

# Optimal Power Flow based Economic Generation Scheduling in Day-ahead Power Market using Interior Point Optimization

Rahul Kumar<sup>1</sup>, Kshitij Choudhary<sup>2</sup> and Brijesh Singh<sup>3</sup>

<sup>1,2,3</sup>Institute of Engineering and Technology, Mangalayatan University, Aligarh-India  
E-mail: <sup>1</sup>[rkbalyan108@gmail.com](mailto:rkbalyan108@gmail.com), <sup>2</sup>[kshitij.jain1521@gmail.com](mailto:kshitij.jain1521@gmail.com), <sup>3</sup>[brijesh.singh@mangalayatan.edu.in](mailto:brijesh.singh@mangalayatan.edu.in)

---

**Abstract**—*The present work deals with the economic rescheduling of the generation in an hour-ahead electricity market. The schedules of various generators in a power system have been optimizing according to active power demand bids by various load buses. In this work, various aspects of power system such as congestion management, voltage stabilization and loss minimization have also taken into consideration for the achievement of the goal. The interior point (IP) based optimal power flow (OPF) methodology has been used to obtain the optimal generation schedule for economic system operation. The IP based OPF methodology has been tested on a modified IEEE-30 bus system. The obtained test results shows that not only the generation cost is reduced also the performance of power system has been improved using proposed methodology.*

## 1. INTRODUCTION

The power system is one of the biggest fields in the area of electricity. This is one of the fields where lots of operational activities have been implemented to further improvement. A power system can be defined as a network of electrical components which are used for the generation, transmission and distribution of electrical power. In the present time scenario the power system has developed as a market which is known as the Power Market. One of the major changes which have come in the power system is its development as an open market. The increase in the demand of electricity with the increasing rate of industrialization and the exponentially increasing rate of urbanization has made the power market a major attraction for the investors. As the market has evolved, more and more investors, public units as well as private units have invested in the power market resulting in the fast evolution of the power market [1-3].

Power generation becomes a more attractive part of system and most of the private investors have shown interest in this part. Power market provides various opportunities for the generation investor. The main objective of these investors is to generate economical power and optimize their respective revenues (profits). Because of number of municipal and private generation participants, profit optimization becomes a challenging task in the power market and also this become

more complex due ahead based market operations. Now a day, the power markets have operates on the basis of bidding and auction based mechanism. Normally, these biddings or auctions have based on day-ahead/hour-ahead or minute-ahead based mechanism. The distribution companies have applied the bidding of power on the basis of these mechanisms and the generating companies have supplied the power on the basis of these biddings and system constraints. This mechanism arise an operational problem of scheduling of generators in the system. All the generating companies have tried to get maximum profit by minimum fuel consumption and also fulfill all the operational constraints of the system. This mechanism can provide a solution for revenue increment in the system. Therefore, an optimal decision has been adopted by the system operators to get an efficient system operation with maximum profit. Te optimal power flow (OPF) based rescheduling of generators has frequently used in the market operation to solve the present problem. Many researchers worldwide are working in the area of OPF. Many techniques are developed by researchers to minimize the generation cost in the power system [4].

In the present investigation interior point (IP) based optimal power flow (OPF) technique is used to obtain the optimal rescheduling of generators and minimize the per day total generation cost in a power market. OPF means intelligently adjusting the power system settings in such a way that it manages load flow and at the same time optimizing the operating conditions while fulfilling particular constraints. One another benefit of using the optimal power flow technique is reduces the losses in the system. The problem in the present time scenario is as the power system has emerged as a market, the investors want more profit by injecting and drawing more and more power through the transmission lines without thinking about the capability of the transmission lines which results in the problem of congestion in the transmission system and ultimately resulting in the instability of the whole system. Thus, the OPF based operation has a better opportunity for efficient and secure operation for the power system [5-9].

The present investigation deals with the economic rescheduling of the generation of electricity in an hour-ahead power market. The IEEE-30 bus system is used in this case for the study of the results. In this work, the load buses have applied an hourly based bidding to the system operator and on the basis of these bidding; the generators have scheduled their generations. The optimal schedules of generation have decided using optimization technique. The optimization technique used in this case is the IP method. The IP technique is used for the calculation of OPF of large systems. The result shows the effect of the proposed configuration over the cost of the generated system as well as the effects which occur on the congestion management of the transmission lines and the losses in the system. The cost comparison is done between the results obtained using AC load flow study and OPF based study. The purpose of the present work is to get the better solution for the system which can provide a less costly operation with more congestion free and stable system.

## 2. MATHEMATICAL FORMULATION

In OPF based solution the main objective is to obtain the minimum generation cost. OPF includes the cost of generators and constraints as variable. The OPF based problem formulation is constituted by three terms; first related with generating cost, second associated with equality constraints and the third term is associated with inequality constraints. The objective function defined as

$$F(x) = \min \sum_{day} \sum_{i=1}^{Ng} C_i(P_{gi}) \quad (1)$$

### A. Equality constraints

$$\sum_{i=1}^{Ng} P_{gi} + \sum_{j=1}^{Nl} P_{dj} + P_l = 0 \quad (2)$$

$$\sum_{i=1}^{Ng} Q_{gi} + \sum_{j=1}^{Nl} Q_{dj} + Q_l = 0 \quad (3)$$

### B. Inequality constraints

The active power generated by each unit must satisfy the maximum and minimum operating limits during contingency states

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \quad (4)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \quad (5)$$

The voltage security at each bus also consider for both cases

$$V_i^{min} \leq V_i \leq V_i^{max} \quad (6)$$

The active power flow through each branch of the network must satisfy the security limits during both pre and post contingencies.

$$P_{ij} \leq P_{ij}^{max} \quad (7)$$

where

$C_i$  Operation cost;

$P_{gi}$	Generator output;
$Ng$	No. of generators;
$P_{di}$	Active power demand at load bus;
$Q_{di}$	Reactive power demand at load bus;
$P_{loss}$	Active power loss;
$Q_{loss}$	Reactive power loss;
$Nl$	No. of load buses;
$P_{gi}^{min}, Q_{gi}^{min}$	Minimum active and reactive power limits of generators;
$P_{gi}^{max}, Q_{gi}^{max}$	Maximum active and reactive power limits of generators;
$P_{ij}$	Power flow in lines between bus $i$ and $j$ ;
$P_{ij}^{max}$	Maximum limit of lines between bus $i$ and $j$ ;
$V_i$	pre contingency voltage at bus.

## 3. PROPOSED INTERIOR POINT BASED OPF SOLUTION METHODOLOGY

In the present work, the interior point (IP) based optimization has been used as solution technique and applied to obtain the optimal generation schedules to the minimum generation cost [6]. In general, the problem defined as a non-linear optimization problem.

Minimize  $f(x)$

Subject to  $h(x) = 0$  (8)

And  $g_{min} \leq g(x) \leq g_{max}$  (9)

Where the objective function  $f(x)$  generally represents the fuel cost of generation, transmission loss, or the corrective controls, etc.,  $h(x)$  represents the power flow equations and  $g(x)$  includes component and variable inequalities. In this method the inequality constraints are transformed into equality constraints by the addition of nonnegative slack variables. This modification can reformulate Eq. (8) as:

Minimize  $f(x)$

Subject to  $h(x) = 0$

$g(x) - z_1 - g_{min} = 0$

$g(x) + z_u - g_{max} = 0; z_1, z_u \geq 0$  (10)

where  $z_1$  and  $z_u$  are slack variables.

The Lagrangian function for the system of (10) may be written as

$$L = f(x) - \lambda^T h(x) - \pi_1^T (g(x) - z_1 - g_{min}) - \pi_u^T (g(x) + z_u - g_{max}) \quad (11)$$

where  $\lambda$ ,  $\pi_1$  and  $\pi_u$  are the vectors of Lagrange multipliers. The KKT optimal condition for the above can be written as

$$\Delta_x L = \nabla f(x) - \nabla h(x)^T \lambda + \Delta g(x)^T \pi_1 - \nabla g(x)^T \pi_u = 0 \quad (12)$$

$$\Delta_\lambda L = -h(x) = 0 \quad (13)$$

$$\Delta \pi_1 L = -(g(x) + z_1 + g_{min}) = 0 \quad (14)$$

$$\Delta \pi_u L = -(g(x) + z_u - g_{max}) = 0 \quad (15)$$

$$\Delta_{z_1} L = Z_1 \pi_1 = 0; \quad \pi_1, Z_1 < 0 \quad (16)$$

$$\Delta_{z_u} L = Z_u \pi_u = 0; \quad \pi_u, Z_u < 0 \quad (17)$$

Due to complimentary conditions some difficulty has to be raised in (16) and (17). These difficulties have been overcome by introducing a perturbation factor  $\mu > 0$  in Lagrangian function through the incorporation of logarithmic barrier as

$$L_\mu = f(x) - \mu \sum (\ln z_1 + \ln z_u) - \lambda^T h(x) - \pi_1^T (g(x) - z_1 - g_{min}) - \pi_u^T (g(x) + z_u - g_{max}) \quad (18)$$

when the KKT conditions are applied in (18) then (16) and (17) are transformed as

$$\Delta_{z_1} L_\mu = Z_1 \pi_1 - \mu e = 0 \quad (19)$$

$$\Delta_{z_u} L_\mu = Z_u \pi_u - \mu e = 0 \quad (20)$$

where  $e = [1, 1, 1, \dots, 1]^T$  and  $\mu$  is known as the barrier parameter. The original complementary conditions are satisfied with forcing the value of  $\mu$  from a non-zero value to zero value as iteration proceeds. After inclusion of the barrier parameter in (11)-(18), (19), and (20) are called the perturbed KKT conditions. By the application of Newton's method to perturbed KKT equations

$$\begin{bmatrix} \pi_1 & 0 & Z_1 & 0 & 0 & 0 \\ 0 & \pi_u & 0 & Z_u & 0 & 0 \\ -Z_1 & 0 & 0 & 0 & \nabla_{g(x)}^T & 0 \\ 0 & -Z_u & 0 & 0 & -\nabla_{g(x)}^T & 0 \\ 0 & 0 & \nabla_{g(x)} & -\nabla_{g(x)} & \nabla_x^2 L_\mu & -\nabla h(x)^T \\ 0 & 0 & 0 & 0 & -\nabla h(x) & 0 \end{bmatrix} \times \begin{bmatrix} \Delta Z_1 \\ \Delta Z_u \\ \Delta \pi_1 \\ \Delta \pi_u \\ \Delta x \\ \Delta \lambda \end{bmatrix} = - \begin{bmatrix} \nabla_{z_1} L_\mu \\ \nabla_{z_u} L_\mu \\ \nabla_{\pi_1} L_\mu \\ \nabla_{\pi_u} L_\mu \\ \nabla_x L_\mu \\ \nabla_\lambda L_\mu \end{bmatrix}$$

$$\begin{bmatrix} \pi_1 & 0 & Z_1 & 0 & 0 & 0 \\ 0 & \pi_u & 0 & Z_u & 0 & 0 \\ -Z_1 & 0 & 0 & 0 & \nabla_{g(x)}^T & 0 \\ 0 & -Z_u & 0 & 0 & -\nabla_{g(x)}^T & 0 \\ 0 & 0 & \nabla_{g(x)} & -\nabla_{g(x)} & \nabla_x^2 L_\mu & -\nabla h(x)^T \\ 0 & 0 & 0 & 0 & -\nabla h(x) & 0 \end{bmatrix} \times \begin{bmatrix} \Delta Z_1 \\ \Delta Z_u \\ \Delta \pi_1 \\ \Delta \pi_u \\ \Delta x \\ \Delta \lambda \end{bmatrix} = - \begin{bmatrix} \nabla_{z_1} L_\mu \\ \nabla_{z_u} L_\mu \\ \nabla_{\pi_1} L_\mu \\ \nabla_{\pi_u} L_\mu \\ \nabla_x L_\mu \\ \nabla_\lambda L_\mu \end{bmatrix} \quad (21)$$

where  $\nabla_x^2 L_\mu = \nabla_x^2 f(x) - \nabla_x^2 h(x)^T \lambda + \nabla_x^2 g(x)^T \pi_1 - \nabla_x^2 g(x)^T \pi_u - \nabla_x^2 g(x)^T \pi_u$

The Newton's direction has been obtained by solving (22) directly or by solving reduced system.

$$\begin{bmatrix} H & -J_h^T \\ -J_h & 0 \end{bmatrix} * \begin{bmatrix} \Delta x \\ \Delta \lambda \end{bmatrix} = - \begin{bmatrix} \psi \\ h(x) \end{bmatrix} \quad (22)$$

Firstly  $\Delta x$  and  $\Delta \lambda$  computing then

$$\Delta Z_1 = \nabla g(x)^T \Delta x - \nabla_{\pi_1} L_\mu$$

$$\Delta Z_u = -\nabla g(x)^T \Delta x - \nabla_{\pi_u} L_\mu$$

$$\Delta \pi_1 = Z_1^{-1} (-\pi_1 \Delta Z_1 - \nabla_{z_1} L_\mu)$$

$$\Delta \pi_u = Z_u^{-1} (-\pi_u \Delta Z_u - \nabla_{z_u} L_\mu)$$

where

$$H = \nabla_x^2 L_\mu + \nabla g(x) (Z_1^{-1} \pi_1 - Z_u^{-1} \pi_u) \nabla g(x)^T$$

$$J_h = \nabla h(x)$$

$$\psi = -\nabla_x L_\mu - \nabla g(x) (Z_1^{-1} \pi_1 - Z_u^{-1} \pi_u) \nabla g(x)^T + Z_1^{-1} \nabla_{z_1} L_\mu - Z_u^{-1} \nabla_{z_u} L_\mu$$

After computing above variable updates the variables and value of  $\mu$  by using new primal and dual variables.

$$x^{k+1} = x^k + \alpha_p^k \Delta x \quad \lambda^{k+1} = \lambda^k + \alpha_d^k \Delta \lambda$$

$$z_1^{k+1} = z_1^k + \alpha_p^k \Delta z_1 \quad \pi_1^{k+1} = \pi_1^k + \alpha_d^k \Delta \pi_1 \quad (23)$$

$$z_u^{k+1} = z_u^k + \alpha_p^k \Delta z_u \quad \pi_u^{k+1} = \pi_u^k + \alpha_d^k \Delta \pi_u$$

where  $\alpha_p^k$  and  $\alpha_d^k$  are step lengths parameters. The maximum step length has been determined by Newton's direction as following

$$\alpha_p^k = \min \left\{ 1, \gamma \min \left\{ -\frac{z_1^k}{\Delta z_1} / \Delta z_1 < 0, -\frac{z_u^k}{\Delta z_u} / \Delta z_u < 0 \right\} \right\} \quad (24)$$

$$\alpha_d^k = \min \left\{ 1, \gamma \min \left\{ -\frac{\pi_1^k}{\Delta \pi_1} / \Delta \pi_1 < 0, -\frac{\pi_u^k}{\Delta \pi_u} / \Delta \pi_u < 0 \right\} \right\} \quad (25)$$

To ensure that the next point will satisfy the strict positivity conditions use  $\gamma$  as a safety factor. To reduced the complementary gap the value of  $\mu$  should be proportional to this gap and describe as

$$\mu^{k+1} = \sigma^k \frac{\rho^k}{2p} \tag{26}$$

$$\rho^k = (Z_1^k)^T \pi_1^k + (Z_u^k)^T \pi_u^k \tag{27}$$

where  $p$  is number of inequality constraints,  $\rho^k$  is complementary gap and  $\sigma^k$  is called the centering parameter which is given by  $\sigma^k = \max\{0.99\sigma^{k-1}, 0.1\}$ , with  $\sigma^0 = 0.2$ .

The convergence of solution is terminated when these two factors becomes sufficiently small.

1. Complementary gap.
2. Norm of right hand side vector scaled by summation of all primal variables.

#### 4. TEST RESULTS AND DISCUSSIONS

The proposed algorithm has been simulated in MATLAB on Intel (R), Core 2 Duo and 2.66 GHz processor. In order to show the effectiveness of the proposed algorithm, modified IEEE-30 bus system with hour-ahead demand biddings have been selected. In the present system, all the generators have its own operational constrain and all of them have right to optimally reschedule the generators fulfilling objective.

In this work, the IP based solution techniques are applied to obtain the optimal generation schedules to obtain the economic generation schedules. The IP based OPF algorithm has been applied with started by initialization the IP parameters. Initially, the tolerance value  $\varepsilon$  is selected as  $1 \times 10^{-4}$  and centering parameter  $\sigma$  is selected in the range of (0, 1) for IP. In each trail of OPF, the convergences have been achieved within 5 to 6 iterations for modified IEEE-30 bus system respectively. It has been observed that the value of objective function is minimum using OPF for modified IEEE-30 bus system. It can be concluded that the selection of appropriate parameters provide a significant effect on the convergence of global solution.

##### Modified IEEE-30 bus test system

The standard modified IEEE-30 bus system consists of 6 generator buses and 24 load buses. In the modified IEEE-30 bus system, all generators and loads operates collectively and form a power system network as shown in Fig. 1. The marginal cost functions of generators are listed in Table 1 and their connectivity in modified IEEE-30 bus system is shown in Fig. 1. Various active power load curves (24-hour) pattern on each load buses for modified IEEE-30 bus system has been considered in the present work. In order to observe the congestion management in the system, the transfer limits of branches are also considered in the problem formulations.

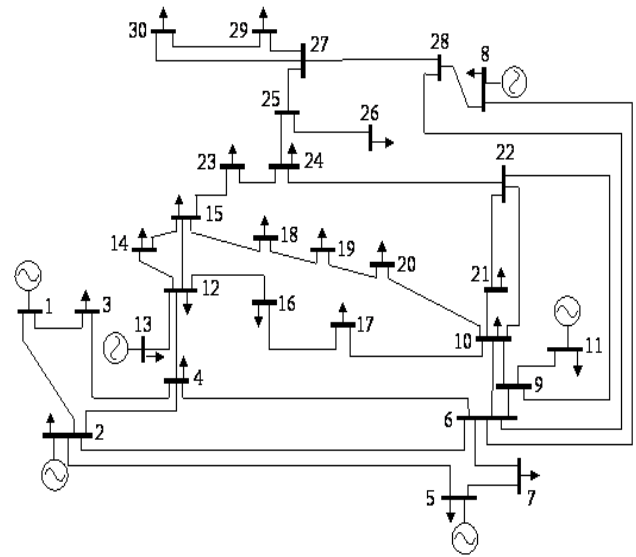


Fig. 1: Modified IEEE-30 bus System Model

Table 1: Cost function of generation in using modified IEEE-30 bus system model

Generator bus	Pmax (MW)	Pmin (MW)	Marginal generation cost function \$/hr
1	50	10	2P+0.02P <sup>2</sup>
2	50	10	1.75P+0.0175 P <sup>2</sup>
5	100	10	1P+0.0625 P <sup>2</sup>
8	100	10	3.25P+0.00834 P <sup>2</sup>
11	50	10	3P+0.025 P <sup>2</sup>
13	50	10	3P+0.025 P <sup>2</sup>

#### 5. CASE STUDIES

The following cases have been considered and carried out on modified IEEE-30 bus system to find the effectiveness of OPF method using IP technique.

Case 1:	Load flow analysis using initial generators schedules.
Case 2:	Economic rescheduling of generators using IP based OPF method.

##### Case 1:

In this case, initial schedules of generators and consumers demands have been considered for load flow (LF) analysis. The power flows in the lines of the system due to initial schedules poses congestion in the system at various time slots or bulk loading conditions. These initial schedules have been decided in such a way that the system can operates efficiently. However, the results obtained by LF shows that sometimes, the system technical constraints have not satisfied. The obtained load flow results show that some of the lines have operated beyond their respective line limits which cause the problem of congestion in the lines which causes more power loss in the system. Also, the results obtained by LF analysis shows that the voltage profiles of all buses have also deviated

for its minimum and maximum limits. Thus, OPF based scheduling is required to fulfill all the technical constrains.

### Case 2:

In this case, all the constraints of system components and the transfer limits of the lines have been considered in the problem objective for studying problem objective and congestion management. In the present case study, suggested IP technique has been used to obtain an optimal solution for the test system using OPF. All the generators and load buses are chosen to participate in the problem objective of congestion management with minimum generation cost for the test system. The parameters selection for IP has been also been plays an important role in optimization techniques.

### Selection of IP Parameters

In the present work, the suggested IP based solution technique is applied to obtain the optimal generation schedules to alleviate the congestion in the lines. The mathematical formulation of IP method in equations (8)-(27) reveals that the performance of this method depends upon initialization parameters such as maximum number of iteration, centering parameter and tolerance value. Thus, in the initialization of IP based OPF algorithm, the maximum number of iteration  $Iter_{max} = 50$ , centering parameter =  $\sigma \in (0,1)$  and tolerance  $\varepsilon = 10^{-6}$ .

After application of OPF based optimal rescheduling using IP, the generation levels are increased or decreased in modified IEEE-30 bus system to achieve the objective of the work. In the present work, the line flow limits have also considered in the problem formulation. The obtained results shows that after application of IP based OPF method; the lines flows comes into their respective limits and the problem of overflow or congestion have been resolved as in initial schedule. Therefore, the IP based OPF method has also provide an efficient solution for congestion management. Similarly, the voltage profile and the losses in the system have also improved with OPF based generators rescheduling. These test results reveals that apart from economic generation schedule the OPF based generation rescheduling provides various other advantageous solutions for the power network operations such as congestion management and voltage control of each buses. Detailed analyses of these advantageous features have been delineated in next sub section.

## 6. ANALYSIS FOR GENERATION WELFARE

The generation cost and welfare (profits) obtained by generators using IP based OPF for the test system in a day has given in these Table 3. The results show that the welfare of the generators has been improved by using IP based OPF method. The total generation cost in a day for initial schedule is **18826.9 \$/day** and the total generation cost in a day using IP based OPF is **16475.1 \$/day** as given in Table 2. Thus, the result reveals that the total generation cost obtained by IP

based OPF method provides substantial saving of **2351.8 \$/day**.

**Table 3: Total Generation cost using LF and OPF**

No. of hours	Generation Cost using Load Flow	Generation Cost using OPF
0	697.372	620.13
1	641.445	558.23
2	599.168	509.65
3	562.515	472.01
4	541.404	444.59
5	539.382	441.31
6	590.494	491.27
7	618.602	527.83
8	654.857	573.65
9	699.268	616.93
10	769.748	670.75
11	813.561	705.83
12	838.607	730.23
13	827.254	728.77
14	829.708	723.81
15	808.758	702.23
16	831.01	789.3
17	905.447	801.01
18	984.029	864.2
19	1075.79	938.83
20	1108.94	977.14
21	1045.42	934.57
22	970.79	869.8
23	873.292	783
Total Generation Cost in a day (\$/day)	18826.9	16475.1

## 7. CONCLUSION




In this work, as mentioned earlier, LF study and IP based OPF study were performed on the IEEE-30 bus system and the results for both the cases were observed. By comparing the results carried out by performing the LF study and OPF study it is clear that OPF study gives far much better results than the LF study and the results obtained by the means of OPF never violate the limit of the system while the results obtained during the LF study shows that the limit of system was violated many times and the system drifted towards contingency. Also, one of the main reasons for which the study was conducted was to see the effect of OPF study on the price of the active power generation. After the comparison it is clear that use of OPF study on a system has given a significant reduction in the generation cost of the system. Hence, the present work clearly shows that the generation scheduling using IP based OPF provides better results and makes the system more efficient as well as less costly.

## REFERENCES

- [1] John J. Grainger & William D. Stevenson Jr., "Power System Analysis", McGraw Hill Publication, 1994.

- [2] C.L. Wadhwa, “ Electrical Power System ” , New Age International Publishers, 2010.
- [3] O. Alsac & B. Stott, “Optimal Load Flow With Steady-State Security ”, Power Systems Laboratory, University of Manchester, Institute Of Science And Technology Manchester, U.K., 1974.
- [4] Salih Fadil , Ahmet Yazıcı & Burak Urazel, “A Security-constrained Economic Power Dispatch Technique Using Modified Subgradient Algorithm Based on Feasible Values and Pseudo Scaling Factor for a Power System Area Including Limited Energy Supply Thermal Units ”, Department of Electrical and Electronics Engineering, Eskisehir Osmangazi University, Eskisehir, Turkey, Department of Computer Engineering, Eskisehir Osmangazi University, Eskisehir, Turkey , 2011.
- [5] N. Karmarkar, “a new polynomial-time algorithm for linear programming”, 1984.
- [6] Hua Wei H. Sasaki J. Kubokawa & R. Yokoyama, “ An Interior Point non-linear programming for optimal power flow problems with a Novel data structure ”, IEEE Transactions on Power Systems, Vol. 13, No. 3, August 1998. <http://indiasmartgrid.org/>
- [7] Rajabi-Ghahnavieh, M. Fotuhi-Firuzabad, Mohammad Shahidehpour & R. Feuillet, “Optimal Allocation of Available Transfer Capability in Operating Horizon”, IEEE Transaction on Power Systems, May 2009.
- [8] Zhang Chang-hua, Cheng Yu-hua, ChenYong, HuangQi & Song Yong-hua, “Available Transfer Capability Assessment Considering Economic Constraint”, 2008.

### About the Author

	Rahul Kumar belong to Aligarh (UP), DOB is 10.08.1992, pursuing his B.Tech in Electrical and Electronics Engineering from Mangalayatan University, Aligarh (UP). (rkbalyan108@gmail.com)
	Kshitij Choudhary belong to Guna (MP), DOB is 15.09.1993, pursuing his B.Tech in Electrical and Electronics Engineering from Mangalayatan University, Aligarh (UP). (kshitij.jain1521@gmail.com).
	Brijesh Singh belong to Jaunpur (UP), DOB is 05.12.1981, Received his B.Tech in Electrical Engineering in 2003 from IET, Purvanchal University Jaunpur, M.Tech (Power system) in 2009 from KNIT Sultanpur (UP). Presently he is faculty of department of Electrical Engineering, Institute of Engineering and Technology, Mangalayatan University, Aligarh. His field of interest includes Power system operation & control, optimization and Artificial Intelligence. (brijesh.singh@mangalayatan.edu.in)