrocatalysts for Borohydride Oxidation** Loreta Tamašauskaitė-Tamašiūnaitė, Rasa Čekavičiūtė, Dijana Šimkūnaitė, and Algirdas Selskis	Abstract	Buy now ☐

Track	Additional Paper	Free	Subscription
701-112	**A Strategic Roadmap to Meet the Future Energy Projections for Sustainable Development of Pakistan** Muhammad Aleem and Murad Ali	Abstract	Buy now ☐

Abstracts may contain minor errors and formatting inconsistencies.
Please contact us if you have any concerns or questions.

Add Checked Papers to Cart

Show Digital Object Identifers *What are Digital Object Identifers?*

Rates (USD): N/A (Hardcopy) ; $331.50 (Online) ; $390.00 (CD)

(The Hardcopy and CD proceedings also include the Online version)

For **complete proceedings** please choose one of the following:

Add Hardcopy | Add Online Subscription | Add CD

Online Edition	$331.50	Buy Now
CD Edition	$390.00	Buy Now
Individual Articles (Online):	$25.00	

Hard Copy Subscriptions are not available for EuroPES 2011

ISSN: N/A ;
ISBN: N/A ;
ISSN (CD): N/A ;
ISBN (CD): 978-0-88986-883-0 ;
ISSN (Online): N/A ;

Loading Information

Go Back

0 Privacy & Legal RSS Newsletters Sitemap

DETERMINATION OF TARIFF FOR WHEELING CONTRACTS CONSIDERING FAIRNESS CONGESTION COST ALLOCATION

Amir Bashian
Graduate Student- Ferdowsi University of Mashhad
amir.bashian@stu-mail.um.ac.ir

Toktam Sharifian Attar
Khorasan Regional Electricity Company
t.sharifian@ieee.org

Mohammad Hossein Javidi
Faculty Member of Ferdowsi University of Mashhad
h-javidi@ferdowsi.um.ac.ir

Mehrdad Hojat
Graduate Student- Ferdowsi University of Mashhad
me.hojjat@stu-mail.um.ac.ir

ABSTRACT

Fair transmission cost allocation, among network users, is very important in restructured power system. On the other hand, transmission pricing is the basis issues for transmission cost allocation.

In this paper, a fair method for specifying transmission tariffs especially for wheeling contracts during peak and off-peak periods is proposed. Calculating congestion cost, when the wheeling contract leads to transmission congestion, is the main objective of our proposed method. In this method, the congestion cost is allocated to all users whose transactions contribute in congestion. The cost is allocated according to their contribution in network congestion. The method utilizes power transfer distribution factors. Then, Fairness of the method is analyzed. The proposed method has been implemented on 9-bus IEEE test system. Simulation results confirm the advantages of the method. The results also show that by using the method, the cost related to congestion will completely be recovered.

KEY WORDS

Congestion Cost, Transmission Tariff, Wheeling Contract.

1. INTRODUCTION

Power systems in many countries of the world have experienced restructuring during the past decade. The aim has been to increase the efficiency in power generation and to offer better services to electric power consumers [1]. After restructuring of power systems, transmission lines have been subjected to more attention. In restructured power systems, bilateral contracts have received more attention. In this environment, determination of contract tariff has become more important than before.

In the new environment, attention should be paid to: 1) how to create necessary incentive for investment in transmission and 2) how to recover the investments on transmission fields.

Wheeling has been defined as “the usage of a utility’s transmission facilities to transmit power for other buyers and sellers” [11]. Therefore, a wheeling contract refers to the right for a buyer and a seller to use a utility’s transmission network for energy transfer. At least three parties are involved in a wheeling transaction: a buyer, a seller and one or more utilities that transmit the power from the seller to the buyer. The third party is paid for the use of its network [6]. The wheeler may not necessarily be the owner of transmission network, but it mainly refers to the operator of the network. Until now, several methods have been proposed for wheeling cost. Wheeling cost models mainly have been based on two principles: the amount of transmission capacity used for the transaction and the cost for transmission capacity.

A wheeling transaction is defined as an injection into one or more nodes of the network and simultaneous retrieval from one or more nodes of the network. It can be separated into three groups, specified as follows [3]:

1- Point to point wheeling transaction: both injection and retrieval are located in the same network. In the case of injection, this is an independent power producer (IPP).

2- Interconnected system-point: in this case, the retrieval of electrical energy is released in distribution network and injection is located outside of this network.

3- Point-inter connected system: in this case, the retrieval of electrical energy is located outside of network and injection is located inside of network.

Wheeling contracts have several impacts on wheeler network such as increasing losses, transmission congestion and deviation from optimal power generation [10]-[13]. Normally, a wheeler tries to keep the power generation in its optimal pattern.

For any wheeling contract, the forced losses due to the contract must be recovered by sellers and buyers.

In this paper, the transmission cost is divided into two parts: capacity cost and congestion cost. For a fair transmission cost allocation, the method utilizes power transfer distribution factors. Firstly, transmission capacity cost is calculated using distribution factors and MW-MILE method [15]. Then with implementation of wheeling contract to the network, congestion costs related to wheeling contracts are allocated to the contract parties, fairly.

This paper is organized as following: in section 2, the existing different methods for transmission cost allocation are briefly explained. In section 3, the distribution factors method is described. In section 4, our proposed method for specifying fair hourly tariff of wheeling contracts has been described. In section 5, the proposed method has been implemented on a 9-bus IEEE test system. Using simulation results in section 5, the validity of the method is evaluated. Finally, in section 6, the fairness of the method from the viewpoint of network's owner and users will be studied.

2. OVERVIEW OF TRANSMISSION PRICING METHODS

From network owner's point of view, transmission pricing should recover the total costs for transmission services. On the other hand, network users would like pricing schemes for usage of system be reasonable. Different methods for transmission pricing have been proposed. Based on proposed methods, so far, the wheeling prices mainly mainly utilize one of two basic methods:

1- Marginal cost methods [2]
2- Embedded cost methods [15]

A complete wheeling charge method has to fulfill the following items [7], [8]:

1- Conciseness and transparency
2- Recovery of invested cost
3- Efficient operation of electric network
4- Fairness and acceptability for wheeling service users

Marginal cost methods do not necessarily satisfy the first and the second items mention above. Therefore, embedded cost methods are more acceptable. On the other hand, the embedded cost methods have remarkable features. Embedded cost methods are advantageous, because they not only allocate total costs among transmission network users according to their usage of system, but also, these methods can recover the investment cost [8]. In embedded cost methods, network owner cannot obtain excess profit by market power. However, as in these methods, the total cost for transmission usage is recovered; it is more acceptable for network users [5]. On the other hand, the embedded cost method may be disadvantageous, because this method, in its general form, does not identify high or low usage of network. The main deficiency for both of above mentioned methods is that they do not consider the costs for congestion and losses.

Embedded cost methods include post stamp, contract path and MW-mile methods. In the first two methods load flow calculation is not performed. On the other hand, the MW-Mile method is based on load flow calculation. In MW-mile method, transmission embedded cost is allocated among transactions in proportion to the ratio of flow magnitude contributed by each particular transaction. To consider reactive power transactions together with active power in transmission facilities, MW-mile method may be expanded as MVA-mile method. In this way, both active and reactive power changes are considered [5], [14]. In [7], wheeling charges are calculated based on identification of transactions paths. Utilizing this method, some of disadvantages of conventional MW-mile method may be resolved.

In this paper, a fair method for specifying transmission tariffs especially for wheeling contracts during peak and off-peak periods is proposed. In this method, the congestion cost is allocated to all users whose transactions contribute in congestion.

3. DISTRIBUTION FACTOR METHOD

Distribution factors are calculated using linear load flow. Then, using these factors, the effect of each generator and load on transmission flow can be evaluated with respect to these factors [9].

3.1 Generalized Generation Distribution Factors (GGDF or D Factors)

These factors specify the amount of change in real power of a transmission line caused by variation in generation of a certain generator. They may be negative or positive. D factors are defined as below:

$$\begin{aligned} F_{l-k} &= \sum_{i=1}^{N} D_{l-k,i} G_i \\ D_{l-k,i} &= D_{l-k,r} + A_{l-k,i} \\ D_{l-k,r} &= \left\{ F^{0}_{l-k} - \sum_{i=1}^{N} A_{l-k,i} G_i \right\} \sum_{i=1}^{N} G_i \end{aligned} \qquad (1)$$

F_{l-k}: total transmission flow between buses l and k

F^0_{l-k}: transmission flow between buses l and k obtained in previous iteration

$D_{l-k,r}$: D factor related to line connecting buses l and k caused by generation variation in reference bus

G_i: total generation in bus i

$A_{l-k,i}$: Generation Shift Distribution Factors(GSDF or A factors) related to line connecting buses l and k caused by generation changes in bus i.

GGDF factors determine the total usage of transmission network related to injections in the network.

3.2 Generalized Load Distribution Factors (GLDF or C Factors)

These factors determine the contribution of each load in transmission line flow. C factors are defined as below [9]:

$$C_{l-k,r} = \left\{ F^{0}_{l-k} + \sum_{\substack{j=1 \\ j \neq r}}^{N} A_{l-k,j} L_j \right\} / \sum_{j=1}^{N} L_j \qquad (2)$$

$$C_{l-k.j} = C_{l-k,r} - A_{l-k,j} \qquad (3)$$

$$C_{l-k.r} = \left\{ F^{0}_{l-k} + \sum_{\substack{j=1 \\ j \neq r}}^{N} A_{i-k,j} L_j \right\} / \sum_{j=1}^{N} L_j \qquad (4)$$

F_{l-k}: total transmission flow between buses l and k

$F^{0}_{l\text{-}k}$: transmission flow between buses l and k obtained in previous iteration

$C_{l\text{-}k,j}$: C factor related to the line between buses l and k caused by demand in bus j

$C_{l\text{-}k,r}$: GLDF related to the line between buses l and k caused by demand in bus r

L_j: total demand in bus j

Notice that GLDF factors are calculated with DC load flow.

4. PROPOSED METHOD FORMULATION

In this paper, the transmission cost is divided into two parts: capacity cost and congestion cost. The congestion cost is allocated to all users whose transactions contribute in congestion. Distribution factors are used to allocate this cost to different buses. Capacity cost is calculated using distribution factors and utilizing the MW-mile method. Then, applying wheeling contracts to the network, the congestion cost related to the contract is allocated fairly to contract parties.

4.1 Calculation of Capacity Cost

In this paper, transmission capacity cost is calculated using the method in [9]:

$$TC_t = TC \cdot \frac{\sum_{k\in K} C_k L_k MW_{t,k}}{\sum_{t\in T}\sum_{k\in K} C_k L_k MW_{t,k}} \quad (5)$$

TC_t: the allocated cost to contract

TC: total transmission cost

L_k: length of line k (mile)

C_k: cost per MW due to line unit length

T: set of contracts

K: set of transmission lines

According to the above formulation, each user of the network should pay for transmission cost corresponding to its contribution to flows of transmission lines which can be calculated using distribution factor method.

4.2 Congestion Cost Calculation

Applying wheeling contracts, due to system congestion and losses, the wheeler network deviate from its optimal generation pattern. So wheeler should receive additional costs imposed by contract parties. To do this, OPF[1] is executed for the network until injections and deviations of generations from the optimal pattern are calculated. This cost will be added to transmission cost. Therefore, if congestion occurs in any line, the congestion cost must be allocated only to contract parties. After calculating the contribution of each user in congested lines, according to distribution factors, the congestion cost will be calculated and added to transmission tariff. The wheeling tariff, then, can be written as below:

[1] Optimal Power Flow

$$TP = \frac{TC + CC}{P} \quad (6)$$

TP: wheeling tariff for the contract

TC: transmission capacity cost

CC: congestion cost

P: the amount of transmitted power

According to the above formulation, we can evaluate wheeling tariff for the contract fairly considering congestion cost. It should be noted that, if the congestion occurs in the network, the transmission cost will be different for peak and off peak hours.

The flowchart for the proposed method is illustrated in figure 1. The proposed method is implemented on 9-bus test system shown figure 2.

5. CASE STUDY AND DISCUSSION OF THE RESULTS

To investigate the proposed method, it has been applied to the 9-bus test system shown in figure 2 [4]. The network data are given in the appendix. It is also assumed that there is a wheeling transaction between buses 6 and 8. In this contract, the seller and the buyer are located in buses 8 and 6, respectively.

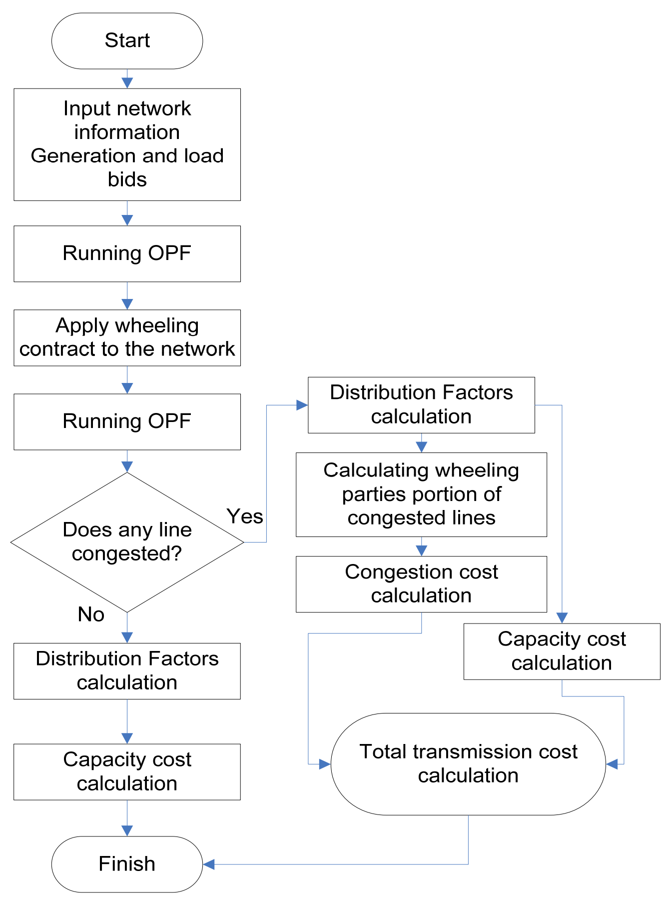


Figure 1. Flowchart of the proposed method

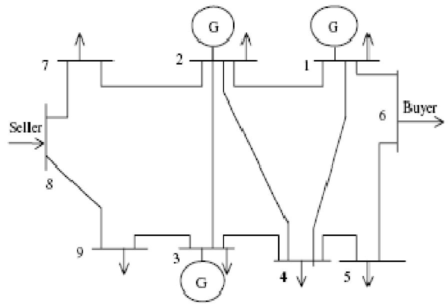


Figure 2. The 9 bus test system

5.1 Calculation of Transmission Cost during Peak Period

Assume a contract for exchanging power between contract parties at buses 6 and 8 with the amount of 60 MW are available, considering network topology, distribution factors C and D for these buses can be calculated as Table (1).

Table 1

Distribution factor due to wheeling transaction

Line	Cij,6	Dij,8
1-2	0.364595	-0.06408
1-4	0.029261	0.063964
1-6	0.59453	0.007066
2-3	-0.00768	0.205655
2-4	0.170499	0.005038
2-7	-0.00318	0.397659
3-4	0.280049	-0.10669
3-9	0.000999	0.609874
4-5	0.442296	-0.01657
5-6	-0.43124	0.011689
7-8	0.002026	-0.39153
8-9	-0.00168	-0.60149

Considering values in table 1 and D factors for the three generators, the contribution of injection buses in the network from the transmitted power will be as those shown in table (2).

Table 2

Transmission usage allocation applying distribution factor

Line	Line cost	Pij^{G8}	Pij^{G1}	Pij^{G2}	Pij^{G3}
1-2	200	-3.84	-34.93	100.38	34.42
1-4	840	3.84	37.20	12.27	-10.27
1-6	1000	0.42	21.57	37.64	16.61
2-3	760	12.34	12.34	88.56	-69.94
2-4	300	0.30	-2.19	51.53	12.19
2-7	400	23.86	11.00	42.54	-3.08
3-4	320	-6.40	-10.49	34.17	57.63
3-9	120	36.59	6.58	5.92	29.91
4-5	600	-0.99	9.09	47.21	30.21
5-6	80	0.70	-8.15	-1.13	3.42
7-8	280	-23.49	4.27	-0.24	26.06
8-9	380	-36.09	8.63	35.88	-6.51
total	5280	-	-	-	-

Now, using equation (5), considering values in table (2), the capacity cost due to the contract are calculated as below:

$$TC_t = TC \cdot \frac{\sum_{k \in K} C_k L_k MW_{t,k}}{\sum_{t \in T} \sum_{k \in K} C_k L_k MW_{t,k}} \qquad (7)$$

$$= 5280 \times \frac{50812}{50812 + 88963 + 221566 + 140363}$$

$$= 534.76 \frac{\$}{hr}$$

Therefore, the transmission capacity cost that should be paid by contract parties can be calculated as mentioned above.

In the test system, if the wheeling contract is not considered, the generation cost will be equal to 5638.13 $/h. On the other hand, considering the wheeling transaction for the network, the line 1-4 becomes congested. This is mainly because of the fact that the transfer capacity is only 60 MW. After generation re-dispatch in the network, the generation cost deviate from the optimum value and increases to 5923.47 $/h.

Considering the section 4.2, the excess cost related to congestion problem must be compensated by transaction parties. Table I shows that the distribution factor for both buyer and seller. As it can be observed, they are equal to 0.029261 and 0.063964 respectively. This means that the seller and buyer should pay 68.7% and 31.3% of congestion cost, respectively. Therefore, the transmission cost due to the capacity and congestion cost is equal to:

TTC = TC + CC (8)

= 534.76 + 285.34 =820.1 $/hr

In (8), TTC is the total transmission cost. According to (6), wheeling tariff for mentioned transaction is equal to:

$$TP = \frac{TC + CC}{P} = \frac{820.1}{60} = 13.66 \frac{\$}{MWh} \qquad (9)$$

Wheeler receives the tariff calculated in (9) from transaction parties. It should be noted that this cost must be compensated by transaction parties according to their contribution in transmission capacity and the congestion they cause. Transmission capacity cost for both seller and the buyer is paid equally. However, the congestion cost will be allocated between both contributors according to their portion in congestion (table 3).

Table 3

Wheeling tariff

Wheeling Tariff for contract parties ($/MWh)		
seller	buyer	tariff
4.456	4.456	capacity
3.267	1.488	congestion
7.723	5.944	total

5.2 Calculation of Transmission Cost during Off Peak Period

The network data for off peak period is given in table (10). In this case, line 1-4 is loaded less than 60 MW and therefore, it will not be congested. Data for line flow and D factors are listed in table (4).

Table 4
D factors in off peak period

Line	Flow (MW)	Dij,8	Dij^{G1}	Dij^{G2}	Dij^{G3}
1-2	9.69	-0.21683	-0.28088	0.328652	0.214912
1-4	52.99	0.179851	0.333093	0.033962	-0.06753
1-6	62.78	0.044929	0.2301	0.15213	0.125591
2-3	25.53	0.237307	0.086643	0.2499	-0.38779
2-4	24.64	-0.03665	-0.0105	0.171102	0.078407
2-7	18.1	0.400995	0.056855	0.094474	-0.05246
3-4	24.52	-0.19727	-0.067	0.1297	0.349497
3-9	1.79	0.589746	0.004768	-0.0325	0.113073
4-5	50.29	-0.04896	0.103597	0.180239	0.206319
5-6	0.58	0.046873	0.046212	-0.02917	-0.05483
7-8	22.16	-0.40008	0.063166	0.025606	0.172318
8-9	37.67	-0.59306	0.115324	0.152903	0.006117

The transmission capacity cost in this case is equal to:

$$TC_t = TC \cdot \frac{\sum_{k \in K} C_k L_k MW_{t,k}}{\sum_{t \in T} \sum_{k \in K} C_k L_k MW_{t,k}} \quad (10)$$

$$= 489.61 \frac{\$}{hr}$$

Considering (6), the wheeling tariff for this contract will be equal to:

$$TP = \frac{TC}{P} = \frac{489.61}{60} = 8.16 \frac{\$}{MWh} \quad (11)$$

Transmission capacity cost for the seller and the buyer will be divided equally. Therefore, the seller and the buyer each will pay 4.08 $/MWh. We can see that during off peak period, the transmission cost is less than that of the peak period. The main reason is the absence of congestion in all lines.

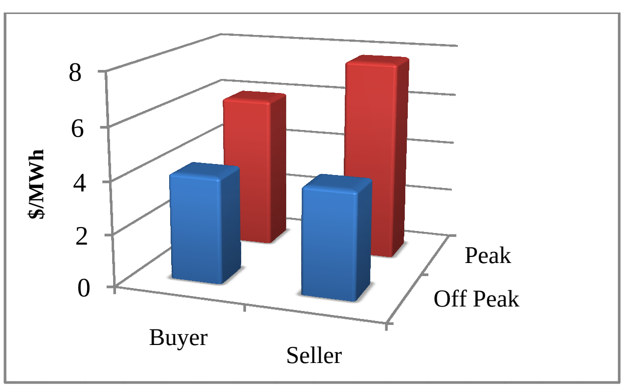


Figure 3. Wheeling tariff comparison in peak and Off-peak periods

6. ANALYSIS OF THE METHOD FAIRNESS

In this section, fairness of the method is investigated with calculating LMP (Locational Marginal Pricing) in the wheeler network with and without the wheeling contract. In section 5-A, the generation cost with and without contract are calculated. These costs are obtained from LMP at network buses. The LMP and generation at injection buses with and without the transaction are listed in table (5).

Table 5
LMP and generation in injection buses

Bus No.	Before Contract		After Contract	
	Generation(MW)	LMP($/MWh)	Generation(MW)	LMP($/MWh)
1	269.6	8.761	122.34	8.302
2	250.61	8.82	337.5	9.16
3	117.21	9.093	186.04	9.763

According to table (5), without wheeling contract, the generation cost is equal to 5638.13 $/h. However, applying the wheeling transaction to the network, the line 1-4 is congested. This is because this line can transfer only 60 MW. So after re-dispatch in the network, the generation cost deviates from the optimum value and increases to 5923.47 $/h. If the line 1-4 is not congested, the LMP and generation are as shown in table 6.

Table 6
LMP and generation in injection buses

Bus No.	With Contract(without congestion)	
	Generation(MW)	LMP($/MWh)
1	290.54	8.921
2	238.5	8.775
3	108.28	9.014

We can see that, the generation cost in this case is equal to 5660.78 $/h. So, if congestion does not occur, the imposed cost to the wheeler network is low. Therefore, the wheeler just receives the capacity cost and spends this money for network expansion.

If congestion occurs in the wheeler network, the users of the network should pay excess charges related to the wheeling contract. The LMP and load at all buses of network are listed in table (7).

Table 7
LMP and load in wheeler network

Bus No.	Before Contract		After Contract	
	Demand(MW)	LMP($/MWh)	Demand(MW)	LMP($/MWh)
1	80	8.761	80	8.302
2	80	8.82	80	9.16
3	80	9.093	80	9.763
4	120	9.366	120	12.94
5	120	9.736	120	12.527
6	0	9.341	0	11.193
7	70	9.585	70	9.808
8	0	9.648	0	9.801
9	70	9.675	70	9.957

According to table (7), without wheeling contract, the loads should pay about 5774 $/h. On the other hand, applying the wheeling transaction to the network, the demand charge deviate from the optimum value and increases to 6618 $/h. Therefore, when wheeling contract is applied to the network, the wheeler loads should pay about 844 $/h more than the normal condition. The total wheeling cost in section 5.1 is evaluated to be about 820 $/h. Therefore, the wheeler can pay this cost to the network loads to compensate the excess cost imposed. The results show that the proposed method can compensate the imposed cost to the wheeler network fairly.

7. CONCLUSION

Proper transmission pricing can promote the efficient operation of power system and encourage investment in production and transmission. The marginal cost method may not cover all of the investment and operation costs. Therefore, the embedded cost methods are more acceptable.

In this paper, the transmission pricing method is evaluated. Then, the wheeling tariff has been modified to allocate the congestion cost to all users who contribute in congestion according to their contribution to the congestion. Also, the wheeling tariffs during peak and off peak periods are compared.

8. APPENDIX

Table 8
Test system data

Line No.	Start and End Bus	R(p.u)	X(p.u)	Y(p.u)
1	1-2	0.042	0.0168	0.041
2	1-4	0.031	0.121	0.031
3	1-6	0.053	0.21	0.051
4	2-3	0.031	0.126	0.031
5	2-4	0.084	0.336	0.082
6	2-7	0.053	0.21	0.051
7	3-4	0.053	0.21	0.051
8	3-9	0.053	0.126	0.051
9	4-5	0.03	0.126	0.031
10	5-6	0.031	0.126	0.031
11	7-8	0.03	0.126	0.031
12	8-9	0.015	0.0513	0.015

Table 9
Wheeler generators data

Generator	$C(P_g)=A.P_g^2+B.P_g+C$ (\$/hr)			Q_{gmax} (MVar)	Q_{gmin} (MVar)	P_{gmax} (MW)	V (p.u)
	A	B	C				
1	0.00156	7.92	561	800	-800	1000	1.06
2	0.00194	7.85	310	100	-90	400	1.045
3	0.00482	7.97	78	100	-90	400	1.01

Table 10
Wheeler buses load

Condition	load	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5	Bus 7	Bus 9
Peak	Active(MW)	80	80	80	120	120	70	70
	Reactive(MW)	30	30	30	50	50	20	20
Off peak	Active(MW)	50	50	50	50	50	40	40
	Reactive(MW)	20	20	20	20	20	20	20

REFERENCES

[1] Bin Liu, Yafang Liu and Tsuginon Inaba, “A New Wheeling Price Calculation Method Considering Transmission Line Congestion and Loss Costs”, 2004 lnternatlonal Conference on Power System Technology,Singapore, 21-24 November 2004.

[2] S P Zhu,“Some Considerat ions on Transmission Services Concerning Optimizing Wheeling Parties’ Benefits”, IEEE Catalogue No. 95TH8130.

[3] E. Handschin, L. Muller, T. Nikodem, R. Palma, “Comparison of Pricing Methodologies for Wheeling Transactions in Liberalised Energy Supply Systems”, Paper accepted for presentation at the International Conference on Electric Utility Deregulation and City University, London, 4-7 April 2000.

[4] Yousefi, G.R, Seifi, H, “Wheeling charges with consideration of consumer load modeling”, Power Systems Conference and Exposition, 2004. IEEE PES, Publication Year: 2004, Page(s): 168 - 173 vol 1.

[5] M. Majidi Q, M. S. Ghazizadeh, S. Afsharnia,” A Novel Approach to Allocate Transmission Embedded Cost Based on MW-Mile Method under Deregulated Environment”, 2008 IEEE Electrical Power & Energy Conference.

[6] Mohammad Yusri Hassan, “MW-Mile Charging Methodology for Wheeling Transaction”, A thesis submitted for degree of doctor of Philosophy at the university of Strathclyde, june 2004.

[7] Hiromu Hamada, Hideo Tanaka, Ryuichi Yokoyama, “Wheeling Charge Based on Identification of Transaction Paths in Deregulated Power Markets,”Universities Power Engineering Conference (UPEC), 2009 Proceedings of the 44th International Publication Year: 2009.

[8] R. Gnanadass and N. P. Padhy,”A New Approach for Transmission Embedded Cost Allocation in Restructured Power Market”, Journal of Energy & Environment 4 (2005) 37 – 47.

[9] Mohammad Shahidehpour, HAtim Yamin and Zuyi Li,” Market Operation in Electric Power Systems”,Shahidehpour. Mohammad,1995.

[10] Ji Wang, Furong Li,”Optimal economic environmental dispatch considering wheeling charge, “Universities Power Engineering Conference, 2004. UPEC 2004. 39th International, Publication Year: 2004, Page(s): 398 - 401 Vol. 1.

[11] Pornthep Panyakaew and Parnjit Damrongkulkamjorn, “Optimal Loss Allocation of Multiple Wheeling Transactions in a Deregulated Power System”, 5th International Conference on Electrical and Computer Engineering ICECE 2008, 20-22 December 2008, Dhaka, Bangladesh.

[12] T. Nakashima, T. Niimura, IS. Okada, R. Yokoyama, N. Okada, “Multiple-Impact Assessment of Wheeling and Independent Power Producers In a De-Regulated Power System” , Electrical and Computer Engineering, 1998. IEEE Canadian Conference on, Publication Year: 1998, Page(s): 89 - 92 vol.1.

[13] M. P. Abdullah, M. Y. Hassan and F. Hussin, “Congestion Cost Allocation in a Pool-Based Electricity Market” ,2nd IEEE International Conference on Power and Energy (PECon 08), December 1-3, 2008, Johor Baharu, Malaysia.

[14] Ching-Tzong Su, Ji-Horng Liaw, “Power Wheeling Pricing Using Power Tracing and MVA-KM Method”, Paper accepted for presentation at PPT 2001 2001 IEEE Porto Power Tech Conference 10th -13th September, Porto, Portugal.

[15] H. H Happ,” Cost of Wheeling Methodologies”, IEEE Trans, Power system, Vol 9, No 1,February 1994, pp 147-156.