ACTA TECHNICA CORVINIENSIS
– Bulletin of Engineering
Tome X [2017]
Fascicule 2 [April – June]
ISSN: 2067 – 3809

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POWER FLOW CONTROL FOR DISTRIBUTION GENERATOR IN EGYPT USING FACTS DEVICES

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Abstract: A purpose of power flow studies is to minimize the power distribution losses and the cost of power drawn from the substation, without affecting the voltage regulation. The current electrical power needs are increasing rapidly in line with technological developments. Optimal Power Flow (OPF) problem is to optimize a certain objective over power network variables under certain constraints. The variables may include real and reactive power outputs, bus voltages and angles, the objective may be the minimization of generation cost or maximization of user utilities and the constraints may be bounded on voltages or power levels, or that the line loading not exceeding thermal or stability limits. Optimal reactive power dispatch problem as a sub-problem of the Optimal Power Flow (OPF) is a very important optimization problem in power systems as proper management of reactive power injection into the power system can minimize losses in real power, voltage deviations and save voltage stability. The power system uses the simplified symbol such as a one-line diagram, per-unit system, moreover direct on various regard of alternating current power parameters, such as voltages, voltage angles, active power and reactive power. Researchers studied many different solutions have been proposed to solve the OPF problems. This paper presents a survey for Flexible Alternating Current Transmission Systems (FACTS) that can consider for OPF in power system.
Keywords: Power System, OPF, FACTS

INTRODUCTION

The current electrical power needs are increasing rapidly in line with technological developments. This electrical power needs the increase in contrast with depletion of the energy sources availability of oil and coal [1]. Optimal Power Flow (OPF) problem is to optimize a certain objective over power network variables under certain constraints. The variables may include real and reactive power outputs, bus voltages and angles, the objective may be the minimization of generation cost or maximization of user utilities and the constraints may be bounded on voltages or power levels, or that the line loading not exceeding thermal or stability limits [2].

Researchers studied many different solutions have been proposed to solve the OPF problems for examples; using advanced power converter technologies [3], a stand-alone Renewable Energy (RE) system based on Energy Storage (ES) [4], multi-objective Evolutionary Algorithm (EA) for high levels of penetration from Distributed Generations (DG) [5]. Gravitational Search Algorithm (GSA) is proposed to find the optimal solution for optimal power flow (OPF) problem in a power system [6], using the Jaya Algorithm (JA) one from methods that's used with OPF [7] and realized OPF problem by means of Particle Swarm Optimization (PSO) algorithm with consideration Static Var Compensation (SVC) system and Static Synchronous Compensator (STATCOM) [8].

OPF PHYSICAL CONSTRAINTS

OPF includes any optimization problem which seeks to optimize the operation of an electric power system (specifically, the generation and transmission of electricity) subject to the physical constraints imposed by electrical laws and engineering limits on the decision variables [9] [14]. Since power flow is considered under steady state balanced condition, a positive sequence model of the power grid is adopted for power flow solution [10].

The basic equation for power flow analysis is derived from the nodal analysis equations for the power system, OPF constraints may be categorized into equality constraints and inequality constrain [15].

OPF formulations incorporating the AC power flow show in equations (1), (2) are both nonlinear and non-convex for N bus power system [11].

$$P_i = \sum_{j=1}^{n} |Y_{ij}||V_i||V_j| \cos(\theta_{ij} + \delta_j - \delta_i) \qquad (1)$$

$$Q_i = \sum_{j=1}^{n} |Y_{ij}||V_i||V_j| \sin(\theta_{ij} + \delta_j - \delta_i) \qquad (2)$$

FACTS SYSTEM CLASSIFIED

It is well documented that the planning and the optimum operation of an electrical system involve developing evolution scenarios of the electrical energy requirement such as installation and implementation of FACTS controllers [9].

The purpose of FACTS controllers is to facilitate the supply of loads inflexible and rapid fashion while providing optimal management of electrical networks. Voltage problems can constrain transfers and can result in more blackouts than first-swing instability, poor damping, and thermal overloads combined.

Today, heavily utilized transmission systems may require more MVAR of compensation for each MW of new load to survive single contingencies without voltage collapse. Reactive power planning and operations are very complex. Most system planners develop rules to define limits to system loading, determine constrained interface limits and demonstrate the steady state effect of system modifications.

For a variety of generation dispatches, the limiting contingency could be different and the cause of the transmission limitation could vary among voltage, dynamic stability, or thermal restrictions. Furthermore, different pricing considerations would change the magnitude and economic value of bottled energy.

Based upon each scenario, the transmission planner could propose shunt capacitors, power system stabilizers, transmission line upgrades (including phase angle regulators), FACTS controllers, or combinations of improvements.

The likelihood of each case scenario would then need to be considered to formulate a final plan [12]. The variables in power system depend on the type of busses that's simulating with FACTS devices. Each bus in power system can be classified as:

- **Load bus (P-Q bus)**

Buses without generators are defined a load busses, they generated active power P, and reactive power Q, are taken as zero. The load drawn by these buses are simulated by active power (P) also reactive power (Q) in which the negative sign contains the power flowing out of the bus. So this bus is referred to as P-Q bus [10].

- **Generator bus**

This is a sources bus that's generators are connected. The active power and voltage magnitude are specified in this bus, while the reactive power and phase angle require calculating [10]. This bus also the voltage magnitude is kept without changes by setting field current of the synchronous generator.

In another hand, if this bus has a renewable energy source as solar or wind energy, it's controlled through a prime mover while voltage is controlled through the generator excitation. By keeping input power constant through turbine governor control and fixing bus voltage by using Automatic Voltage Regulator (AVR) system. Reactive power supplied by the generator depends on the system configuration logic. By increasing the prime mover's governor set points increases the power that generator supplies to the power system [10].

- **Slack bus (Swing or reference Bus)**

This is an arbitrarily-selected bus a special generator bus serving as the reference bus for the power system. Its voltage is assumed to be fixed in both magnitude values, phase angle and simulated by per unit value ($1\angle 0^\circ$ Pu), in slack bus P and Q are unknown.

OPF SOFTWARE SIMULATION

OPF can be simulate by programming software as example using World Power Simulator (WPS) and power system simulator, figure (1) shows single line diagram using WPS software for simulate OPF by the values of voltage magnitude, voltage angle, active power and reactive power for a design 6 bus which depend on 14-Busses IEEE standers.

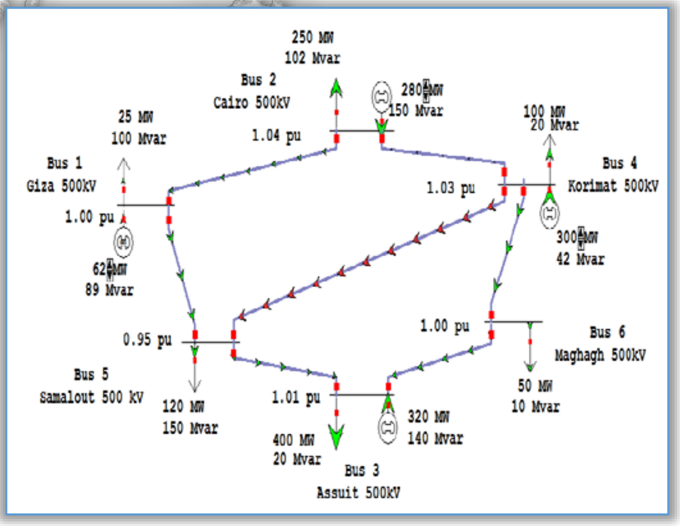

Figure 1. Single line diagram for small electrical grid OPF simulator

Table (1) shows the data for busses in the system, by start the system to simulate energizing busses its will show the optimum operation for the voltage, voltage angle, the output active power and output reactive power from generators. The results showing in table (2) and table (3).

Table (1) Data for busses in the system

Bus No.	Name of Bus	Types of Bus
Bus 1	Giza 500kV	Slack Bus
Bus 2	Cairo 500 kV	Generator Bus
Bus 3	Assuit 500kV	Generator Bus
Bus 4	Korimat 500kV	Generator Bus
Bus 5	Samalout 500 kV	Load Bus
Bus 6	Maghagha 500kV	Load Bus

Table (2) Data for Busses Loads with generator Bus

No of Bus	Name of Bus	Load - MW	Bus Load Mvar	Gen MW	Gen Mvar
Bus 1	Giza 500kV	25.0	100.00	61.72	88.87
Bus 2	Cairo 500kV	250.0	102.00	279.65	150.09
Bus 3	Assuit 500kV	400.0	20.00	320.00	140.11
Bus 4	Korimat 500kV	100.0	20.00	300.00	41.55
Bus 5	Samalout 500kV	120.0	150.00	-	-
Bus 6	Maghagha 500 kV	50	10.00	-	-

Table (3) Data for Voltage magnitude and Voltage angle

No of Bus	Name of Bus	Bus Nom kV	Bus PU Volt	Bus optimal Volt (kV)	Bus Angle (Deg)
Bus 1	Giza 500kV	500.00	1.00000	500.000	0.00
Bus 2	Cairo 500kV	500.00	1.04000	520.000	0.55
Bus 3	Assuit 500kV	500.00	1.01000	505.000	-6.47
Bus 4	Korimat 500kV	500.00	1.03000	515.000	0.89
Bus 5	Samalout 500kV	500.00	0.95363	476.815	-2.58
Bus 6	Maghagha 500 kV	500.00	1.00460	502.300	-3.79

APPLICATION TO ADD FACTS CONTROLLERS

FACTS is a transmission system which use reliable high-speed thyristor based high-speed controllable elements such as SVC, TCSC, and UPFC etc. [16]. Are designed based on state of the art developments in power semiconductor devices.

Issues include increased utilization of existing facilities such as secure system operation at higher power transfers across existing transmission lines which are limited by stability constraints, the development of control designs for FACTS devices, and determination of functional performance requirements for FACTS components [13].

The maximum benefit from a FACTS Controller is obtained when its use is coordinated with other transmission equipment. This requires that the utility applying the controller consider the information infrastructure and communications required for this coordination. It also requires decisions made with system operators about defining reference values for the FACTS Controllers and switching procedures for conventional transmission equipment (tap changing transformers, switched capacitors, etc.)

An important activity that must be part of the application is an estimate of the functional reliability of the overall system and specific analysis that shows the security of the system considering possible malfunctions of portions of the coordinated control. An important part of the application to add FACTS Controllers to a transmission system is the functional specification for the Controller.

In addition to the ratings and standards requirements there are several considerations that may be unique to FACTS Controllers [17]. These include the communication interfaces with the system, the level of automation in the substation and coordination of substation switching equipment and relays. Some utilities also standardize the symbols used to depict equipment in graphical displays and the acronyms and abbreviations used in all printed documents.

This equipment includes substation event recorders that are invaluable for both documenting the benefit of FACTS Controllers and diagnosing control and protection issues. A careful determination of how much of this equipment is to be supplied with the FACTS Controller and how much will be added by the utility greatly enhances both the acceptance and usefulness of FACTS products [12] [18].

CONCLUSION

The proposed of study OPF with FACTS by different techniques to updates and new plans level of Conventional Generation (CG). FACTS can provide control of voltage magnitude, voltage phase angle and impedance. Therefore, it can be utilized to effectively increase power transfer capability of the existing power transmission lines, and reduce operational and investment costs. In this paper shows the software method depending on IEEE-30 bus systems. FACTS devices it is clear that discussed in this paper to reduce the power losses total cost in the system. Also various FACTS controllers like STATCOM, SVC and UPFC etc.

References

[1.] Ontoseno Penangsang, Primaditya Sulistijono and Suyanto “Optimal power flow using multi-objective genetic algorithm to minimize generation emission and operational cost in micro-grid “ International Journal of Smart Grid and Clean Energy, PP; 410:416, vol. 3, 2014.

[2.] K. Mani Chandy, Steven H. Low, Ufuk Topcu and Huan Xu " A Simple Optimal Power Flow Model with Energy Storage" 49th IEEE Conference on Decision and Control, December 15-17, Hilton Atlanta Hotel, Atlanta, GA, USA, 2010.
[3.] Chao-Tsung Ma and Tzung-Han Shr "Power Flow Control of Renewable Energy Based Distributed Generators Using Advanced Power Converter Technologies" Journal of Clean Energy Technologies, DOI: 10.7763, PP; 48:53, Vol. 3, No. 1, January 2015.
[4.] Kodjo Agbossou, Mohanlal Kolhe, Jean Hamelin, and Tapan K. Bose "Performance of a Stand-Alone Renewable Energy System Based on Energy Storage as Hydrogen", IEEE transactions on energy conversion, PP; 633:640, VOL. 19, 2004.
[5.] Keshav Pokharel, Maizura Mokhtar, and Joe Howe "A Multi-Objective Planning Framework for Optimal Integration of Distributed Generations" Centre for Energy and Power Management which is partly funded by BAE Systems UK.
[6.] Serhat Duman, Ugur Guvenc, Yusuf Sonmez and Nuran Yorukeren "Optimal power flow using gravitational search algorithm " elsevier journal, Energy Conversion and Management 59, PP: 86–95; 2012.
[7.] Warid Warid, Hashim Hizam, Norman Mariun and Noor Izzri Abdul-Wahab "Optimal Power Flow Using the Jaya Algorithm "mdi journal engineering, Energies, 2016.
[8.] Nanda Kumar Easwaramoorthy and R. Dhanasekaran "Solution of Optimal Power Flow Problem Incorporating Various FACTS Devices "International Journal of Computer Applications (0975 – 8887) Vol 55, 2012.
[9.] Afshin Lashkar Ara, Ahad Kazmi and Mohammad Behshad "Improving power systems operation through multi-objective optimal location of optimal unified power flow controller "Turkish Journal of Electrical Engineering & Computer Sciences, PP: 1893- 1908, 2013.
[10.] Anumaka, M. C. "Power Flow Study on Alternating Current (Ac) Power System" (IJITR) International journal of innovative technology and research, Volume No.2, P; 1068 – 1071, 2014.
[11.] Ingrida Steponavičė, Ingrida Steponavice and Steffen Rebennack "Optimal power flow: a bibliographic survey I Formulations and Deterministic Methods " Energy Systems manuscript, 2012.
[12.] IEEE Working group "Transmission System Application Requirements for FACTS Controllers" IEEE Power & Energy Society; The Institute of Electrical and Electronic Engineers, Inc, IEEE 2013.
[13.] Abdel-Moamen M. A and Narayana Prasad Padhy "Optimal Power Flow Incorporating FACTS Devices - Bibliography and Survey" IEEE-2003.
[14.] Jennifer F. Marley, Maria Vrakopoulou and Ian A. Hiskens "An AC-QP optimal power flow algorithm considering wind forecast uncertainty" Innovative Smart Grid Technologies - Asia (ISGT-Asia), IEEE 2016.
[15.] Miguel Chávez-Lugo, Claudio R. Fuerte-Esquivel and Claudio A. Cañizares "Practical Security Boundary-Constrained DC Optimal Power Flow for Electricity Markets" IEEE Transactions on Power Systems, 2016.
[16.] Sajan Varma "FACTS devices for stability enhancements" International Conference on Green Computing and Internet of Things (ICGCIoT), ISBN: 978-1-4673-7910-6, IEEE – 2015.
[17.] Ishit Shah, Neha Srivastava and Jigar Sarda " Optimal placement of multi-type facts controllers using real coded genetic algorithm" Electrical, Electronics, and Optimization Techniques (ICEEOT), International Conference on, ISBN: 978-1-4673-9939-5, IEEE-2016.
[18.] D. G. Ramey and M. Henderson "Overview of a Special Publication on Transmission System Application Requirements for FACTS Controllers" Power Engineering Society General Meeting, IEEE - 2007.

ISSN:2067-3809