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Formulation of Distributed Optimal Power Flow Control Using Partitioning Strategy

Manoj Bhaurao Deokate[1], Dr. Rajesh S. Surjuse*[2]

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Abstract: The main objective and purpose of the present study is to demonstrate the formulation of OPF (Optimal Power Flow) distribution using a partitioning system and to determine the generation cost. OPF is one of the significant issues in analyzing the energy system. Thus, to resolve the OPF problem with power networks deal with system size problems and streaming processing methods. In a distributed partitioning system, the whole system independently tries to resolve a minor problem based on the limited inputs according to their areas. In a distributed system, the entire standard IEEE bus system should be divided into sub-sections in two areas. Processors should be capable of resolving minor issues related to partitions by allocating space properly. The case study of the IEEE-14 Bus system is being tested and the findings obtained are exhibited.

Keywords: *AC-OPF, Distributed, Consensus, Partitioning, MATPOWER.*

1. Introduction

From the past many years of study, the power network size will become larger and larger, which leads the more power system issues. The objective is to offer an optimal algorithm to resolve the complicated energy system issues [1] [5] [13] [18] [19] [22] [29] [32]. Much research has been done on the use of metaheuristic techniques to address the optimal power flow solutions [7] [10] [11] [14] [22] [24] [25] [29]. But still need to provide the optimal solution for the cost of generation as per the demand.

The main purpose of this article is to reduce the generation cost by considering the constraints which include equality and inequality constraints. Whereas an equality constraint describes the power injection connection with voltage and phase, as well as inequality constraints that explain the voltage, line flow and generator limit.

To achieve the defined objective is to analyze the technique and divide the complete system into smaller sub-systems using a distributed partitioning system with consideration of equality and inequality constraints and to resolve them independently by using suitable algorithms and to compile the findings of the sub-systems to find a complete solution[10] [16]. For this, need to identify the area to partition and apply the concept to demonstrate how the standard IEEE bus system can be subdivided into specific regions or areas[11] [15] [16] [19] to achieve the defined goal.

[1]*Research Scholar, Department of Electrical Engineering,*
Government College of Engineering, Chandrapur-442403(Maharashtra) India.
ORCID ID: 0009-0000-1771-4788
Email ID: mbdeokate25@gmail.com
[2]*Associate Professor, Department of Electrical Engineering,*
Government College of Engineering, Nagpur-441108 (Maharashtra) India.
** Corresponding Author Email ID: surjusemnit@rediffmail.com*

2. Objective of the Paper

The issue of AC OPF is nonconvex and nonlinear. The main aim of the present research is to reduce the generation cost using a distributed partitioning system by considering the constraints which include equality constraints that explain the power injection connection with inequality constraints and voltage phase that explain the limits of generator, line flow and voltage.

3. Distributed Optimal Power Flow

An improvement in performance over the centralized case is obtained by distributed optimization. The highly non-convex AC OPF issue is known to scale very poorly w. r. t. number of lines and buses. We use a distributed optimization technique with the shift to more renewable, variable and distributed generation to gain better computing performance and scalability. The number of control variables inside the electric power system is growing as a result of the demand response program's deployment, which raises the size and complexity of the optimization issues that define these controllable devices ideal settings. Such an expansion will eventually be difficult to manage effectively with the traditional centralized method. Therefore; the distributed optimization system improves the resilience and reliability of future power systems. Generally, in distributed systems using partitioning, the optimization issue for the entire system is divided into smaller sub-problems each related to a particular area of the region. The idea that these smaller issues may be handled concurrently is then explored, with the guarantee that the convergence to the overall best solution is ensured via information sharing between adjacent sections [8] [9].

4. Objective of Partitioning

A significant amount of computational attempts and resources are needed for centralized control due to the highly linked network of the power system. Distributed computing requires that the systems be ideally divided into clusters since the AC OPF is non-convex.

The goal of the optimization problem known as network partitioning is to reduce the number of nodes inside a cluster and the tie lines that connect the clusters. It may be most effective to separate the massive, linked network into clusters. A balance between the cluster's size and interconnectivity amongst clusters is needed to reduce the execution time overall [17].The primary goals of the partitioning problems are as follows:

To reduce the number of nodes inside a cluster;

To reduce the number of lines inside a cluster; and

To reduce the number of tie clusters between the lines.

The third goal depicts communication between the clusters, while the first two indicate the computing load on each cluster. Therefore, network partitioning is essentially an optimization issue in combinatorial theory.

The requirement that each cluster's nodes establish connections with other clusters or regions applies to the problems of optimization.

To examine the best configuration for the control variables. The goal of network partitioning is to achieve a balance of nodes between the clusters and to limit the number of connection lines connecting the clusters. It is framed as an optimization problem. Using the techniques, the connectedness of the resulting clusters is verified. Improved results were obtained when the suggested technique was evaluated using IEEE standard test cases. A big linked power system network's decentralized control center may readily apply this partitioning for distributed computing applications. The system converges more quickly with the optimum partition and distributed optimization than with the centralized approach, proving the partitioning method's need as well as its efficacy.

5. Formulation of AC-OPF system

The power system of the IEEE 14 bus supplied by MATPOWER is considered. A case study of the bus system is split into two partitions and the attained results of the suggested algorithm are revealed [1] [4] [11] [29] [30].

Fig. 1 shows a single-line diagram. To make the OPF problem appropriate, the suggested diagram is split into 2 partitions namely area A and area B.

Buses 1 to 5 are located in Area A, while buses 1, 2 and 3 are connected to generators.

The generators are linked to buses 6 and 8, which are located in Area B.

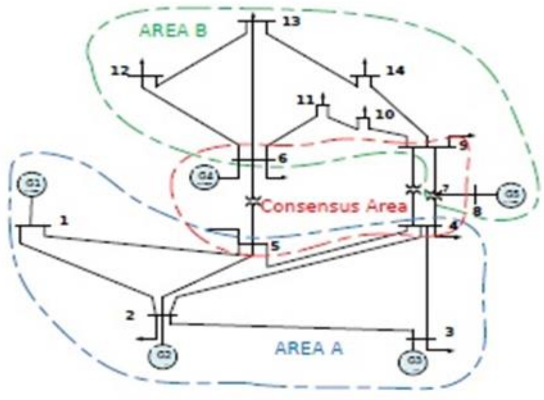

Fig 1: Optimal Partition of IEEE 14-Bus System Splits into 2 Areas

The division of the IEEE 14 buses into two sections is seen in Figure 1. The buses are restricted to the areas indicated by the dashed lines.

The term "load flow" refers to the electricity flow in any electrical system. An essential issue in load flow study is the power system's concern with addressing a series of imprecise statistical computations. Kirchhoff's laws, which are dependent on the active & reactive power injections to the system and the voltage amplitude and class in every area, provide the foundation for the load flow problem [1] [8] [12] [14] [15] [20] [24-25] [30] [32]. The electrical power systems usually have three different types of buses, namely generation bus, load bus, and slack bus, which are considered and play an important role during the coding and execution of the program as per the distributed partitioning system with respect to active region or area.

Optimization Vector: $[PQV\theta]^T$ (1)

The OPF is a non-convex, non-linear challenge with continuous and binary variables in its most practical version. AC-OPF have voltage magnitudes, voltage angles, reactive power, active power, and the limits of each one of these, because there is a limit on how much the generator can produce and there is a limit also on the reactive power that can inject or withdraw from the network. The same goes for the voltage magnitude. The voltage angle is not necessary but it helps for optimization. It also has equality & inequality constraints on the decision variables.

5.1 Optimal Power Flow

It is the economic activity function of the electric power system. Obtaining a comprehensive profile of active voltage and power magnitude is the purpose of the OPF. The main aim is to reduce the overall cost of generating operations while meeting network constraints [1][9][11][15][20][22][24][25][32]. The problem of dynamic control of the optimal power flow requires precision which requires arrange of equality and inequality constraints. Need to identify the control variable of the system and define the mathematical expression accordingly.

Minimization of total generation cost:

$$\min_{u} \sum_{i=1}^{N_G} C_i(P_i) \qquad (2)$$

Where,

Pi – No. Of generators with power capacity

Ci – Cost of each generator-$/MWh

Continuous and binary variables are involved in the nonconvex and nonlinear optimization of the AC OPF issue. Each generator bus has adjustable actual power, voltage magnitude, reactive power outputs and voltage angles. The objective function consists of the generation cost along with constraints, which include equality constraints that define the voltage phase and power injection relationship and inequality constraints that define the power generation, as well as line flow limitations [1] [3] [7] [10] [11] [12]] [13] [14] [19] [24] [25] [27].

5.2 AC Optimal Power Flow Statement

In the IEEE bus system, every bus number is denoted as i. Suppose Y to be the "branch admittance matrix", $\overline{I_\imath}$ and $\overline{V_\imath}$ represents the current and voltage injection at bus i. Therefore, net power injection at bus i could be presented as under:

$$S = \overline{V}_i \cdot \overline{I}_i^* \qquad (3)$$

$$P_i(V,\theta) = \sum_{j=1}^{N} \left(V_i V_j \left(G_{ij} \cos(\theta_i - \theta_j) + B_{ij} \sin(\theta_i - \theta_j) \right) \right) \qquad (4)$$

$$Q_i(V,\theta) = \sum_{j=1}^{N} \left(V_i V_j \left(G_{ij} \sin(\theta_i - \theta_j) - B_{ij} \cos(\theta_i - \theta_j) \right) \right) \qquad (5)$$

Here $\overline{I}_i$, is obtained by $\overline{V}_j$ and $Y_{i,j}$ in equation (6) below, G indicates the bus conductance matrix, $G_{ij} = R_e(Y_{ij})$ and, B presents the bus "susceptance matrix", $B_{ij} = I_m(Y_{ij})$ as well as Y denotes the bus "admittance matrix".

$$\overline{I}_i = \sum_j Y_{i,j} \cdot \overline{V}_j \qquad (6)$$

AC OPF issue is developed to minimize the total of individual polynomial cost functions of real as well as reactive power generations fP_{gi} and fQ_{gi}, correspondingly, for every generator on the mentioned buses (1,2,3,6,8) revealed in equation (7). Whereas the optimization variables x shown in equation (8) consist of generator reactive power (Q_g), real power (P_g), voltage magnitudes V, and angle Ɵ. Therefore, the cost-effective function of real and reactive power generation is shown in equation (7);

$$\min_{x} \sum f_P(P_{gi}) + f_Q(Q_{gi}) \qquad (7)$$

Subject to the equations (9) to (14)

Equations (9) to (12) present the inequality constraints with upper as well as lower bounds for reactive power, all bus voltage angles and magnitudes, generator real power. Equation (13) and (14) present the equality constraints, which include real & reactive components, presented as functions of V, Ɵ and power generations P_g, Q_g.

Real power and reactive power load demand P_d and Q_d at bus are supposed to be constant and are presented in the file of MATPOWER input [8]. The AC OPF is a non-convex optimization issue owing to the nonlinear equality constraints connected to the injection of power.

5.3 OPF Constraints

It is a nonlinearly constrained optimization challenge with generally comprehensible equality and inequality constraints. The active & reactive power balances are equality constraints on the ideal power flow. [1] [3] [9], [14], [19], [25-26].The limits on the generation of both power with respect to the power source boundary, the voltage magnitude limit, and the angle limit are the inequality constraints of the OPF issue.

5.3.1 Equality Constraints

The relationship of the power injection with the voltage phase and the inequality constraints defining generator, line flow and power limits.

The optimization vector x for the typical problem of AC OPF is composed of the ngx1 vectors of generator real and reactive power injections P_g & Q_g and the nbx1 vectors of voltage angles Ɵ along with magnitudes V_m=V [1] [7-8] [11] [14].

$$x = \begin{bmatrix} Pg \\ Qg \\ V \\ \theta \end{bmatrix} \qquad (8)$$

5.3.2 Inequality Constraints

The inequality constraint equations show the lower and higher limits of real generator power, reactive power and bus voltage angles along with magnitudes [1] [7-9] [11] [13-14] [19] [25]] [27] [30].

Subject to

$$\underline{P_{gi}} \leq P_{gi} \leq \overline{P_{gi}} \qquad (9)$$

$$\underline{Q_{gi}} \leq Q_{gi} \leq \overline{Q_{gi}} \qquad (10)$$

$$\underline{V_i} \leq V_i \leq \overline{V_i} \qquad (11)$$

$\underline{\theta_i} \le \theta_i \le \overline{\theta_i}$ (12)

$P_{gi} - P_{di} - P_i(V, \theta) = 0$ (13)

$Q_{gi} - Q_{di} - Q_i(V, \theta) = 0$ (14)

5.4 OPF Algorithm

The AC OPF problem may be resolved by the MATPOWER code.

$\min_x f(x)$ cost of generation Pg (15)

Subject to $g(x) = 0$ power balance (16)

$h(x) \le 0$ branch flow limits (17)

$x_{min} \le x \le x_{max}$ variable bounds (18)

6. Various Control Variables

6.1 Decision Variables (P Q V Ө)

The variables that are initialized with the default values of Reactive Power Q, Voltage magnitude V, Real Power P, as well as voltage angle Ө. (i.e., P, Q, V, Ө), are identified as Area A and Area B decision variables, respectively, and are represented by the symbols x_A and x_B. The decision variables for each region will be specified, and it is depending on how the area is divided.

Assume that the decision variables for areas A and B are X_A and X_B, correspondingly.

$$x_A = [P_{g1A}, P_{g2A}, P_{g3A}, Q_{g1A}, Q_{g2A}, Q_{g3A}, V_{1A},, V_{9A,,,},, \theta_{1A},, \theta_{9A}]$$

(19)

$$x_B = [P_{g4B}, P_{g5B}, Q_{g4B}, Q_{g5B}, V_{4B}, V_{5B}, V_{6B}, V_{7B},, V_{14B}, \theta_{4B},, \theta_{14B}]$$

(20)

Every region determines its buses, phase angles, voltage magnitudes and real & reactive power of the internal generators. The phase voltage angles and levels for the buses in the overlapping region are determined by both areas.

6.2 Global Variables (z)

The variable of consensus area is the global variable which is denoted by z and it is initialized with the default value of Voltage magnitude V and voltage angle Ө.

$z = [V_4 V_5 V_6 V_7 V_9 \theta_4 \theta_5 \theta_6 \theta_7 \theta_9]^T$ (21)

6.3 Objective of Control Variables

The "objective function" for Area A & B depends on the power generated by the generators in Area A and Area B subject to inequality constraints of P, Q, V, Ө with its lower and upper band or limits and equality constraints subject to real and reactive power generation and demand. To achieve the objective this iteration will continue till to get the optimal solution.

7. Partitioning of IEEE-Bus into clusters

7.1 AREA A

The division of the IEEE 14 buses into two sections is seen in Figure 1. The buses are confined to the areas indicated by the dashed lines.

In partition A, we take into account the consensus area's load, boundary buses, buses, and generators in area A to manage all system loads and provide the necessary energy while taking the economy as a whole into account;

Area A's buses: 1 to 5.

Boundary Buses: 6, 7, & 9.

Branches: 1-2,1-5,2-3,2-4,2-5,3-4,4-5,4-7,4-9,5-6.

7.2 AREA B

The partition area B is shown in Figure 1, where we took into account the load on the consensus area, boundary buses, generators and buses in area B to regulate the total load on the system and objective to provide the necessary energy by taking the economy as an entire;

Own buses of Area B: 6-14.

Buses at Boundary: 4 and 5.

Branches: 6-11,6-12,6-13,7-8,7-9,9-10,9-14,10-11,12-13,13-14,

5-6,4-7,4-9.

7.3 CONSENSUS AREA

Consensus Buses: 4, 5,6,7,9.

Decision variables for every area will be described in accordance with the area's partition. As a result, area A's defined variables are designated as $(.)_A$, while area B's variables are designated as $(.)_B$. Express the bus variables as well.

Here i indicate the bus number and k represents the number of iterations.

Suppose X_A & X_B $(.)_i^k$ denote the "decision variables" for areas A and B.

$x_A = [P_{gA} Q_{gA} V_{1A},,, V_{7A} V_{9A} \theta_{1A},,, \theta_{7A} \theta_{9A}]^T$ (22)

$x_B = [P_{gB} Q_{gB} V_{4B},,, V_{14B} \theta_{4B},,, \theta_{14B}]^T$ (23)

Where $P_{gA} = [P_{g1}, P_{g2}, P_{g3}]$

$Q_{gA} = [Q_{g1}, Q_{g2}, Q_{g3}]$ (24)

$$P_{gB} \text{ includes}[P_{g4}, P_{g5}]\ Q_{gB} \text{ includes}[Q_{g4}, Q_{g5}] \quad (25)$$

z is the vector of the consensus variables:

V and Ɵ are the default values that are initialized for the global variable z. The input file is used to establish the lower as well as upper boundaries of the objective variables in (10)–(13). Consensus local variable and global variable vector z are related.

Assume that the consensus local variables in partitions A and B are x_{CA} and x_{CB} correspondingly.

$$x_{CA} = [V_{4A}, V_{5A}, V_{6A}, V_{7A}, V_{9A}, \theta_{4A}, \theta_{5A}, \theta_{6A}, \theta_{7A}, \theta_{9A}] \quad (25)$$

$$x_{CB} = [V_{4B}, V_{5B}, V_{6B}, V_{7B}, V_{9B}, \theta_{4B}, \theta_{5B}, \theta_{6B}, \theta_{7B}, \theta_{9B}]$$

(26)

8. Operation and Analysis Tools of Power System

Additionally, MATPOWER utilizes the expandable OPF so that users may access, change, or optimize problem-solving without having to rewrite parts shared with the conventional format of OPF [1-2] [11] [23] [28]. Inside MATPOWER has the advantage of using several additional capabilities. MATPOWER uses this internally constrained cost variable (CCV) method to automatically generate a suitable auxiliary variant, cost time and the corresponding set of limitations for any line-up generating costs in AC or DC OPF. The dispatchable loads retain a fixed power factor and additional equality constraints are automatically added to implement the necessity for any "negative generator" being applied to the model.

9. Optimal Power Flow Command

In the present case study, the active as well as reactive power of the generators connected to the buses in areas A & B has been determined by putting the given difficulties into practice and performing a worldwide flexible study of the MATLAB code. The findings received for areas A and B, checked and solved using "runopf" with case code command in MATPOWER are represented by the system summary and bus data. The findings [2][21] illustrate the fuel expenses of both the suggested algorithm and MATPOWER.

10. Remark

If the two areas are interconnected to the distributed generation region, then it means that the solution for region A independently does not guarantee a solution with the same need for total load demand.

When two areas are interconnected to the distributed generation region, then the optimal solution of area B independently does not guarantee an optimal solution for the whole load.

This occurs due to the commitment to maintaining the voltages at interconnecting buses in two regions, while the flow of load between the branches changes to meet the need for total load.

11. Result

The MATPOWER results of the IEEE-14 Bus system are revealed in Table 1. The system is converging and all three case studies with generation capacity, actual generation, Load, and Losses are being compared. The goal of producing the necessary energy while taking the economy into account is being achieved.

Table 1. MATPOWER Result

S.N.	CASE STUDY		IEEE-14 BUS	AREA A	AREA B
1	OVERALL COST ($/MWHr)		8081.53	8879.52	10903.48
2	Convergence Time (Second)		3.32	0.19	0.7
3	Generation Capacity	P(MW)	772.4	572.4	500
		Q(MVAr)	148	100	96
	Actual Generation	P(MW)	268.29 Pg1=194.33 Pg2=36.72 Pg3=28.74 Pg6=0.0	263.08 Pg1=96.15 Pg2=66.94 Pg3=100.00	262.65 Pg6=182.50 Pg8=80.16

4			Pg8=8.49		
		Q(MVAr)	67.63 Qg1=0.0 Qg2=23.69 Qg3=24.13 Qg6=11.55 Qg8=8.27	67.04 Qg1=0.0 Qg2=27.04 Qg3=40.00	91.16 Qg6=48.00 Qg8=43.16
5	Load (MW)	P(MW)	259	259	259
		Q(MVAr)	73.5	73.5	73.5
6	Losses	P(MW)	9.29	4.08	3.65
		Q(MVAr)	39.16	35.14	36.11

12. Conclusion

The implementation of Distributed Optimal Power Flow using a partitioning system performs on the different scenarios conducted to test our methodology for specific non-convex AC OPF. Based on the three Case studies, it concludes that the system is converging and achieved the defined objective of this paper.

References

[1] Hamid Eghbalpour, “Application of Distributed Optimization Technique for Large-Scale Optimal Power Flow Problem” Spring 2019. Memorial University of New foundland, Canada.

[2] Ray D. Zimmerman, Carlos E. Murillo-S´anchez, Robert J. Thomas, “MATPOWER: Steady-State Operations, Planning and Analysis Tools for Power Systems Research and Education”

[3]] N.M.Huebner, M. Suriyah, T. Leibfried, “Distributed Optimal Power Flow in Hybrid AC–DC Grids,”IEEE Trans. Power Syst., vol. 34, no. 4, pp. 2937–2946, July 2019.

[4] R.Wiget and G. Andersson, “DC optimal power flow including HVDC grids,” in Proc. Elect. Power and Energy Conf. (EPEC), Halifax, NS, Canada, Aug. 2013.

[5] F. Nejabatkhah and Y. W. Li, “Overview of Power Management Strategies of Hybrid AC/DC Microgrid,” IEEE Trans. Power Electron, vol. 30, no. 12, pp. 7072–7089, Dec. 2015.

[6] F. Sass, T. Sennewald, A. K. Marten, and D. Westermann, “Mixed AC-HVDC benchmark Test system for Security Constrained OPF calculation”, Transmission Distribution IET Generation, vol. 11, no. 2, pp. 447–455, 2017.

[7] N. Meyer-Huebner, F. Gielnik, M. Suriyah, and T. Leibfried, “Dynamic optimal power flow in ac networks with multi-terminal HVDC and energy storage,” IEEE Innovative Smart Grid Technologies—Asia, Nov. 2016, pp.300–305.

[8] B. H. Kim and R. Baldick, “A comparison of distributed optimal power flow algorithms,” IEEE Trans. Power Syst., vol. 15, no. 2, pp. 599–604, May 2000.

[9] D. K. Molzahn et al., “A survey of distributed optimization and control algorithms for electric power systems,”IEEE Trans. Smart Grid, vol. 8,no. 6, pp. 2941–2962, Nov. 2017.

[10] B. A. Robbins and A. D. Domınguez-Garcia, “Optimal Reactive Power Dispatch for Voltage Regulation in Unbalanced Distribution Systems,” IEEE Trans. Power Syst., vol. 31, no. 4, pp. 2903–2913, 2016.

[11] T.Erseghe, “Distributed optimal power flow using ADMM,” IEEE Trans. Power Syst., vol. 29, no. 5, pp.2370–2380, Sep. 2014.

[12] A. Engelmann, Y. Jiang, T. M¨uhlpfordt, B. Houska, and T. Faulwasser, “Toward distributed OPF using ALADIN,” IEEE Trans. Power Syst., vol. 34, no. 1, pp. 584–594, Jan. 2019.

[13] E.Iggland, R. Wiget, S. Chatzivasileiadis, and G. Anderson, “Multi-area DC-OPF for HVAC and HVDC grids,” IEEE Trans. Power Syst., vol. 30, no. 5, pp. 2450–2459, Sep. 2015.

[14] Ray D. Zimmerman, Carlos E. Murillo-Sanchez, Robert J. Thomas, , “MATPOWER’s Extensible Optimal Power Flow Architecture,” 2009 IEEE Power & Energy Society General Meeting. Conference

paper 26-30 July 2009 IEEE Xplore date 02October 2009.

[15] Giulio Binetti, Ali Davoudi, Frank L. Lewis,"Distributed Consensus-Based Economic Dispatch with Transmission Losses," IEEE TRANSACTIONS ON POWER SYSTEMS, vol. 29, Issue no. 4,Page(s):1711 – 1720, 4, July 2014.

[16] Minyue Ma, Lingling Fan, ZhixinMiao,"Consensus ADMM and Proximal ADMM for Economic Dispatch and AC OPF with SOCP Relaxation,"IEEE Transaction on Power System, 21 November 2016.

[17] S. Boyd, N. Parikh, E. Chu, B. Peleato, and J. Eckstein,, "Distributed optimization and statistical learning via the alternating direction method of multipliers," Foundations and Trends, vol. 1, p. 1–122, 2011.

[18] A. Teixeira, E. Ghadimi, I. Shames, H. Sandberg, and M. Johansson,, "The ADMM algorithm for distributed quadratic problems: Parameter selection and constraint preconditioning," IEEE Trans. Signal Process, vol. 64, Issue no. 2, pp. 290-305, Jan.15, 2016

[19] J. Guo, G. Hug and O. Tonguz, "A Case for Nonconvex Distributed Optimization in Large-Scale Power Systems," IEEE Transactions on power systems, vol. 32, Issue no. 5, page(s): 3842 - 3851 September 2017.

[20] Yamin Wang, Lei Wu, Shouxiang Wang, "A Fully-Decentralized Consensus-Based ADMM Approach for DC-OPF with Demand Response," IEEE TRANSACTIONS ON SMART GRID, vol. 8, Issue no. 5,page(s): 2637 - 2647 November 2017.

[21] Ray D. Zimmerman, Carlos E. Murillo-Sánchez, "MATPOWER, Open-source Electric Power System Simulation and Optimization Tools for MATLAB," Cornell, [Online]. Available: http://www.pserc.cornell.edu/MATPOWER/

[22] A. A. Eajal, M. A. Abdelwah., E. F. El-Saadany, and K. Ponnambal, “A Unified Approach to the Power Flow Analysis of AC/DC Hybrid Microgrids,” IEEE Trans. Sustainable Energy, vol. 7, issue no. 3, pp. 1145– 1158, Jul.2016.

[23] R. Mudumbai and S. Dasgupta, “Distributed Control for the Smart Grid: The Case of Economic Dispatch,” in Infor. Theory Appl. Workshop (ITA). IEEE, 24 April 2014, pp. 1–6.

[24] S. Magn´usson, P. C. Weeraddana, and C. Fischione, “A Distributed Approach for the Optimal Power-Flow Problem Based on ADMM and Sequential Convex Approximations,” IEEE Trans. Control Network Syst., vol.2, issue no. 3, pp. 238–253, Sept. 2015.

[25] A. K. Marvasti, Y. Fu, S. Dor Mohammadi, and M. Rais-Rohani, “Optimal Operation of Active Distribution Grids: A System of Systems Framework,” IEEE Trans. Smart Grid, vol. 5, issue no. 3, pp. 1228–1237, May 2014.

[26] P. ˇ Sulc, S. Backhaus, and M. Chertkov, “Optimal Distributed Control of Reactive Power via the Alternating Direction Method of Multipliers,” IEEE Trans. Energy Conv., vol. 29, issue no. 4, pp. 968–977, Dec. 2014.

[27] W. Zheng, W. Wu, B. Zhang, H. Sun, and Y. Liu, “A Fully Distributed Reactive Power Optimization and Control Method for Active Distribution Networks,” IEEE Trans. Smart Grid, vol. 7, no. 2, pp. 1021–1033, Mar.2016.

[28] Z. Qiu, G. Deconinck, and R. Belmans, “A Literature Survey of Optimal Power Flow Problems in the Electricity Market Context,” in power Systems Conference and Exposition, 2009. PSCE ’09.IEEE/PES, March 2009,pp.1–6.

[29] Niklas Wehbring, Daniel Schema, Falko Wähner, and Albert Moser, “A Distributed Optimal Power Flow for Secondary Control of Hybrid AC/DC Networks’’ 2019 IEEE Milan PowerTech 26 August 2019.

[30] Saddam Aziz, Jianchun Peng Huaizhi Wang and Hui Jiang, “ADMM-Based Distributed Optimization of Hybrid MTDC-AC Grid for Determining Smooth Operation Point’’ IEEE Access, Volume: 7, Page(s): 74238 –74247, June 13, 2019.

[31] HongjunGao;JiayiWang;YouboLiu;LingfengWang;Ju nyong Liu, “An Improved ADMM-Based Distributed Optimal Operation Model of AC/DC Hybrid Distribution Network Considering Wind Power Uncertainties’’IEEE Systems Journal, Early Access Articles (1), Page(s): 1 – 11 03 June 2020.

[32] NicoHuebner;YannickRink;MichaelSuriyah;ThomasL eibfried,“Distributed AC-C Optimal Power Flow in the European Transmission Grid with ADMM” IEEE, 2020 55th International Universities Power Engineering Conference (UPEC), 1-4 Sept. 2020.

[33] AamirNawaz;HongtaoWang,“RiskAware Distributed Optimal Power Flow in Coordinated Transmission an d Distribution System’’ Journal of Modern Power Systems and Clean Energy, SGEPRI, Volume: 9, Issue: 3, page(s): 502 – 515, May2021.