IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 4, Issue 7, July 2016

Power System Planning With Renewable Resources Integration

Avnish Paul[1], Raminder Kaur[2], Dr. Tarlochan Kaur[3]

Student, Dept of Electrical Engg, PEC University of Technology, Chandigarh (UT), India[1, 2]

Head, Dept of Electrical Engg, PEC University of Technology, Chandigarh (UT), India[3]

Abstract: Generation and transmission systems are two important parts of power systems which are mainly considered for expansion. GEP is related to the investment on energy production and determines size, place, technology and the time of installing new plants to satisfy the forecasted load within the given reliability criteria over a planning horizon. TEP is the other important planning in power systems and denotes when, where and how many lines should be installed to ensure an adequate level of energy supply to customers, taking into account the load growth and reliability. In recent years, integration of renewable into main grid and ongoing deregulated environment take many challenges to power system expansion planning. In recent years, integration of renewable into main grid and ongoing deregulated environment take many challenges to power system expansion planning.

Keywords: Graver's 6-Bus System (Thermal, Thermal and Thermal) GRAV_TTT, Renewable integration, deregulated, solar, wind.

I. INTRODUCTION

The integration of the renewable energy such as wind and solar goes hand in hand with the transmission expansion planning. Renewable energy resources produce less greenhouse gases and provide energy at low variable cost. However the intermittent and non-dispatch able nature of the renewable resources are some of the complex issues associated. Also most the renewable resources are location constrained and are usually located in regions with insufficient transmission facilities. In order to deal with the challenges presented by renewable resources as compared to conventional resources, the transmission network expansion planning procedures need to be modified. New high voltage lines need to be constructed to connect the remote renewable resources to the existing transmission network to serve the load centres. Moreover, the existing transmission facilities may need to be reinforced to accommodate the large scale penetration of renewable resource.

Economic benefits and environmental issues are the two major concerns of the power system planning and its operations. Several strategies such as integration of renewable energy resources are adopted by the network planner to overcome these problems. As there are limitations of conventional energy resources, major attraction is moving towards the renewable power resources and other portable power devices. The power system planning is to be done in an optimized way to prevent the system failure, load shedding and reliability. In mathematical terms the problem can be reduced to a set of nonlinear equations where the real and imaginary components of the nodal voltages are the variables. The number of equations equals twice the number of nodes. The nonlinearities can roughly be classified being of a quadratic nature. The result of a power flow problem tells the operator or a planner of a system in which way the lines in the system are loaded, what the voltages at the various buses are, how much of the generated power is lost and where limits are exceeded. The power flow problem is one of the basic problems in which both load powers and generator powers are given or fixed. Today, this basic problem can be efficiently handled on the computer for practically any size system.

II. AC POWER FLOW APPROACH

Restructuring and deregulation of the power industry have changed the objectives of power system expansion planning and increased the uncertainties. As a result, new approaches and criteria are needed for transmission expansion planning in deregulated power system.

In the steady state, an n-node power system may be represented by the 2n power-flow equations:

$$P_i^G - P_i^L = P_i^N = V_i \sum V_j Y_{ij} \cos(\theta_i - \theta_i - \Phi_{ij}) \ldots(1)$$

$$Q_i^G - Q_i^L = Q_i^N = V_i \sum V_j Y_{ij} \sin(\theta_i - \theta_i - \Phi_{ij}) \ldots(2)$$

where,

P_i^G = active power generated at node i,
P_i^L = active power consumed at node i,
P_i^N = net active power injected at node i (active injection),
Q_i^G = reactive power generated at node i,
Q_i^L = reactive power consumed at node i,
Q_i^N = net reactive power injected at node i (reactive injection),
V_i = voltage magnitude at node i,
θ_i = voltage phase angle at node i
Y_{ij}, Φ_{ij} = admittance magnitude and phase angle between connected nodes i, j.

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 4, Issue 7, July 2016

If all but 2n of the variables P_i^N, Q_i^N, V_i and θ_i are given,these 2n unknowns (selected as independent variables) can be determined by solving the 2n power-flow equations (1) and (2). A concise way to represent this system of 2n algebraic equations is the vector equation g (x , u) = 0

where u =vector of independent (or control) variables, with m components; x=vector of dependent (or state) variables, with 2n components; and g= the 2n power-flow equations (1) and (2).

III. OPTIMAL POWER FLOW

OPF functionally combines the power flow with economic dispatch. Minimize cost function, such as operating cost, taking into account realistic equality and inequality constraints

a.) Equality constraints
- bus real and reactive power balance
- generator voltage setpoints
- area MW interchange

b.) Inequality constraints
- transmission line/transformer/interface flow limits
- generator MW limits
- generator reactive power capability curves
- bus voltage magnitudes (not yet implemented in Simulator OPF)

c.) Available Controls
- generator MW outputs
- transformer taps and phase angles

Generation and distribution of power must be accomplished at minimum cost but with maximum efficiency. This involves the real and reactive power scheduling of each power plant in such a way as to minimize the total operating cost of the entire network In other words, the generator's real and reactive power is allowed to vary within certain limits so as to meet a particular load demand with minimum fuel cost.

This is called the Optimal Power Flow (OPF) or sometimes known as the Optimal Power Dispatch or Economic Dispatch (ED) problem.Optimal Power Flow (OPF) plays an important role in power system operations and planning. In the normal operating condition OPF is used to determine the load flow solution which satisfies the system operating limits and minimize the generation costs. In power system planning. OPF is used for capacitor placement studies and transmission capability studies.

STATEMENT OF THE AC OPTIMUM POWER-FLOW PROBLEM:
A natural objective for optimizing a power system is economy, that is, the hourly operating cost F which is a function of the active generations P_i^G only:
$F=\sum V_i\,(P_i^G)= F(x,u)$, $\quad i = 1,\ldots\ldots,n.$

$$\underline{V}_i \le V_i \le \overline{V}_i$$
$$\underline{Q}_i^G \le Q_i^G \le \overline{Q}_i^G$$
$$\underline{P}_i^G \le P_i^G \le \overline{P}_i^G$$
$$\underline{P}_{ij} \le P_{ij} \le \overline{P}_{ij}$$
$$\underline{I}_{ij} \le I_{ij} \le \overline{I}_{ij}$$
$$\underline{S}_{ij} \le S_{ij} \le \overline{S}_{ij}$$

The regulated power system was the traditional power system called as vertically integrated market where one regulated utility was responsible for generation, transmission and distribution.

In vertically integrated power systems, network expansion was intended to meet the present and future system reliability standards at a minimum investment cost. So in such a system planners have complete access to the required information for planning.

In these systems location of generation and loads, size of loads and generating units, availability of units, load pattern, and dispatch pattern are known. Therefore, planners can design the least cost transmission plan based on certain reliability criteria. Trans miss ion planning in regulated systems is modelled with a deterministicetermini tic optimization.

The objective function is cost of planning and operation, with technical and economic constraints. The deregulated power system is the one in which generation and distribution is unbundled in a view to be more economical and reliable as compared to the traditional one.

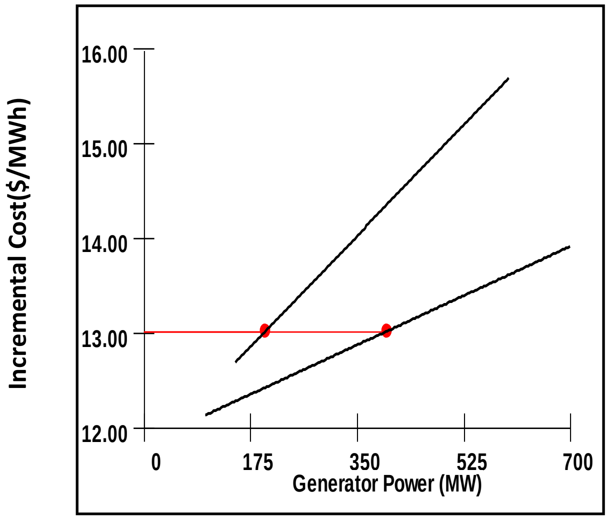

Figure 1: Incremental Cost Curve

The deregulation introduces the competition in generation in a view to improve the efficiency and in transmission to increase the reliability of the system resulting in transformation of traditional power system and introducing the new challenges in all aspects of generation, transmission and distribution.

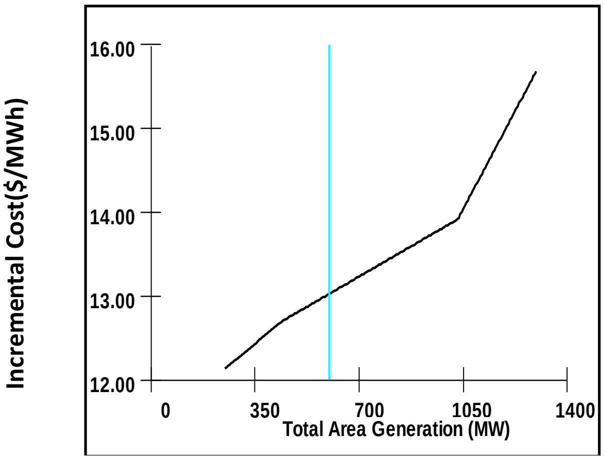

Figure 2: Area supply Curve

IV. AUTOMATIC GENERATION CONTROL

Automatic Generation Control (AGC) forms an essential part of power system operation and control of large interconnected networks. This section gives a brief introduction on the basic concepts of AGC, which in this paper, is used in conjunction with OPF solutions. In practical cases, load is never constant and it varies throughout the day. This causes the system frequency to change due to the imbalance between generation and load. Since the exact forecast of load cannot be assured, it is necessary, through AGC, to balance the generation and the load so as to maintain the system frequency at its nominal operating value, typically 50Hz or 60Hz .Each area has its own control centre, where the AGC system continuously monitors the system frequency and actual power flows in tie lines to neighbouring areas. The net interchange of power over tie -lines of an area is the algebraic difference between area generation and area load. AGC then automatically changes generators' outputs to restore net interchange power to scheduled values. This is to remove the Area Control Error (ACE) so as to maintain the system frequency. The ACE is a composite measure formed by the system frequency deviation combined with the deviation from the scheduled net power interchange. See books by Sadat, Grainger and Stevenson for detailed information. In Power World Simulator, when the system is under OPF AGC control, all generators' outputs are varied automatically by AGC in conjunction with the solutions solved by the OPF algorithm to drive the ACE to zero regardless of the load conditions. This maintains the system frequency while minimizing operating costs and satisfying all necessary OPF constraints

V. SIMULATION AND RESULTS

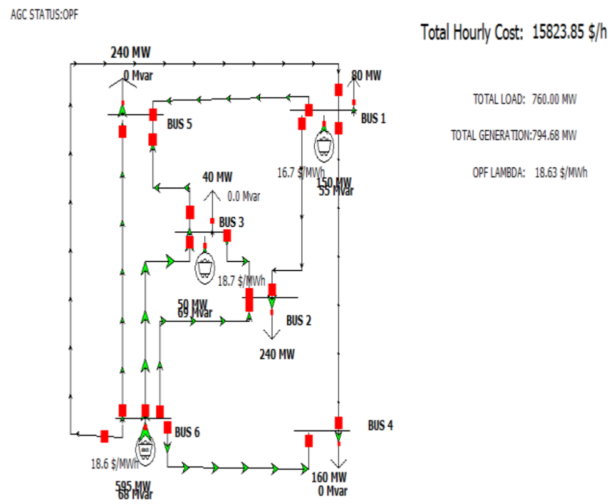

Figure 3: Graver's 6-Bus System (Thermal, Thermal and Thermal) abv. GRAV_TTT

Table 1: Bus Records: (GRAV_TTT)

Bus Records:									
Number	Name	Type	Nom kV	PU Volt	Volt (kV)	Angle (Deg.)	Load MW	Gen MW	Gen Mvar
1	BUS 1	PQ	138	1.04	143.52	-12.39	80	150	55.43
2	BUS 2	PQ	138	0.9484	130.882	-21.12	240		
3	BUS 3	PV	138	1.04	143.52	-11.25	40	50	68.97
4	BUS 4	PQ	138	1.0305	142.209	-9.09	160		
5	BUS 5	PV	138	0.9695	133.794	-19.59	240		
6	BUS 6	Slack	138	1.04	143.52	0		594.66	67.86

Table 2: Generator Records: (GRAV_TTT)

Gen Records:												
Number of Bus	Name of Bus	OPF MW Control	Gen MW	Cost $/Hr (generation only)	MW Marg. Cost of Bus	IC for OPF	Initial MW	Initial Cost	Max MW	Cost Model	Fuel Type	Profit $/hr
1	BUS 1	If Agcable	150	2975.32	18.63	16.74	150	2975.32	150	Cubic	Coal	-180.11
3	BUS 3	If Agcable	50	1784.82	18.63	18.67	50	1784.82	360	Cubic	Coal	-853.09
6	BUS 6	If Agcable	594.7	11063.33	18.63	18.63	594.7	11063.33	600	Cubic	Coal	18.07

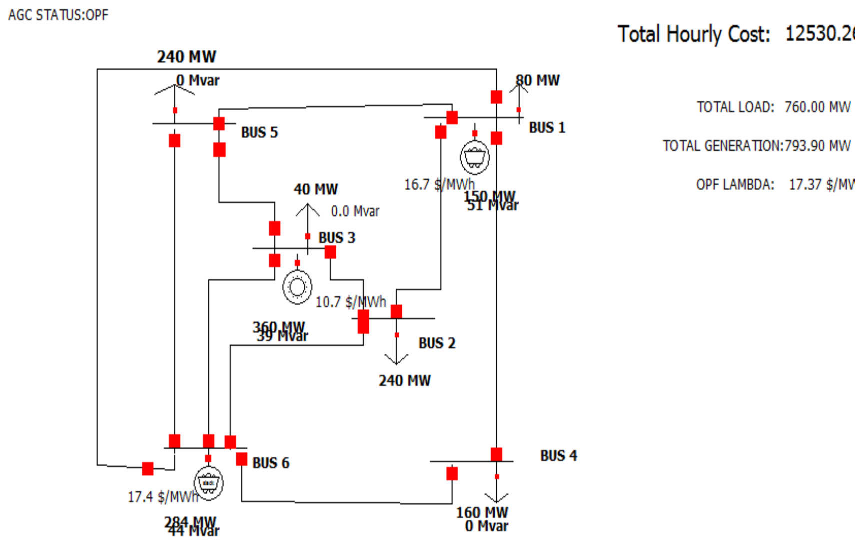

Figure 4: Graver's 6-Bus System (Thermal, Wind and Thermal) abv. GRAV_TWT

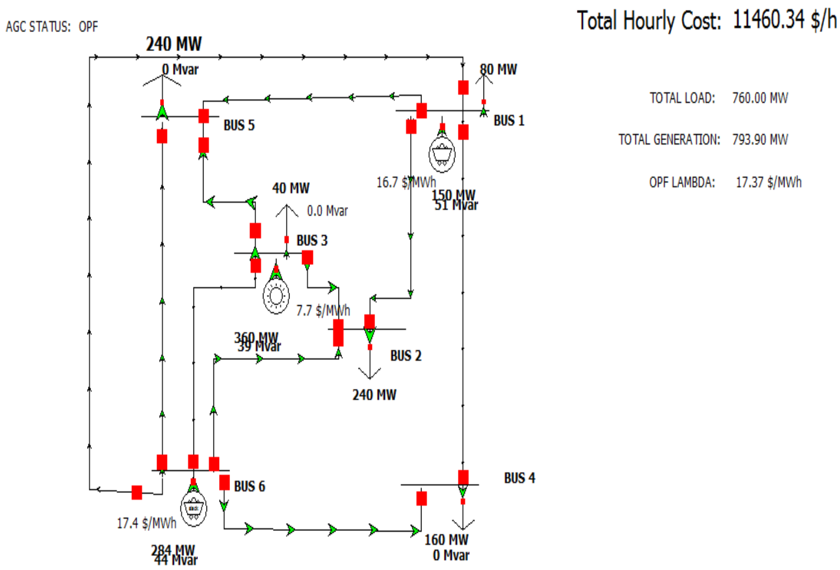

Figure 5:Graver's 6-Bus System (Thermal, Solar and Thermal)abv. GRAV_TST

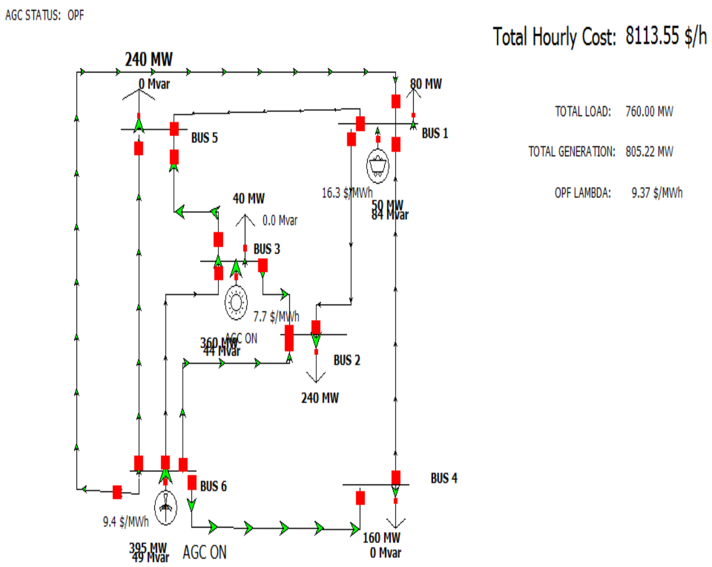

Figure 6: Graver's 6-Bus System (Thermal, Solar and Wind)abv. GRAV_TSW

Table 3: COMPARATIVE STUDY OF DIFFERENT SYSTEMS

S.No.	System Abrevation	NORMAL LOAD		15% INCREASED LOAD	
		TOTAL HOURLY COST($/h)	OPF λ ($/MWh)	TOTAL HOURLY COST($/h)	OPF λ ($/MWh)
1	GRAVER_TTT	15823.9	18.63	18238.99	19.25
2	GRAVER_TWT	12531	17.37	14762.79	18
3	GRAVER_TST	11460	17.3	13702.99	18
4	GRAVER_TSW	8113.55	9.37	9365.35	9.76

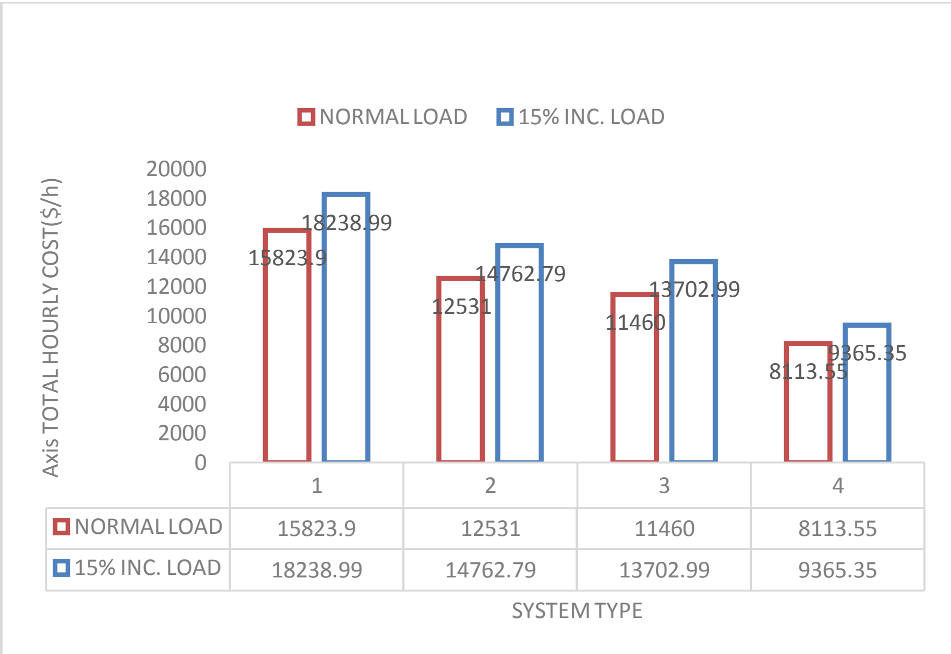

Figure 7: Variation of Hourly Cost

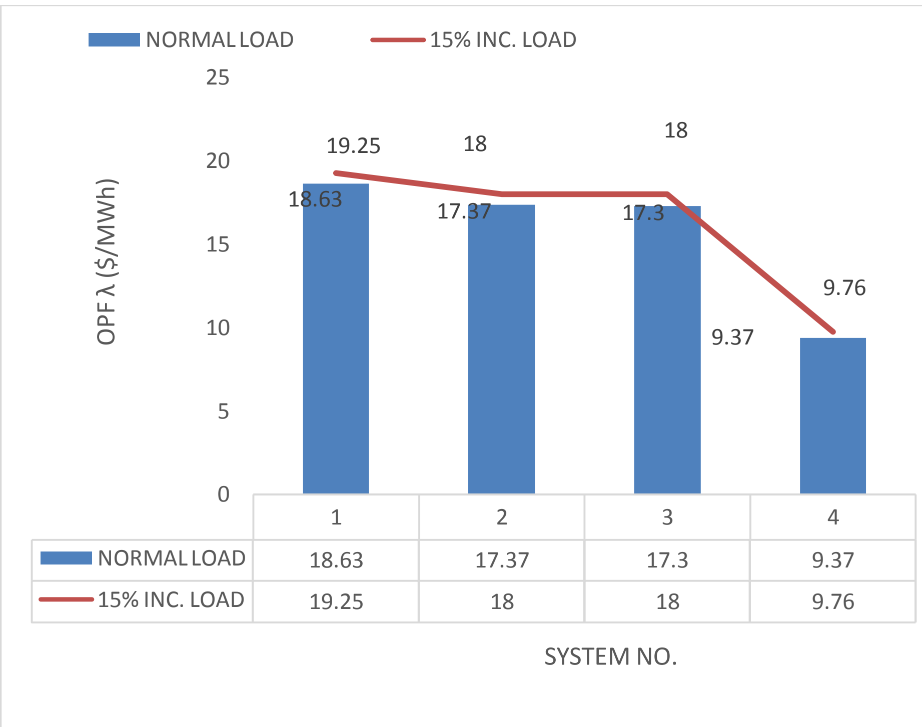

Figure 8:VARIATION OF OPF LAMBDA

- As we can see here in the first model when all the generators are Thermal the Total hourly cost as well as the OPF λ is maximum. After that when one of the generator is replaced by the Wind the hourly cost as well as the OPF λ falls to a lesser value and so on further when it's replaced by the solar the quantities falls to much lesser value. Hence here in the last case where there is one thermal, one solar and one wind the Total hourly cost and Optimal Power Flow λ are least. This shows that how the addition of the renewables is affecting our existing system due to their zero fuel costs and lesser hourly costs.
- The observing the supply area curves let us take here Figure 4. 1 Area Supply curve GRAV_TSW the load here is being supplied by the renewables itself up to a certain limit of load. This is being done automatically as the AGC (Automatic Generation Control) status is ON.
- The generators here at Bus 1, 3, and 6 will participate in the OPF if there individual AGC status is ON.
- In basic gravers system (thermal, wind and solar) the same is done with the Economic Dispatch and OPF respectively to show the difference in the OPF lambda in both the cases.

REFERENCES

[1] Adminstration, U. E., 2013. Energy Information Adminstration. [Online] Available at: https://www.eia.gov/forecasts/aeo/ electricity_generation.cfm [Accessed Dec 2015].

[2] AmirsamanArabali, Mahmoud Ghofrani, Student Mehdi Etezadi-Amoli, Life Senior Member, Mohammed Sami Fadali, and MoeinMoeini - Aghtaie,(2014) "A Multi-Objective Transmission Expansion Planning Framework in Deregulated Power Systems With Wind Generation" IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 29, NO. 6.

[3] Amin Khodaei , Mohammad Shahidehpour , Lei Wu and Zuyi Li (2012) "Coordination of Short-Term Operation Constraints in Multi-Area Expansion Planning" IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 27, NO. 4.

[4] AzimLotfjou, Yong Fuand Mohammad Shahidehpour (2012) "Hybrid AC/DC Transmission Expansion Planning" IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 27, NO. 3.

[5] Carlos Adrian Correa, Ricardo Andres Bola˜nos, Alejandro Garces (2012) "Environmental Transmission Expansion Planning Using Non-linear Programming and Evolutionary Techniques"

[6] ChandrakantRathore, Ranjit Roy, Utkarsh Sharma, Jay Patel (2013) " Artificial Bee Colony Algorithm Based Static Transmission Expansion Planning"

[7] David Pozo, EnzoE. Sauma, Javier Contreras(2013), A Three-Level Static MILP Model for Generation and Transmission Expansion Planning, IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 28, NO. 1.

[8] D. E. Newman, B. A. Carreras, M. Kirchner and I. Dobson, (2011). "The Impact of Distributed Generation on Power Transmission Grid Dynamics", © 2011 IEEE, 44rd Hawaii International Conference on System Science, January, Kauai, Hawaii

[9] E. E. Sauma and S. S. Oren, "Proactive planning and valuation of transmission investments in restructured electricity markets," J. Reg. Econ., vol. 30, no. 3, pp. 261–290, 2006.

[10] Enrique Bustamante-Cedeno˜ ,Sant Arora (2009) "Multi-step simultaneous changes Constructive Heuristic Algorithm for Transmission Network Expansion Planning" Electric Power Systems Research.

[11] F. H. Murphy and Y. Smeers, "Generation capacity expansion in imperfectly competitive restructured electricitymarkets," Oper. Res., vol. 53, no. 4, pp. 646–661, 2005.

[12] George A. Orfanos, Pavlos S. GeorgilakisGeorge A. Orfanos, Pavlos S. Georgilakis(2013) Transmission Expansion Planning of Systems with Increasing Wind Power Integration, IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 28, NO. 2,

[13] G. A. Orfanos, P. S. Georgilakis and N. D. Hatziargyriou "A Recursive Harmony Search Algorithm for Security Constrained Transmission Expansion Planning"

[14] G. Latorre, R. Cruz, J. Areiza and A. Villegas, (2003) "Classification of publications and models on transmission expansion planning," IEEE Transactions on Power Systems, vol. 18

[15] no. 2, pp. 938- 946,

[16] M. Leite da Silva, S. M. P. Ribtiro, V. L. Anenti, R. N. Allan, and M. B. Da CoultoFilho , (1990) "Probabilistic load flow techniques applied to power system expansion planning," IEEE Trans. PWRS Vol. 5, No. 4, pp. 1047-1053.

[17] M. Lu, Z.Y. Dong , T.K. Saha (2005) "A Framework for Transmission Planning in a Competitive Electricity Market" IEEE/PES Transmission and Distribution Conference & Exhibition: Asia and Pacific Dalian, China

[18] M. Oloomi, H. M. Shanechi, G. Balzer and M.Shahidehpour, (2003) "Transmission planning approaches in restructured power systems," in Proc. IEEE/Power Eng. Soc. Power Tech. Conf., Bologna, Italy, vol.2.

[19] M. Oloomi, G. Balzer, H. M. Shanechi and M.Shahidehpour, . (2004) "Market-based transmission expansion planning," IEEE Trans. Power Syst., vol. 19, no. 4, pp.2060–2067.

[20] M. R. Hesamzadeh, D. R. Biggar, N. Hosseinzadeh, and P. J. Wolfs, "Transmission augmentation with mathematical modeling of market power and strategic generation expansion—Part I," IEEE Trans. Power Syst., vol. 26, no. 4, pp. 2040–2048, Nov. 2011.

[21] NingYang ,Fushuan Wen (2005) "A chance constrained programming approach to transmission system expansion planning" Electric Power Systems Research 75 (2005) 171–177

[22] R. Romero, A. Monticelli, A. Garcia and S. Haffner,(2002)"Test systems and mathematical models for transmission network expansion planning," IEEE Proceedings –Generation, Transmission & Distribution, vol. 149, no. 1,pp. 29-36,

[23] P. Maghouli, S. H. Hosseini, M. O. Buygi, and M. Shahidehpour,(2009) "A multi-objective framework for transmission expansion planning in deregulated environment," IEEE Trans. Power Syst., vol. 24, no. 2, pp. 1051–1061

[24] Corporation, P. W., 2014. Power World. [Online] Available at: http://www.powerworld.com/files/M02Optimal-Power-Flow.pdf [Accessed Jan 2016].

[25] R. Garcia-Bertrand, D. Kirschen, and A. J. Conejo, ., 2008 "Optimal investments in generation capacity under uncertainty," in Proc. 16th Power Systems Computation Conf.

[26] S. Chuang, F.Wu, and P. Varaiya, "A game-theoretic model for generation expansion planning: Problem formulation and numerical comparisons," IEEE Trans. Power Syst., vol. 16, no. 4, pp. 885–891, Nov. 2001

[27] Silvio Binato, GersonCouto de Oliveira, and Joao Lizardo de Araújo (2001) "A Greedy Randomized Adaptive Search Procedure for Transmission Expansion Planning" IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 16.

[28] S. Vassena, P. Mack, P. Rousseaux , C. Druet and L. Wehenkel (2003) "A Probabilistic Approach to Power System Network Planning under Uncertainties" IEEE Bologna PowerTech Conference

[29] S.Wogrin, E. Centeno, and J. Barquin, "Generation capacity expansion in liberalized electricity markets: A stochasticMPEC approach," IEEE Trans. Power Syst., vol. 26, no. 4, pp. 2526–2532, Nov. 2011

[30] Te6filo De la Torre,James W. Feltes, TomisGdmez, San Romiin Hyde hI. Merrill(1999) "Deregulation, Privatization, And Competition: Transmission Planning under Uncertinity" IEEE Transactions on Power Systems, Vol. 14, No. 2.

[31] T. Li and M. Shahidehpour, "Strategic bidding of transmission-constrained GENCOs with incomplete information," IEEE Trans. Power Syst., vol. 20, no. 1, pp. 437–447, Feb. 2005.

[32] Nanduri, T. K. Das, and P. Rocha, "Generation capacity expansion in energy markets using a two-level game theoretic model," IEEE Trans. Power Syst., vol. 24, no. 3, pp. 1165–1172, Aug. 2009.

[33] V. S. K. Murthy Balijepalli, S. A. Khaparde (2010) "Novel Approaches for Transmission System Expansion Planning Including Coordination Issues"

[34] Xinsong Zhang, Yue Yuan, Boweng WU, Qiang Li,(2011) "A Novel Algorithm for Power System Planning Associated with Large-scale Wind Farms in Deregulated Environment" , IEEE Transaction on Power System Deregulation.