Post National Grid Reinforcement Analysis of QESCO Network for Reliable and Optimal Operation

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Abstract

Energy is an important input for economic development of every country and electric power sector is an indispensable infrastructure in any economy. Quetta Electric Supply Company (QESCO) supplies electric power throughout Balochistan province of Pakistan except District Lasbela. Balochistan covers 43% of the geographic area of Pakistan but is considered to be the least power consuming province. The load is far away from the source and radially fed resulting in low voltage profiles and frequent blackout of the company grid network. Power flow studies have great significance in determining the best criteria for designing a power system and planning the future expansion of power system. This research focuses on reinforcement analysis of QESCO network using Power System Simulator for Engineering (PSS/E) by simulating load flow analysis model. The operation of the three available power sources has been studied for maximum performance of the grid network. Different scenarios have been analyzed and quantified by applying all the parameters and values of QESCO power system and inferences have been obtained on the basis of results generated by the PSS/E Software. The comparison study has been carried out for the three N-1(loss of one source) contingency situations for the available sources and best possible network topology for optimal operation of QESCO network is proposed.

Key words: Load Flow; Contingency Analysis; PSS/E Software; Grid Network Reinforcement

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INTRODUCTION

Electrical Energy crisis imperiled the economic development of Pakistan. Population of the country is increasing rapidly but energy resources are not growing proportionately to meet the load demand. Optimal utilization of the available energy resources is essential to get maximum benefit and outcome from these resources.

An electric power system is a network of electrical components deployed to generate, transfer, and utilize electric power. Quetta Electric Supply Company (QESCO) is delivering electrical power to the Balochistan province (except District Lasbela) of Pakistan. Balochistan is geographically the largest province of the country but is the least power consuming province with annual load growth rate of 3.5%. The load is supplied at 11KV level from sub-transmission networks of 132kV and 66kV through substations of 132/11KV and 66/11KV. There are sixty 132kV and ten 66kV substations (NTDCL, 2015). In a network of long distanced transmission lines connecting power generation sources with mainly inductive load (70%-80% agricultural load), a very low voltage profile prevails. There was only a single and radial 220KV source from Thermal Power Station Guddu via Sibi to Quetta which is violation of National Electrical Power Regulatory Authority (NEPRA) codes. Any disturbance could easily lead to a huge electricity breakdown or even a blackout. The National Transmission and Dispatch Company (NTDC) has recently commissioned two additional 220KV sources for QESCO; a 220kV transmission line stretched from Daddu to 220KV substation at Khuzdar in the south-east of the province and a 220kV transmission line feeding northern area of the company stretched from D.G Khan to 220KV substation at Loralai. But these transmission lines are not yet fully interconnected as a transmission ring.

Power system planning has many components and planning of transmission is one of the most important features. The main aim of most transmission network expansion plans is to explore the optimal topology for reliable and stable system. National Electric Power Regulatory Authority (NEPRA) is regulator of Pakistan's electrical power sector. In normal condition, QESCO is bound to maintain voltage profile in the range of ± 5% while ± 10% under N-1 contingency conditions (Malik, 2007). To meet the criteria, the Distribution Companies (DISCOS) use different simulation tools like PSS/E, ETAP etc. for optimal power system planning. The contingency analysis is a tool which simulates and measures the outcomes of hindrances that appear in power system in the very near future. The target of transmission and distribution network of electric power system operation is to optimize and to obtain the maximum utilization of the available resources. Power flow study provides the magnitude and phase angle of the voltage at each node (bus bar), the Real Power (P) and Reactive Power (Q) power flowing in each line. In this research paper different iterative techniques have been applied to analyse the best possible grid network topology for QESCO Network. The anticipated load growth in 2017 is used for simulation results by using PSS/E Software.

MATERIALS AND METHODS

Different techniques have been used for load flow studies in different countries. The load flow studies of Bangladesh Power System were analysed and accomplished using Power System Application Framework (PSAF) developed by CYME International TD Inc. (Mehnaz et al., 2013). The transmission system development planning of Lao Peoples Democratic Republic has been analysed for N-1 (loss of one source) contingency using IEEE 30 bus system for the sensitivity analysis. The maximum power flow was calculated for normal condition and a single transmission line fault. The results gave a better position for planning the transmission lines capacities and help in reducing the cascading failures probability (Totonchi et al., 2013). In (Udaykumar and Sudarshana Reddy, 2015) the grading of contingencies was carried out with more accurate and exact method using MATLAB environment. Similarly a general framework is proposed to assess the capability of a system to sustain the impact of any contingency (Allan and Silva, 1995).
The goal of this research is to make general guidelines for the entire transmission system encompassing QESCO network and taking maximum benefit from all available sources.
The Power Flow Analysis has been performed to find the following parameters;

1. |V| magnitude of voltage at each bus
2. Phase Angle of voltage at each bus
3. P (Real), Q (Reactive) Power flow in each line

Data Collection

The data has been collected for the QESCO Grid network and four scenarios were modeled for analysis purpose i.e.

i. Peak Load: June 2015
ii. Off Peak Load: January 2016
iii. Peak Load: June 2019
iv. Off Peak Load: January 2020

Software Selection

Siemens Energy's Power Technologies International (PTI) PSS/E V32.0 software was used to carry out this research. This is a powerful tool for power system engineers to simulate various scenarios of contingency analysis and substation reliability with addition to power flow analysis of complete power system.

Modelling and Simulation

The modelling and simulation has been carried out on the following assumptions:

- Pakistan Electric Power Company (PEPCO) latest power market survey (PMS) load forecast has been used for QESCO and PEPCO system future loads.
- All existing and proposed power plants, based on NTDC latest generation expansion plan, have been included.
- Latest transmission expansion plans of NTDC have been modelled.
- QESCO's planned/on-going transmission expansion/re-enforcement projects, including substations (extension, augmentation, conversion, new), transmission lines have been included in the studies as per their expected commissioning schedules.
- The existing and planned shunt capacitors at 11 kV and 132 kV has been modeled in the study scenarios.

Contingency Ranking

The QESCO grid network has been manipulated for different topologies to ascertain the best choice for operation and maximum performance. Following topologies were used.

1. With Reinforcement
2. Without Sibbi Reinforcement
3. Without Loralai Reinforcement
4. Without Khuzdar Reinforcement

Network construction and Single Line Diagrams (SLDs)

QESCO grid network was simulated according to the database. Prior to the contingency analysis, it was needed to converge the network using power flow studies numerical iterative techniques (Newton Raphson Method) used by the software. The network converged to the ultimate extent, normal and abnormal (Red buses) conditions found after contingency analysis as shown in Figure 1.

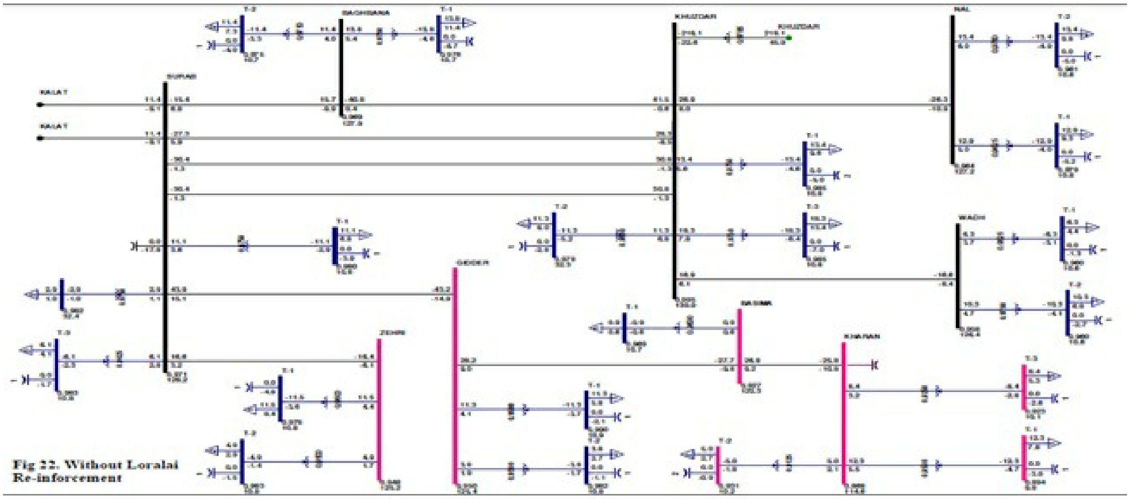

Figure. 1. Single line diagram showing red buses

RESULTS AND DISCUSSION

With Reinforcement Topology

When the QESCO Grid network was simulated for analysis with the availibility of all the three 220 KV sources, two buses were found having voltage greater than 1.05 p.u voltage (Table 1).

Table 1: Buses with Voltage > 1.0500

S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)
1	999	GWDR	132.000	1.0500	138.600
2	9600	SIBBI	132.000	1.0575	139.590

In the network, 20 buses were found having voltage less than 0.95 p.u voltage (Table 2). The topology resulted in the best voltage profile for the network.

Table 2: Buses with Voltage < 0.9500

S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)	S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)
1	8441	JACB-TOF	66.000	0.8759	57.809	11	8443	Dm. J-66	66.000	0.8411	55.514
2	8444	MANJOSHORI	66.000	0.8401	55.445	12	8445	Rojjamal	66.000	0.8479	55.963
3	8502	GADAKHA	66.000	0.8178	53.976	13	8510	Ustamohd	66.000	0.8060	53.195
4	8515	JHAL MGS	66.000	0.7321	48.321	14	9735	Chaman	132.000	0.9437	124.570
5	84401	T-1	11.000	0.9023	9.925	15	84402	T-2	11.000	0.9048	9.953
6	84403	T-3	11.000	0.9048	9.953	16	84441	T-1	11.000	0.9089	9.998
7	84451	T-1	11.000	0.8572	9.430	17	84452	T-2	11.000	0.8237	9.061
8	85021	T-1	11.000	0.8598	9.458	18	85102	T-2	11.000	0.8766	9.642
9	85103	T-1	11.000	0.8479	9.327	19	85151	T-1	11.000	0.7728	8.501
10	85152	T-2	11.000	0.7928	8.720	20	85153	T-3	11.000	0.7800	8.580

Without Sibi Reinforcement Topology

The load flow analysis was carried out to simulate QESCO grid network with N-1 contigency i.e. excluding Sibbi reinforcement and no bus was found having voltage greater than 1.05 p.u voltage (Table 3).

Table 3: Buses with Voltage > 1.0500

BUS#	NAME	BASE KV	V(PU)	V(KV)
None				

QESCO grid network simulated for the load flow studies without Sibi reinforcement resulted in 24 buses with voltages less than 0.95 p.u voltage (Table 4) which are greater than that with all sources topology (Table 1).

Table 4: Buses with Voltage < 0.9500

S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)	S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)
1	8441	JACB-TOF	66.000	0.8602	56.773	13	8443	DM. J-66	66.000	0.8251	54.458
2	8444	MANJOSHORI	66.000	0.8240	54.386	14	8445	ROJJAMAL	66.000	0.8308	54.832
3	8502	GADAKHA	66.000	0.7965	52.660	15	8510	USTAMOHD	66.000	0.7856	51.847
4	8515	JHAL MGS	66.000	0.7092	46.809	16	9765	MUSAFRPR	132.000	0.9155	120.850
5	9768	G.H.ZAI	132.000	0.9374	123.730	17	9770	ZHOB	132.000	0.9041	119.330
6	9855	KHARAN	132.000	0.9197	121.400	18	84401	T-1	11.000	0.8846	9.731
7	84402	T-2	11.000	0.8872	9.759	19	84403	T-3	11.000	0.8872	9.759
8	84441	T-1	11.000	0.8911	9.802	20	84451	T-1	11.000	0.8392	9.232
9	84452	T-2	11.000	0.8064	8.871	21	85021	T-1	11.000	0.8373	9.210
10	85102	T-2	11.000	0.8536	9.390	22	85103	T-1	11.000	0.8251	9.076
11	85151	T-1	11.000	0.7474	8.221	23	85152	T-2	11.000	0.7661	8.427
12	85153	T-3	11.000	0.7545	8.300	24	96201	T-1	11.000	0.9473	10.421

Without Loralai Reinforcement Topology

Simulation of QESCO network modelled without Loralai reinforcement showed no bus having voltage greater than 1.05 p.u voltage (Table 5) this is also undesirable condition for the voltage profile at the lower side.

Table 5: Buses with Voltage > 1.0500

BUS#	NAME	BASE KV	V(PU)	V(KV)
None				

The level of system modelling detail used without Loralai source and the results of this analysis were found abnormal having 85 buses with voltage less than 0.95 p.u voltage (Table 6).

Table 6: Buses with Voltage < 0.9500

S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)	S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)
1	7600	RAKHNI	132.00	0.8803	116.20	44	76102	T-2	11.000	0.8519	9.371
2	7604	KINGRI	132.00	0.8319	109.81	45	76201	T-1	11.000	0.8373	9.211
3	7608	MEKHTAR	132.00	0.7900	104.29	46	84401	T-1	11.000	0.8916	9.807
4	7610	BARKHAN	132.00	0.8389	110.73	47	84402	T-2	11.000	0.8941	9.835
5	7620	KOHLU	132.00	0.8290	109.43	48	84403	T-3	11.000	0.8941	9.835
6	8441	JACB-TOF	66.000	0.8660	57.154	49	84441	T-1	11.000	0.8981	9.880
7	8443	DM.J-66	66.000	0.8313	54.867	50	84451	T-1	11.000	0.8457	9.303
8	8444	MANJOSHORI	66.000	0.8303	54.797	51	85102	T-2	11.000	0.8609	9.470
9	8445	ROJJAMAL	66.000	0.8368	55.230	52	85103	T-1	11.000	0.8324	9.157
10	8502	GADAKHA	66.000	0.8024	52.957	53	85151	T-1	11.000	0.7559	8.315
11	8510	USTAMOHD	66.000	0.7919	52.266	54	85152	T-2	11.000	0.7748	8.522
12	8515	JHAL MGS	66.000	0.7168	47.308	55	85153	T-3	11.000	0.7631	8.394
13	9620	HARNAI	132.00	0.8240	108.76	56	96101	T-1	11.000	0.9308	10.239
14	9630	LORALAI	132.00	0.7214	95.224	57	96201	T-1	11.000	0.7532	8.285
15	9635	DUKI	132.00	0.7531	99.414	58	96301	T-1	11.000	0.6802	7.482
16	9640	SHARIG	132.00	0.8199	108.23	59	96302	T-2	11.000	0.6941	7.635
17	9713	HURAMZAI	132.00	0.9439	124.59	60	96304	T-4	11.000	0.6809	7.490
18	9717	ALIZAI	132.00	0.9415	124.28	61	96351	T-1	11.000	0.6987	7.686
19	9718	BARSHORE	132.00	0.9411	124.22	62	96352	T-2	11.000	0.7019	7.721
20	9720	GULISTAN	132.00	0.9245	122.03	63	96401	T-1	11.000	0.7888	8.677
21	9730	Q.ABDULA	132.00	0.9278	122.47	64	97171	T-1	11.000	0.9409	10.350
22	9735	CHAMAN	132.00	0.9180	121.18	65	97181	T-1	11.000	0.9426	10.368
23	9740	KHANOZAI	132.00	0.7770	102.57	66	97401	T-1	11.000	0.7864	8.650
24	9741	ZIARAT	132.00	0.7707	101.73	67	97402	T-2	11.000	0.7983	8.781
25	9750	MUS.BAGH	132.00	0.7394	97.598	68	97403	T-4	33.000	0.7809	25.771
26	9760	Q.S.ULLA	132.00	0.6481	85.543	69	97404	T-3	11.000	0.7919	8.711
27	9765	MUSAFRPR	132.00	0.4658	61.491	70	97411	T-1	11.000	0.7929	8.722
28	9768	G.H.ZAI	132.00	0.5241	69.178	71	97501	T-1	11.000	0.7448	8.193
29	9770	ZHOB	132.00	0.4359	57.538	72	97502	T-2	33.000	0.7353	24.266
30	9800	KIRDGHEB	132.00	0.9428	124.45	73	97503	T-3	11.000	0.7355	8.091
31	9810	NOSHKI	132.00	0.9320	123.02	74	97601	T-1	11.000	0.6184	6.803
32	9814	MALL	132.00	0.9355	123.48	75	97602	T-2	11.000	0.6163	6.779
33	9845	ZEHRI	132.00	0.9483	125.18	76	97603	T-3	11.000	0.6214	6.835

S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)	S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)
34	9850	GIDDER	132.00	0.9497	125.36	77	97651	T-1	11.000	0.4932	5.425
35	9855	KHARAN	132.00	0.8683	114.61	78	97652	T-2	11.000	0.4804	5.284
36	9859	BASIMA	132.00	0.9268	122.33	79	97681	T-1	11.000	0.5001	5.501
37	9910	ALIZAI	66.000	0.9482	62.580	80	97682	T-2	11.000	0.5132	5.645
38	76001	T-1	11.000	0.8734	9.608	81	97701	T-1	11.000	0.4093	4.502
39	76002	T-2	11.000	0.8720	9.592	82	97702	T-2	11.000	0.4160	4.576
40	76041	T-1	11.000	0.8133	8.946	83	98551	T-1	11.000	0.8941	9.835
41	76042	T-2	11.000	0.7939	8.733	84	98552	T-2	11.000	0.9308	10.239
42	76081	T-1	11.000	0.7686	8.454	85	98553	T-3	11.000	0.9226	10.149
43	76101	T-1	11.000	0.8399	9.238						

This topolgy gave higher number of buses having voltage less than the desired value as compared to other topologies.

Without Khuzdar Reinforcement Topology

Power flow analysis of QESCO network was carried out without Khuzdar reinforcemnt topology. The results showed that no bus had voltage greater than 1.05 p.u voltage like two previous grid network topologies (Table 7).

Table 7: Buses with Voltage > 1.0500

BUS#	NAME	BASE KV	V(PU)	V(KV)
None				

Simulation of the grid network without khuzdar reinforcement topology resulted in 32 buses having voltage less than 0.95 p.u voltage (Table 8) which is greater than that of the QESCO grid network topology having all sources available (Table 1). The load flow results are based on the QESCO maximum demand in 2017 i.e. 1961MW as shown in Table-9. Table-10 is comparative analysis of QESCO network with and without re-inforcement. Power system reliability results with reinforcement situation is far better than other three N-1 contingency scenarios. The results are very healthy for power factor when Grid Network of QESCO is used with all the sources interconnected with each other.

Table 8: Buses with Voltage < 0.9500

S/N	BUS#	NAME	BASE KV	V(PU)	V(KV)	S.No	BUS#	NAME	BASE KV	V(PU)	V(KV)
1	8441	JACB-TOF	66.000	0.8758	57.805	18	84401	T-1	11.000	0.9034	9.937
2	8443	DM.J-66	66.000	0.8418	55.561	19	84402	T-2	11.000	0.9059	9.965
3	8444	MANJOSHORI	66.000	0.8408	55.495	20	84403	T-3	11.000	0.9059	9.965
4	8445	ROJJAMAL	66.000	0.8474	55.930	21	84441	T-1	11.000	0.9102	10.012
5	8502	GADAKHA	66.000	0.8141	53.733	22	84451	T-1	11.000	0.8572	9.429
6	8510	USTAMOHD	66.000	0.8039	53.057	23	84452	T-2	11.000	0.8236	9.060
7	8515	JHAL MGS	66.000	0.7310	48.245	24	85021	T-1	11.000	0.8560	9.416
8	9765	MUSAFRPR	132.00	0.9442	124.63	25	85102	T-2	11.000	0.8746	9.620
9	9770	ZHOB	132.00	0.9338	123.26	26	85103	T-1	11.000	0.8462	9.308
10	9800	KIRDGHEB	132.00	0.9443	124.65	27	85151	T-1	11.000	0.7720	8.492
11	9810	NOSHKI	132.00	0.9350	123.42	28	85152	T-2	11.000	0.7910	8.701
12	9814	MALL	132.00	0.9386	123.89	29	85153	T-3	11.000	0.7791	8.570
13	9845	ZEHRI	132.00	0.9327	123.11	30	98551	T-1	11.000	0.8912	9.804
14	9850	GIDDER	132.00	0.9353	123.46	31	98552	T-2	11.000	0.9278	10.206
15	9855	KHARAN	132.00	0.8638	114.02	32	98553	T-3	11.000	0.9201	10.121
16	9859	BASIMA	132.00	0.9154	120.83	33	98661	T-1	11.000	0.9433	10.376
17	9866	WADH	132.00	0.9461	124.88						

Projection of QESCO's anticipated Demand

Table-9 is the projected demand of QESCO for next four years while Table-10 depicts picture of the load fed by the three 220kV sources with full reinforcement and N-1 contigency scenarios.

Table 9: QESCO's anticipated Demand

QESCO MAXIMUM DEMAND		
Year	Maximum Demand (MW)	**%Age Increase**
2016	1893	**3.5**
2017	1961	
2018	2030	
2019	2102	
2020	2177	

Table 10: Comparative analysis of QESCO network with and without reinforcement of various sources

Network Topology	Max Demand in 2017	Load (MW)	Losses (MW)	Net Power (MW)	Remarks
With reinforcement	1961	1698.9	108.7	1807.6	153.4 MW Power has to be load shed
Without Sibi reinforcement	1961	1244.6	176.7	1420.6	540.6 MW Power has to be load shed
Without Khuzdar reinforcement	1961	1329.2	77.2	1406.4	554.6 MW Power has to be load shed
Without Loralai reinforcement	1961	1292.3	133.7	1426	535MW Power has to be load shed

Power Factor Comparative Analysis

Impact of power factor has been calculated in the four scenarios on the basis of output reports generated in load flow solution of QESCO grid Network as under

$$\text{Power Factor} = \frac{\text{Real Power}}{\text{Apparent Power}} = \frac{\text{MW}}{MVA}$$

$$\text{Where, Apparent Power} = \text{MVA} = \sqrt{(MW)^2 + (MVAR)^2}$$

Power Factor With Reinforcement

With all sources intact the power factor calculated from the output report with reinforcement as under:

Total MW = 1698.9

Total MVAR = 780.4

$$\text{Apparent Power} = \text{MVA} = \sqrt{(MW)^2 + (MVAR)^2} = \sqrt{(1698.9)^2 + (780.4)^2}$$

$$\text{MVA} = 1869.568$$

$$\text{Power Factor} = \frac{1698.9}{1869.568} = 0.9087$$

Power Factor Without Sibi Reinforcement

Without Sibi reinforcement, Power Factor calculated from the Output Report as under:

Total MW = 1244.6

Total MVAR = 784.0

$$\text{Apparent Power} = \text{MVA} = \sqrt{(MW)^2 + (MVAR)^2} = \sqrt{(1244.6)^2 + (784.0)^2}$$

$$\text{MVA} = 1470.94$$

$$\text{Power Factor} = \frac{1244.6}{784.0} = 0.846$$

Power Factor Without Loralai Reinforcement

Without Loralai reinforcement, Power Factor calculated from the Output Report as under:

Total MW = 1292.3

Total MVAR = 816.4

$$\text{Apparent Power} = \text{MVA} = \sqrt{(MW)^2 + (MVAR)^2} = \sqrt{(1292.3)^2 + (816.4)^2}$$

$$\text{MVA} = 1528.57$$

$$\text{Power Factor} = \frac{1292.3}{816.4} = 0.845$$

Power Factor Without Khuzdar Reinforcement

Without Khuzdar reinforcement, Power Factor calculated from the Output Report as under

Total MW = 1329.2

Total MVAR = 841.3

$$\text{Apparent Power} = \text{MVA} = \sqrt{(MW)^2 + (MVAR)^2} = \sqrt{(1329.2)^2 + (841.3)^2}$$

$$\text{MVA} = 1573.07$$

$$\text{Power Factor} = \frac{1329.2}{841.3} = 0.8449$$

CONCLUSION

Energy is an important input for economic development of every country and power sector is an indispensable infrastructure in any economy. An electric power system is a network of electrical components deployed to generate, transfer, and use electric power. Pakistan is facing acute imbalance between energy supply and demand which negatively effects the economic growth of the country. This research work is mainly concentrated on power flow studies of the grid network of QESCO, feeding geographically largest province of the country. Initially QESCO was fed by single and radial 220KV source from TPS Guddu via Sibbi to Quetta. Any disturbance could easily lead to a huge electricity breakdown or even a blackout. Keeping in view the vulnerable position of QESCO grid network the National Transmission and Dispatch Company (NTDC) has commissioned two additional 220KV sources, from Daddu Sind and D.G Khan to Khuzdar and Loralai respectively, for QESCO. But these addition 220 KV transmission lines are not yet interconnected as a transmission ring. In this research work the load flow analysis of QESCO grid network has been performed using PSS/E software for normal and N-1 contingency conditions. Simulation results are very healthy for power system reliability and power factor when Grid Network of QESCO is used with all three sources interconnected with each other.

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