Hanumantha Rao A et al. International Journal of Recent Research Aspects ISSN: 2349-7688, Special Issue: Conscientious Computing Technologies, April 2018, pp. 16-19

Economic Dispatch using a simple Probabilistic method, a case study of Karnataka power Grid

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***Abstract*— The probabilistic evaluation of system behavior has been gaining importance in recent years, though recognized since 1930s, A wide range of probabilistic techniques have been developed. A common concept behind each of these developments is the need to recognize that power systems behave stochastically and all input and output state and event parameters are probabilistic variables. In power system studies, The Optimization technique constitutes a study of paramount importance in power systems for future expansion, stability and reliability of the power systems. A simple method of a Economic dispatch with probable variations in loads has been presented here for a case study of Karnataka power grid.**

***Index Terms*— Power system Optimization, Economic Dispatch, Probabilistic Optimal Power Flow.**

I. Introduction

THE power systems comprising of generation, transmission, and distribution is one of the complex systems, is increasing at a rapid pace due to increase in electricity demand and incorporation of renewable sources such as solar, wind, bioenergy, small hydro etc. Further FACTS controllers are becoming part of the systems control. Such a complex system should operate at optimal state at all times. To achieve optimal operation Economic dispatch, optimal power flow, in different forms are employed.

These studies along with power flow studies treat loads with Real and Reactive powers as constants – a deterministic type of study[3,4], the uncertainties in load consumptions are addressed by probabilistic techniques[1,2]. Further developments in applications of probabilistic techniques applied to power systems are probabilistic type - security analysyis, contingency analysis, unit commitment, transient stability, etc are suggested in literature [8-10].

In this paper we focus on classical economic dispatch technique of optimal operation of power system , and consider the variation of loads with a view of simplifying the analysis though LPOPF and other types are available for addressing the optimization problems.

II. Problem Formulation

A. Review of Classical Economic Dispatch Problem[12]

A cost function C_i assumed for each power plant (assuming all thermal power stations), such that total cost of power generation C_t in an power systems area is to be minimized, simultaneously satisfying the certain constraints.

Minimize C_t = Sum of C_i at all power plants

Subject to constaint: Total generated powers Equals Total Load powers plus Losses

$$C_i = \sum_{i=1}^{ng} C_i = \sum_{i=1}^{ng} \alpha i + \beta i\, P_i + \gamma i\, P_i^2$$

Subject to constaint:

$$\sum_{i=1}^{ng} P_i = P_D + P_L$$

The transmission loss P_L is a Quadratic function of P_is. and loss coefficients. The Details of Solution procedure Using Lagrange method is available along with the MATLAB based programs in [12]

In the above analysis the System Load P_D is assumed to be fixed variable, however it is a randomly changing variable in actual practice. The variations need to be considered , usually Load forecasting techniques are commonly employed.

B. Forecasting the Loads P_D

The forecasted P_D is determined using the past history of Load data , and is assumed to be made of three parts (i) The trend, (ii) The cyclic variation and (iii) random components

The trend part is determined using conventional curve fitting techniques, The cyclic variations by using Fourier series techniques and the third random variations are quite difficult to determine, Random variable analysis is widely used for this purpose. The Modern method of Splines are also very useful to determine P_D.

In this paper we used the MATLAB programs of [12] and functions of spline tool box of MATLAB for simplifying the complexities involved in above stages.

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C. FACTS controllers – Unified Power Flow Controller (UPFC)

The Unified Power Flow controller is versatile FACTS controller which can exercise control of the important power system variables and parameters – Voltage magnitude and phase angle, the line reactance using its Series controller part as well as the Shunt Reactive power using its Shunt controller. The various power flow models for UPFC are available in the literature, we use the exact pi model [14-16] for our analysis purpose, fig 1 shows UPFC in a line and Fig2 its Pi-Model

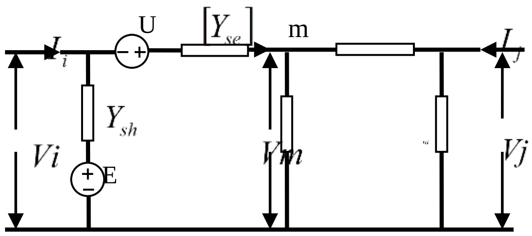


Figure 1 Representation of a UPFC-inserted line

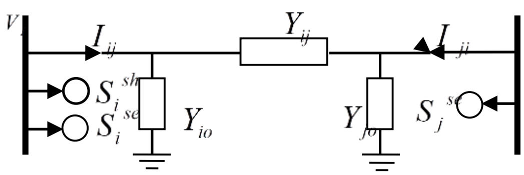


Figure 2 . The equivalent injection Pi-model.

$$P_i^{se} = V_i U\left[\ (G_{bii}\cos(\theta_i-\delta)+B_{bii}\sin(\theta_i-\delta)\ \right]$$

$$Q_i^{se} = ViU\left[-B_{bii})\cos(\theta_i-\delta)+G_{bii}\sin(\theta_i-\delta)\right]$$

$$P_i^{se} = V_i U\left[\ (G_{bii}\cos(\theta_i-\delta)+B_{bii}\sin(\theta_i-\delta)\ \right]$$

$$Q_i^{se} = ViU\left[-B_{bii})\cos(\theta_i-\delta)+G_{bii}\sin(\theta_i-\delta)\right]$$

$$P_i^{sh} = ViE\left[G_{bij}\cos(\theta_i-\beta)+B_{bij}\sin(\theta_i-\beta)\right]$$

$$Q_i^{sh} = ViE\left[-B_{bij}\cos(\theta_i-\beta)+G_{bij}\sin(\theta_i-\beta)\right]$$

$$P_j^{se} = V_j U\left[G_{bji}\cos(\theta_j-\delta)+B_{bji}\sin(\theta_j-\delta)\right]$$

$$Q_j^{se} = V_j U\left[-B_{bji}\cos(\theta_j-\delta)+G_{bji}\sin(\theta_j-\delta\right]$$

where Zse and Zsh (Yse and Ysh) are the impedances (admittances) associated with the series converter and the shunt converter, respectively, where $Y_{se} = G_{se} + jB_{se}$ and $Y_{sh} = G_{sh} + jB_{sh}$. The complex voltage $U = U\angle\delta$ and $E = E\angle\beta$ are the controllable voltages inserted from the series branch and the shunt branch respectively, and $Vi = Vi\angle\theta i, Vm = Vm\angle\theta m, and Vj = Vj\angle\theta j$ are the complex voltages at nodes i, m, and j, respectively.

Further simplification in models of UPFC are also possible. The essential control features of UPFC with little loss accuracy can be helpful. To demonstrate the working, a simple 3 – Bus system with UPFC in line 1-3 is employed and the optimal scheduling also shown.

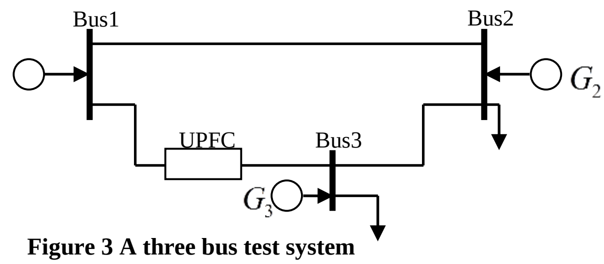


Figure 3 A three bus test system

$G_1 : C_1 = 220+10\ P_1+0.001\ P_1^2$
$G_2 : C_2 = 200+11\ P_2+0.007\ P_2^2$
$G_3 : C_3 = 240+13\ P_3+0.007\ P_3^2$
Generation limits
G_1 (50,400)MW,(-100,100)Mvar
G_2 (50,350)MW,(-100,100)Mvar
G_3 (150,350)MW,(-100,100)Mvar
With R=0.02 X=0.2 B/2=0.04 for all 3 lines
When UPFC parameters assumed:

$$\delta_{se} = 175°, \delta_{sh} = 180°,\ V_{se} = 0.8,\ and\ V_{sh} = 0.2$$

Table 1.Results of the three bus test system

	Case 1	**Case 2**
P_{12}	113.58	142.702
P_{13}	201.753	246.625
P_{23}	85.641	102.771
P_1	315.393	387.159
P_2	274.557	263.97
P_3	171.816	116.296
Total loss [MW]	11.680	17.666
Total Gen.[MW]	761.766	764.735
Total cost [$/MWh]	10341.43	10304.23

Case 1 OPF results without UPFC
Case 2 OPF results with UPFC

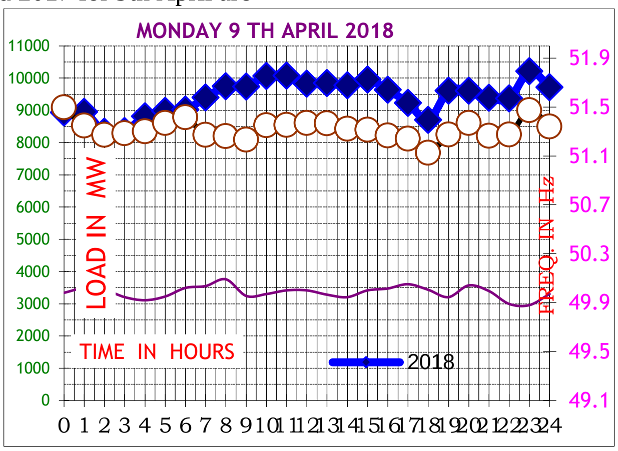
D. Karnataka Power Grid (Optional), The Load Curve

The 400kV power grid of Karnataka state has the following, Ttransmission System parameters of line (per 100Km) in pu
R=0.00209 X=0.01925 B/2=0.29979

From Bus	To Bus	Kms
Northren Part of Karnataka	-	-
RTPS	YTPS	15
YTPS	BTPS	160
RTPS	Munirabad	180
Munirabad	Guttur	50
BTPS	Hiriyur	150
BTPS	Guttur	120
Hiriyur	Nelamangala	140
Guttur	Narendra	160
Guttur	Kaiga	250

Kaiga	Narendra	135
Kudgi	Narendra	250
Southen Part of Karnataka	-	-
Talguppa	Hassan	240
Talguppa	Nelamangala	390
Hassan	Mysore	120
Hassan	UPCL	204
Nelamangala	Bidadi	50
Nelamangala	Hoodi	40
Bidadi	Somanhalli	20
Hoodi	Kolar	60
RTPS	Gooty	165
Gooty	Tumkur	250

The Load curve details of Karnataka State for the Years 2018 and 2017 for 9th April are



TIME	FREQUENCY	LOAD 2018	Prev year's hourly load 2017	2016	2015	2014
0	49.98	8937	9087	7963	7869	6981
1	50.02	8953	8520	8040	8198	6600
2	50.01	8336	8232	7871	7865	6400
3	49.95	8353	8288	7741	7764	6280
4	49.92	8815	8350	7746	7753	6367
5	49.95	8978	8604	7991	8120	6490
6	50.02	9024	8780	7772	7889	6679
7	50.04	9394	8232	7601	8465	7259
8	50.09	9743	8195	7677	8686	7922
9	49.96	9739	8090	7733	8479	8204
10	49.97	10066	8533	8187	8821	8368
11	50.00	10076	8540	8341	8800	8326
12	50.00	9828	8602	8144	8833	8175
13	49.97	9850	8593	8164	8765	8331
14	49.95	9776	8429	7838	8644	8252
15	50.00	9958	8391	7780	8531	8473
16	50.02	9636	8212	7570	8152	8206
17	50.05	9229	8113	7186	8018	8032
18	50.01	8701	7676	6709	7452	7785
19	49.95	9603	8244	8111	8524	8908
20	50.04	9603	8599	8337	8433	8889
21	50.00	9391	8209	8123	7731	8721
22	49.89	9368	8242	8021	7555	8169
23	49.88	10208	9002	8028	7834	8175
24	49.97	9716	8498	7535	7300	7783

The power generations by available conventional resources are as follows (data is for 25-Apr-2017, 09.35AM)

GENERATING STATIONS	CAP (MW)	TOTAL GEN
RTPS	1720	1509
YTPS	800	0
BTPS	1700	449
JINDAL	260 +1200	581
UPCL	1200	1090
SHARAVATHI	1035	139
NAGJHARI	900	394
VARAHI	460	21
KODSALLI	120	112
KADRA	150	141
GERUSOPPA	240	219
JOG	139.2	50
LPH	55	0
SUPA	100	43
SHIMSHA	17.2	0
SHIVASAMUDRA	42	0
MANIDAM	9	2
MUNRABAD	28	0
BHADRA	39.2	0
GHATAPRABHA	32	9
ALMATTI	290	0
TOTAL	10536.6	**5013**
TOTAL NCEP	550	**550**
TOTAL CGS	3745	**3745**

From the above table, the major suppliers are Thermal stations – RTPS, BTPS, UPCL and other private – JSW. Hydel supplies, Non conventional-NCES and central grid supply CGS are not considered for optimal dispatch. Thus system can be viewed as a equivalent 3-bus system. (Fig-3)

The optimal scheduling for sample loads are given below

TIME	LOAD	NCEP + CGS	Remaining Approx	G1	G2	G3
	2018		**3500**	**1500**	**1000**	**1000**
1	8953	**5000**	4000	275.2	164.3	68.0
5	8978	**5000**	4000	275.2	164.3	68.0
6	9024	**5000**	4000	275.2	164.3	68.0
7	9394	**5000**	4300	400	350	279.5

G_1 : RTPS+YTPS $C_1 = 220+10\,P_1+0.001\,P_1^2$

G_2 : BTPS+JSW $C_2 = 200+11\,P_2+0.007\,P_2^2$

G_3 : UPCL $C_3 = 240+13\,P_3+0.007\,P_3^2$

Generation limits

G_1 (50,400)MW,(-100,100)Mvar

G_2 (50,350)MW,(-100,100)Mvar

G_3 (500,350)MW,(-100,100)Mvar

With R=0.02 X=0.2 B/2=0.04 for all 3 lines,

III. CONCLUSION

In this paper an attempt is made for economic scheduling of a real power system. The case study of Karnataka power grid is considered, the load curve of grid considered here for one typical day , however further variation of load values need to be analyzed.

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