IMPACT OF EHV TRANSMISSION LINE ON SYSTEM STABILTY AND REDUCED CONTINGENCY IN POWER SYSTEM

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***ABSTRACT*: *In this research it is emphasized on the fact that old and running in excess transmission network produce line losses and reduces the amount of power transfer to the load centers. This inclusive study presents evaluation of high voltage levels to find an optimum value for less contingency and system stability in power system by discussing all power related parameters. In order to get results, fault transient, system stability and contingency analysis is carried out using a highly efficient simulating tool ETAP (Electrical Transient Analysis Programme).The method of determining critical contingency is termed as selection of sudden outage and this can be performed by scheming operation indices for every outage. Moreover load flow analysis is also performed to get results of power transfer capabilities of extra high voltage transmission lines. This research work will lead us to a system with more efficiency, less contingency, reliability can bear extra load and carry the power to large distance, reducing the line losses and cost.*

Keywords: Contingency Analysis, Performance Indices, Load flow Analysis, Fault Tansient Analysis, System Stability Analysi

1-INTRODUCTION

An electric power system consists of generating units, transmission lines and distribution network. The main function of transmission line is to transfer bulk power to the grid station and consumers. Transmission lines network is considered as the backbone of power system which connects the generating stations with the load centers [6]. The purpose of this research is to reveal the fact that by enhancing the voltage level of the system, the losses should be minimized and maximum power should be transferred from the generating station to the utility end [8].The overall transmission system is interconnected due to economic, security and reliability reasons.The transmission lines requirement is based on the system planning [4]. Whenever a generating unit is added to the system, there is a need of transmission line to transfer the power from the generating station to the load centres. Each country has certain sets for the selection of voltage level and the number of transmission lines for the power system network depending upon the amount of electrical power. The requirement of backup transmission line is also assessed in order to avoid overloading of line in the situation of outage [1].In order to transmit the power over long distance, the electric power generated is then stepped up to 132kV, 220kV, 500kV and 765kV etc. as required. Power is transmitted with the help of transmission lines having high and extra high voltages that usually travel the distance of hundreds of kilo-meters and deliver the power to the grid stations and the end users.

2-TRASMISSION LINES AND AMPACITY PER CONDUCTOR

A transmission line is a conductor which is used to carry the power from the generating unit to the load centers. Different types of conductors are used for the power transmission depending upon the nature of the power and the distance to be travel. Transmission system is considered as a backbone of the power system. If this area is working efficiently then all the system is running smoothly .Both underground and overhead power transmission lines can be used to transmit power depending upon the environment conditions. The conductor current carrying limit is known its ampacity When we have to add conductors to conduit ampacity is considered, modify an existing current and finally introducing a new a design we have to consider the ampacity [4]

TABLE 1.1 AMPACITY TABLES OF DIFFERENT CONDUCTORS

Double Layer	Temp	Normal Ampere	Emergency Ampere
Tiger	50	330	424
	70	464	574
	100	601	727
Wolf	50	378	501
	70	548	683
	100	712	863

3-EXPERIMENTAL SETUP

In order to get results transient, fault, system stability and contingency analysis is carried out by designing one line diagram using a highly efficient simulating tool ETAP (Electrical Transient Analysis Programme) of interconnection scheme of hydro power projects on river Indus and its tributaries in northern areas by year-2030.

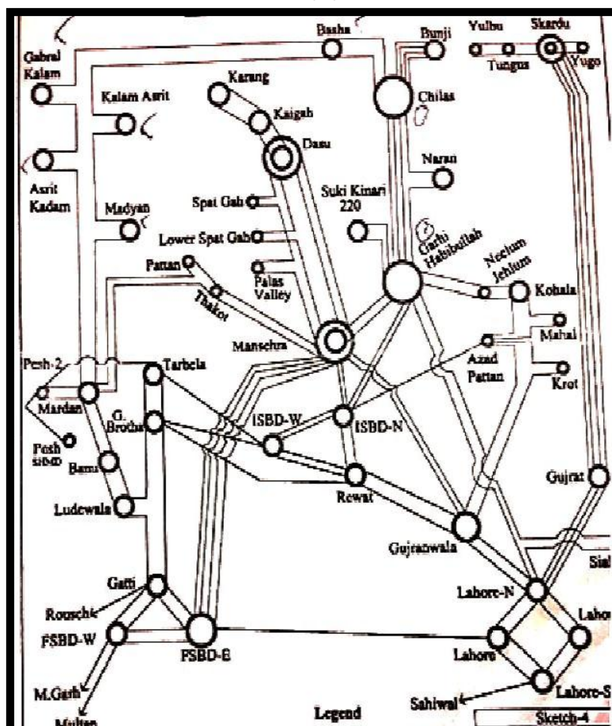

Fig 1.1 Interconnection Scheme of Hydro Power Projects on River Indus and Its Tributaries in Northern Areas by Year-2030

4-FAULT TRANSIENT AND SYSTEM STABILITY ANALYSIS

Steady-state constancy refers to the capability of the power system to recuperate synchronism after small and slow disturbances, such as ground power changes. An extension of the steady-state stability is known as the dynamic stability. Transient stability studies deals with the effects of large, sudden disturbances, such as the occurrence of the fault, the sudden outage of a line [6].Whenever a short circuit fault is smeared on a transmission line, a transient DC offset component, transient and power frequency component is generated on the line due to the voltage and current signal [5].The scrutiny of electric fault transients in a power system provides very important information regarding the load bearing capabilities of the system which are very much helpful in the scheme of different components of the generation and the protection system[5] .It is highly significance to be considered an effect of electromagnetic transients on the long transmission lines. The study of transients of lines usually tells us about the stress on the different components.[6] Single phase switching is used in 765 KV transmission network because all station equipment (circuit breakers and shunt reactors) used in this network are constructed as single phase units which reduce the system instabilities caused by faults and related switching operations[9]. The result of fault transient analysis of 500 kV and 765 kV transmission line systems is as follows:

$$I_k = U_f \ / \ Z_k \qquad (1)$$

$$Z_k = \sqrt{Rk^2 + Xk^2} \qquad (2)$$

where 'U_f ' is the phase voltage of the voltage source and 'Z_k' is the resulting impedance per phase from the voltage source to the fault point and 'R_k' is the total resistance in ohms and 'X_k' is the total reactance in ohms.[6]

The steady state stability restraint is usually demarcated in terms of the preferred margin among the maximum power transfer capability of the system and the operating level as [5]:

$$\% \text{ Stability margin} = \frac{P_{\max} - P_{op}}{P_{\max}} * 100 \qquad (3)$$

5-CONTINGENCY ANAYLYSIS

Contingency analysis method is used to compute the effect of outages in power systems, failure of apparatus, transmission line etc. The off line analysis to determine the impact of each contingency is a monotonous task because power system contains complex network and complicated machinery .

TABLE 1.2 **FAULT TRANSIENT AND SYSTEM STABILITY ANALYSIS OF 765 kV TRANSMISSION LINE NETWORK**

Faulted Bus	Line Voltage	3-Phase Fault	Line-to-Ground Fault	Line-to-Line Fault	Line-to-Line-to-Ground
ID	kV	KA	KA	KA	KA
GUJRAT	765	0.125	0.145	0.142	0.165
ISBD-W	765	0.135	0.25	0.37	0.271
LAHORE-E	765	0.43	0.15	0.13	0.15

TABLE 1.3 FAULT TRANSIENT AND SYSTEM STABILITY ANALYSIS OF 500 kV TRANSMISSION LINE NETWORK

Faulted Bus	Line Voltage	3-Phase Fault	Line-to-Ground Fault	Line-to-Line Fault	Line-to-Line-to-Ground
ID	kV	kA	kA	kA	kA
GUJRAT	500	0.165	0.165	0.189	0.165
ISBD-W	500	0.271	0.271	0.239	0.271
LAHOR-E-E	500	0.15	0.16	0.17	0.15

As far as operation has been concerned only selected outages will lead to adverse circumstances in power system like defilement of voltage and active power flow limits. The process of determining these adverse outages is termed as contingency selection and this can be done by conniving performance indices for each contingencies.[3] The contingency selection by calculating two types of performance indices; active power performance index (PIP) and reactive power performance index (PIV) for transmission line outage has been done[3].The level of most adverse contingency has been done based on the values of performance indices[10].

$$\sum_{i=1}^{L} (P_i / P_{i\max}) 2n \qquad (4)$$

$$\sum_{i=1}^{Npq} [2(V_i - Vinom) / (V_{i\max} - Vi\min)]^2 \qquad (5)$$

where 'Vi' is the voltage of bus 'i' and 'Vj' is the voltage at bus 'j' and 'X' is the reactance of the line connecting bus 'I' and bus 'j' 'Vimax' and 'Vimin' are maximum and minimum voltage limits and 'Vinom' is average of 'Vimax' and 'Vimin' and 'Npq' is total number of load buses in the system[10]

TABLE 1.4 ACTIVE POWER FLOW IN THE PRE AND POST CONTINGENCY STATE OF 500 kV TRANSMISSION LINE NETWORK

Outage Line	Start Bus	End Bus	Pre-Contingency MW Flow	Post-Contingency MW Flow
60	ISBD-W	Rewat	385	355.5
63	Garhi Habibullah	ISBD-N	975	925.7
79	FSBD-E	Mansehra	437	410
49	Lahore-E	Lahore-N	210	198
92	Bannu	Mardan	325	285
96	Gatti	Ludewala	175	172
117	Gujrat	Lahore-N	155	0
83	Mansehra	Garhi Habibullah	115	114
47	Lahore-S	Lahore-E	127	125
42	Gujranwala	Lahore-N	180	75
55	Sialkot	Lahore-N	225	223
88	Bus 120	Ludewala	160	155.6

98	Gatti	FSBD-W	425	0
107	FSBD-E	Gatti	210	180
111	Rewat	Bus 120	165	110
113	Bus-17	Mardan	110	109
118	Bus 147	Gujrat	340	110
127	Bus-161	Bus-147	122	85
130	Bus-151	Bus-153	173	145
51	Lahore-S	Lahore	125	105

TABLE 1.5 ACTIVE POWER FLOW IN THE PRE AND POST CONTINGENCY STATE OF 765 kV TRANSMISSION LINE NETWORK

Outage Line	Start Bus	End Bus	Pre-Contingency MW Flow	Post-Contingency MW Flow
60	ISBD-W	Rewat	385	382
63	Garhi Habibullah	ISBD-N	975	974
79	FSBD-E	Mansehra	175	0
49	Lahore-E	Lahore-N	210	210
92	Bannu	Mardan	325	321.4
96	Gatti	Ludewala	175	172
117	Gujrat	Lahore-N	427	421.9
83	Mansehra	Garhi Habibullah	115	114
47	Lahore-S	Lahore-E	127	125
42	Gujranwala	Lahore-N	180	179.4
55	Sialkot	Lahore-N	225	223
88	Bus 120	Ludewala	160	158.76
98	Gatti	FSBD-W	425	423.56
107	FSBD-E	Gatti	210	208
111	Rewat	Bus 120	70	67.87
113	Bus-17	Mardan	110	109
118	Bus 147	Gujrat	340	110
127	Bus-161	Bus-147	95	94
130	Bus-151	Bus-153	173	171
51	Lahore-S	Lahore	125	124.5

TABLE 1.6 PERFORMANCE INDICES AND CONTINGENCY RANKING OF 765 kV TRANSMISSION LINE NETWORK

Outage Line	Location	PIp	PIv	Ranking
60	ISBD-W -Rewat	1.1693	7.303	10
63	GarhiHabibullah-ISBD-N	0.9807	7.67	11
79	FSBD-E-Mansehra	1.1654	13.35	1
49	Lahore-E-Lahore-N	0.9999	7.321	12
92	Bannu-Mardan	0.982	8.876	9
96	Gatti-Ludewala	0.964	13.26	2
117	Gujrat-Lahore-N	0.9915	0.357	19
83	Mansehra-GarhiHabibullah	1.0747	1.175	17
47	Lahore-S-Lahore-E	0.9807	10.58	4
42	Gujranwala-Lahore-N	1.2396	1.605	16
55	Sialkot-Lahore-N	1.0142	9.591	8
88	Bus 120-Ludewala	1.0127	1.809	15
98	Gatti-FSBD-W	1.0569	1.367	18
107	FSBD-E-Gatti	1.0072	10.45	6
111	Rewat-Bus 120	1.0759	0.084	20
113	Bus-17-Mardan	1.0114	10	7
118	Bus 147-Gujrat	1.0164	2.348	13
127	Bus-161-Bus-147	1.003	10.52	5
130	Bus-151-Bus-153	1.0008	12.55	3
51	Lahore-S-Lahore	1.0076	2.289	14

6-LOAD FLOW ANALYSIS

The load flow study in a power system constitutes a study of principal importance. The study tells the electrical performance and power flows (real and reactive) for stated conditions when the system is operating under steady state. The load calculation study also provides statistics about the line and transformer loads (as well as losses) throughout the system and the voltages at altered points in the network for assessment and continuity of the operation of the power system under critical circumstances. The load flow report of 500 kV and 765 kV transmission line systems is as follows:

$$S_i = V_i I_i = V_i \left(\sum_{k=1}^{n} Y_{ik} V_k\right)^* = V_i \sum_{k=1}^{n} Y_{ik}^* V_k^* \qquad (6)$$

This is derived by defining

$$Y_{ik} = G_{ik} + \mathrm{j}\, B_{ik} \qquad (7)$$

TABLE 1.7 LOAD FLOW ANALYSIS OF 765 KV TRANSMISSION LINE NETWORK

	MW	Mvar	MVA	%PF
Source (Swing Buses)	385	110	225	97.68 Leading
Source (Non Swing Buses)	0	0	0	_
Total Demand	385	0	154.509	97.68 Leading
Total Motor Load	235	246	237	42.19 Leading
Total Static Load	125	147	157	98.75 Leading
Total Generic Load	0	0	0	_
Apparent Losses	39.63	41.8	_	_

7-POWER FLOW COMPARISON

Line losses in 765kV are less than 1% compares to losses as 8 to 9% on the existing lines, by using 765kV lines the losses decreased of 250MW on annual basis .Single circuit of 765kV line can transmit power of 2200MW to 2400MW, 500kV single circuit can transmit only 900MW up to distance of 300 miles [2]. 765 kV transmission line is designed to transmit a power of 4000 MVA (or even more) and line current can be calculated as [7]:

$$I = S\sqrt{3}V \qquad (8)$$

And four wire bundled rail conductor is normally used for 765 kV circuits which has tolerable limit of 3940A [12].In distribution network, usually voltage on the buses having low value and current is high when moving far from substation and thus losses are high. Therefore by using EHV system losses can be reduced because of low value of current in the system [4]. In 765 kV single phase line, the utilization of six conductors increase the geometric mean radius and creates uniform distribution field between conductors which reduces corona effect at acceptable level [12]

TABLE 1.8 LOAD FLOW ANALYSIS OF 500 kV TRANSMISSION LINE NETWORK

	MW	Mvar	MVA	%PF
Source (Swing Buses)	385	110	225	97.68 Leading
Source (Non Swing Buses)	0	0	0	–
Total Demand	385	0	154.509	97.68 Leading
Total Motor Load	235	246	237	42.19 Leading
Total Static Load	125	147	157	98.75 Leading
Total Generic Load	0	0	0	–
Apparent Losses	63.58	41.8	–	–

8- ANALYSIS OF SIMULATION RESULTS

In the scenario of 765 kV transmission line voltage after the event of contingency outage and the readjustment of the system particular for the consequent contingency outage of line, all facilities remain within short-time emergency ratings and the system must be capable of re-adjusting to within applicable emergency ratings while using 765kV transmission line voltage , it is observed that system facing reduce contingency and minimum line outage as per above results and when 500 kV transmission voltage is used line outage has been observed at two areas (125 MW outage line : 117, started from Gujrat to Lahore-N) and (425 MW outage line : 98 ,started from Gatti to FSBD-W) while surprisingly in case of using 765 kV transmission line, outage has been observed only one place (175 MW outage line : 79 ,started from FSBD-E to Mansehra) .Moreover in case of fault transient analysis it has been witnessed that value of short circuit current is small when using 765 kV as transmission voltage as compared to 500 kV as transmission voltage .Line losses in 765kV are less than 1% compares to losses as 8 to 9% on the existing lines, by using 765kV lines ,the loss diminution of 250MW on annual basis .

9-CONCLUSIONS

This research work has demonstrated the system with more efficiency, reliability, can bear extra load and carry the power to large distance and eventually reducing the line losses and cost of the system. Fault transients, system stability and contingency analysis was performed by designing one line diagram of interconnection scheme of hydro power projects on river Indus and its tributaries for finding an optimum value of EHV Transmission Line for system stability and reduced contingency in power system by varying the different parameters of the fault location and setting different voltage level for transmission network. After getting the results it concludes that 765 kV line facing reduced contingencies and more system stability and the network shall remain normal under the sudden outage of temporary single-phase-to-ground fault and successful re-closure (deceased time only 1 sec) and the results of load flow analysis showing reduced line losses in case of 765 kV network .In 765 kV single phase line, the utilization of six conductors increase the geometric mean radius and creates unvarying distribution field between conductors which reduces corona effect at acceptable level. The 765 kV transmission line structure is the economic system as compared to 500 kV as cost of 765kV transmission line construction is only 38% of the 500kV which enables maximum transfer of power with small infrastructure and optimum solution for interconnection scheme of hydro power projects on river Indus and its tributaries by year 2030.

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