Short Circuit Analysis of 500KV Hubco-Jamshoro Transmission Network and Improvement of Voltage Stability

SYED ASIF ALI SHAH*, ABDUL SATTAR LARIK**, AND AHSAN IRSHAD***

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ABSTRACT

In this paper, ETAP (Electrical Transient Analyzer Program) GUI (Graphical User Interface) simulation tool has been used to perform the short circuit analysis of power transmission lines. The existing 500KV Hubco- Jamshoro Transmission network of National Transmission & Dispatch Company, Pakistan has been selected to simulate the network. We provide a method for the analysis of short circuit current values for four different faults, i.e. 3-phase, line-ground, line-line and line-line-ground. It also covers the improvement of voltage stability of the network after integration with proposed projects of Jhimpir and Gharo wind power plants. The results of 3-phase and single phase line to ground faults are carried out using conventional method and to validate them these are compared with that of simulated ones. This paper also provides a way of improvement in voltage stability of Hubco-Jamshoro transmission network after adding the proposed projects of wind power plants at Jhimpir and Gharo.

Key Words: **Asymmetrical and Symmetrical Faults, Transmission Network, Wind Power Plants, Fault Analysis, Voltage Stability.**

1. INTRODUCTION

Any abnormal condition which causes flow of huge current in the conductors can be defined as a fault or short circuit [1-3]. A short circuit can be caused by breakdown of insulation, high voltage surges, human errors or any damage of an insulator. In normal operating conditions, all the circuit elements of an electrical system carry currents whose magnitude depends upon the value of generator voltage and effective impedances of all the power transmission and distribution system elements, including the impedances of loads. The excessive current in the event of short circuit is determined mainly by reactance of an alternator, transformer and transmission line up to the point of the fault in the case of phase to phase faults [4]. When the fault is between phase and earth, the resistance of the path plays an important role in limiting the currents. The calculation of PSCC (Prospective Short Circuit Current), the highest electric current which can exist in a particular electrical system under short circuit conditions, is of particular interest when designing an electrical installation because fuses and circuit breakers must be capable of safely breaking the current in the event of a short circuit [3-5]. A short circuit may lead to Electromagnetic interference, stability problems, mechanical and thermal stress and danger for personnel [6-7].

* Assistant Professor, ** Associate Professor, and *** Graduate Student,
Department of Electrical Engineering, Mehran University of Engineering & Technology, Jamshoro.

2. SYMMETRICAL AND ASYMMETRICAL FAULTS

In a polyphase system, a fault may affect all phases equally which is a "symmetrical fault" [8]. In transmission lines, roughly 5% are symmetrical faults. This is in contrast to any asymmetric fault, where three phases are not affected equally. With asymmetrical faults, the use of symmetrical components helps to reduce the complexity of the calculations. Common types of asymmetrical faults are line-to-line, line-to-ground and double line-to-ground [4,8].

3. FAULT ANALYSIS

This paper uses ETAP GUI to analyze and calculate short-circuit fault currents [8-9] for Hubco-Jamshoro transmission network. Fig. 1(a) shows the block diagram of Hubco-Jamshoro network while Fig. 1(b) shows the Hubco-Jamshoro transmission network simulated in ETAP.

4. SHORT CIRCUIT ANALYSIS

4.1 Three-Phase Fault

Base MVA selected = 380MVA

We consider only the circuits connected to generators in impedance diagram by using static loads, so loads will not contribute in short circuit calculations.

On 380MVA base:

X_1 of JSO Gen1 = 0.2583 p.u

X_1 of JSO Gen 2, 3, 4 = 0.2276 p.u

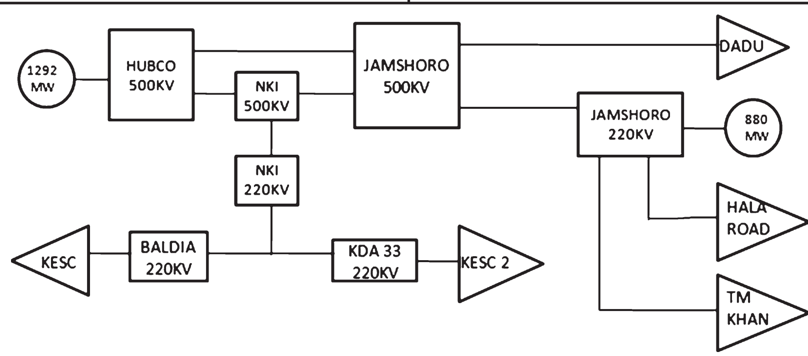

FIG. 1(a). BLOCK DIAGRAM OF HUBCO-JAMSHORO TRANSMISSION NETWORK

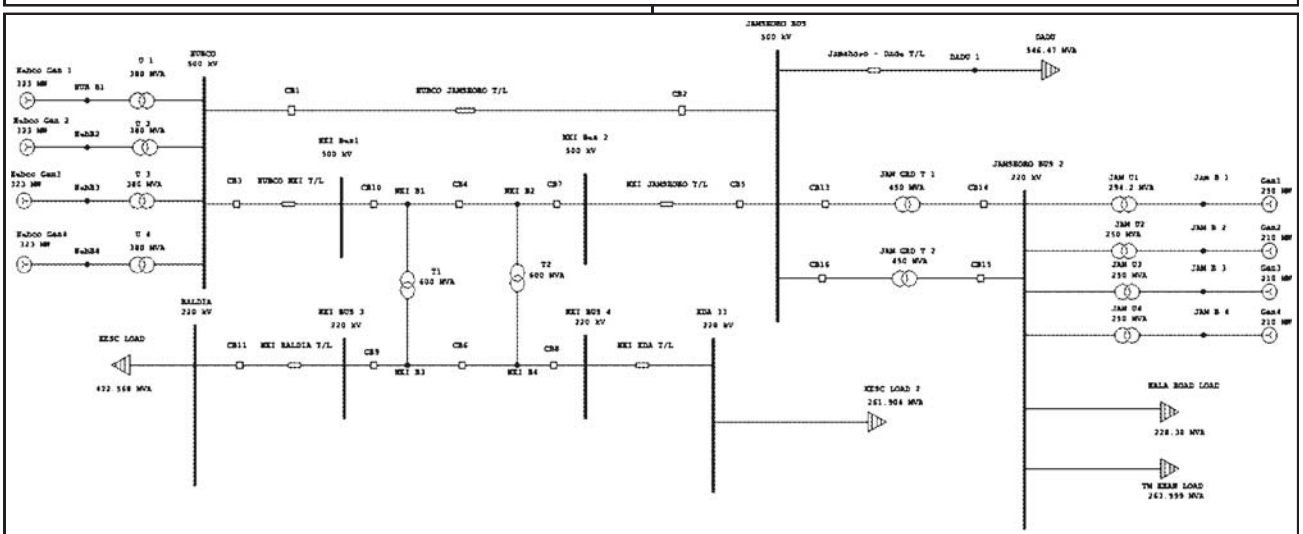

FIG. 1(b). SIMULATION MODEL OF HUBCO-JAMSHORO TRANSMISSION NETWORK

X of JSO U1 = 0.1937 p.u

X of JSO U2, U3, U4 = 0.2052 p.u

Equivalent positive sequence reactance of Jamshoro generators is given by:

X_g of JSO = 0.0579 p.u

Equivalent reactance of Jamshoro unit transformers is given by:

X_t of JSO = 0.0505 p.u

X_1 of HUB Gen 1,2,3,4 = 0.214 p.u

X of HUB U1 = 0.152 p.u

X of HUB U2 = 0.1605 p.u

X of HUB U3 = 0.1512 p.u

X of HUB U4 = 0.1497 p.u

Equivalent positive sequence reactance of HUB generators is given by:

X_g of HUB = 0.0535 p.u

Equivalent reactance of Hubco unit transformers is given by:

X_t of HUB = 0.0380 p.u

X of JSO T_1 = 0.0716 p.u

X of JSO T_2 = 0.0716 p.u

Equivalent reactance of generators at Jamshoro grid station is given by:

X_{equ} of JSO =0.03580 p.u

Z of HUB-JSO T/L = $49.93\angle 86.15\Omega$

Z of HUB-NKI T/L = $6.957\angle 85.94\,\Omega$

Z of NKI-JSO T/L = $41.35\angle 86.006\,\Omega$

For per unit value the formula is given as:

Per unit Z = (Actual Z in ohms)/(Base Z)

In Per unit

Z of HUB-JSO T/L =0.075 p.u

Z of HUB-NKI T/L = 0.0105 p.u

Z of NKI-JSO T/L =0.0627 p.u

The impedance diagram is shown in Fig. 2. By using series and parallel combination, the circuit is reduced to as shown in Fig. 3.

Therefore from Fig. 3 equivalent impedance is given by:

$$Z_{equ} = 0.0607 \quad (1)$$

The Fault MVA is calculated by using formula:

$$\text{Fault MVA} = \frac{\text{Base MVA}}{Z_{equ}}$$

Fault MVA = 6260.296

Calculating 3Φ fault current using formula:

$$I_{3\Phi} = \frac{\text{Fault MVA}}{\sqrt{3} * \text{BaseKV}}$$

$I_{3\Phi}$ = 7.22 kAmps

4.2 Line to Ground Fault

4.2.1 Positive Sequence Network

The impedances used for Positive Sequence network will be same as used in 3Φ fault. Thus positive sequence impedance Z_1 will be same as shown in Equation (1).

Z_1 = 0.0607

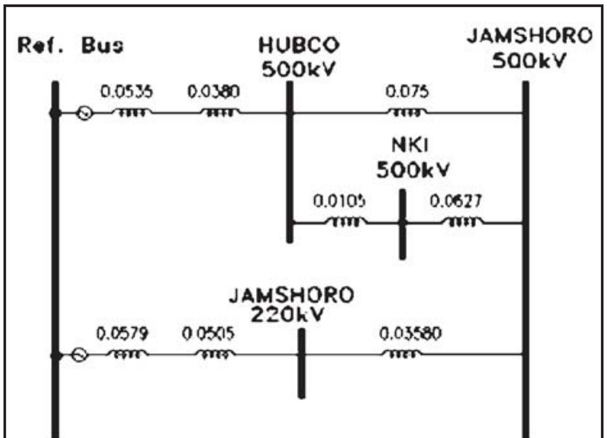

FIG. 2. IMPEDANCE DIAGRAM FOR 3Φ FAULT

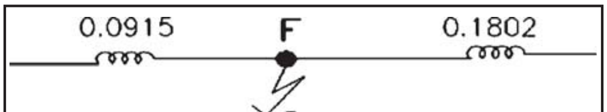

FIG. 3. RESULTANT IMPEDANCE DIAGRAM FOR 3Φ FAULT

4.2.2 Negative Sequence Network

X_2 of JSO Gen 1 = 0.2712

X_2 of JSO Gen 2, 3, 4 = 0.3538

X of JSO U1 = 0.1937

X of JSO U 2, U3, U4 = 0.2052

Equivalent negative sequence reactance of Jamshoro generators is given by:

X_g of JSO = 0.08219

Equivalent reactance of Jamshoro unit transformers is given by:

X_t of JSO = 0.0505

X_2 of HUB Gen 1,2,3,4 = 0.216

X of HUB U1 = 0.152

X of HUB U2 = 0.1605

X of HUB U3 = 0.1512

X of HUB U4 = 0.1497

Equivalent negative sequence reactance of Hubco generators is given by:

X_g of HUB = 0.054

Equivalent reactance of Hubco unit transformers is given by:

X_t of HUB = 0.0380

The impedance diagram for negative sequence network is shown in Fig. 4

Using series parallel combination and after simplifying it, the resultant circuit is shown in Fig. 5

Therefore from Fig. 5 negative sequence impedance is given by:

$Z_2 = 0.0631$

4.2.3 Zero Sequence Network

X of JSO U1 = 0.1937

X of JSO U2, U3, U4 = 0.2052

Equivalent reactance of Jamshoro unit transformers is given by:

X_t of JSO = 0.0505

X of HUB U1 = 0.152

X of HUB U2 = 0.1605

X of HUB U3 = 0.1512

X of HUB U4 = 0.1497

Equivalent reactance of Hubco unit transformers is given by:

X_t of HUB = 0.0380

Z_0 of HUB-JSO T/L = $149.27\angle 73.67$ = 0.22 p.u

Z_0 of HUB-NKI T/L = $21.76\angle 72.26\Omega$ = 0.032p.u

Z_0 of NKI-JSO T/L = $128.64\angle 73.74\Omega$ = 0.195p.u

The impedance diagram for zero sequence network is shown in Fig. 6.

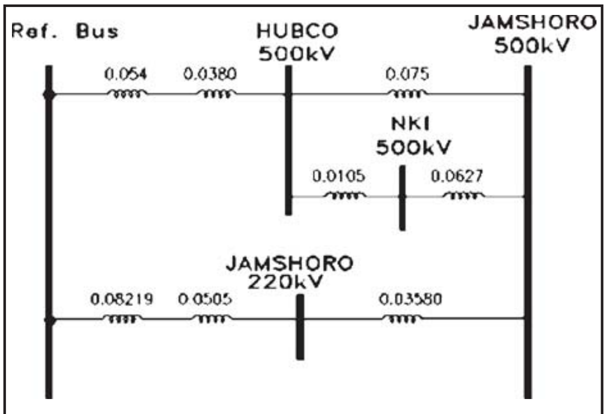

FIG. 4. IMPEDANCE DIAGRAM FOR NEGATIVE SEQUENCE NETWORK

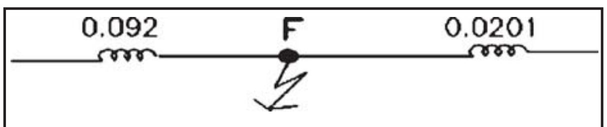

FIG. 5. RESULTANT IMPEDANCE DIAGRAM FOR NEGATIVE SEQUENCE NETWORK

Using Series and parallel formulas, the resultant circuit is shown in Fig. 7.

Therefore from Fig. 7 zero sequence impedance is given by:

$Z_0 = 0.0319$

The values of impedances calculated above are summarized in Table 1.

$Z_{equ} = Z_1 + Z_2 + Z_0$

$Z_{equ} = 0.1557$

The impedance diagram for line-to-ground fault is shown in Fig. 8.

The Fault MVA is calculated by using formula:

$$\text{Fault MVA} = \frac{3 * \text{Base MVA}}{Z_{equ}}$$

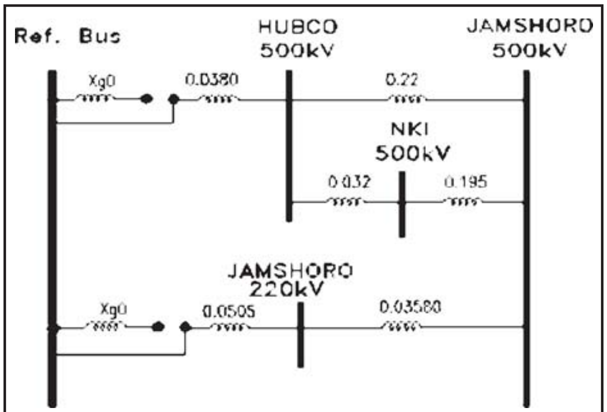

FIG. 6. IMPEDANCE DIAGRAM FOR ZERO SEQUENCE NETWORK

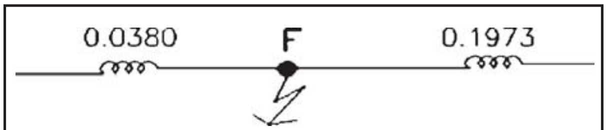

FIG. 7. RESULTANT IMPEDANCE DIAGRAM FOR ZERO SEQUENCE NETWORK

TABLE 1. VALUE OF IMPEDANCE FOR LG FAULT

Positive Sequence (Z_1)	0.0607
Negative Sequence (Z_2)	0.0631
Zero Sequence (Z_0)	0.0319

Fault MVA = 7321.7

Line to Ground Fault current is calculated by using formula:

$$I_{LG} = \frac{\text{Fault MVA}}{\sqrt{3} * \text{BaseKV}}$$

$I_{LG} = 8.43$ kAmps.

5. RESULTS

The simulation results of ETAP with fault at Hubco bus using static loads is shown in Table 2.

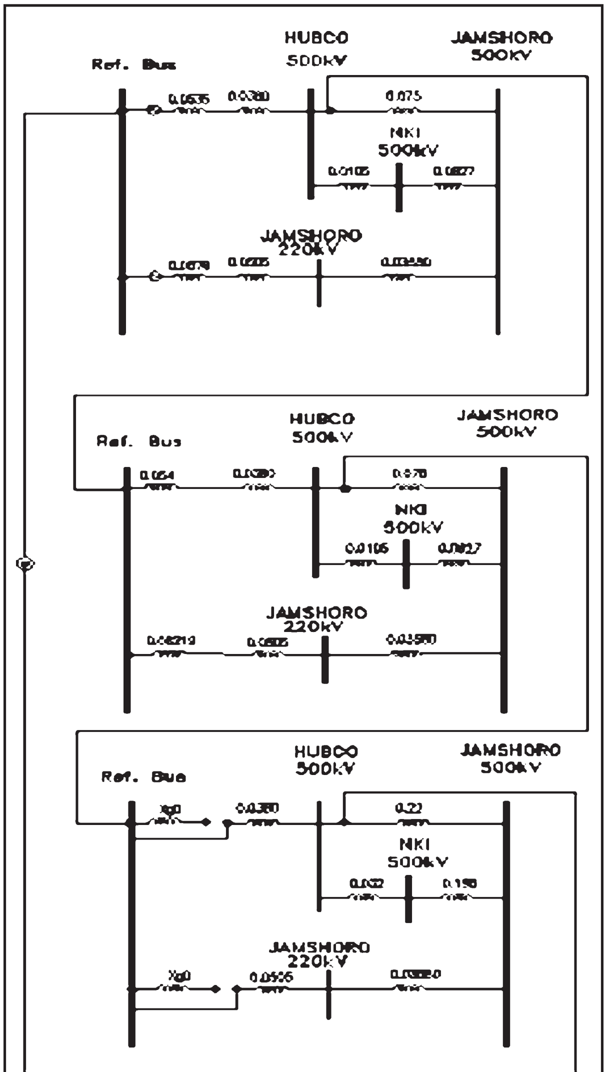

FIG. 8. IMPEDANCE DIAGRAM FOR LINE TO GROUND FAULT

5.1 Static Load

Thus we see that results calculated above are approximately similar to that simulated by ETAP. This verifies the model designed in ETAP. The voltage loadings of buses with static loads are shown in Fig. 9. According to ANSI standards the standard voltage loadings of buses is from 95-102%. The buses in red are thus considered as under voltage buses.

5.2 Lumped Load

In our research work, lumped loads with 50% motor contribution and 50% static load are considered. Short circuit calculations are shown in Table 3 while voltage loadings are shown in Fig. 10. Thus it is observed that short circuit values increase in magnitude as motor load contribute to them. Moreover lumped loads further reduce the voltage loadings of buses. Hence existing Hubco-Jamshoro network is operating with under voltage buses and it requires improvement in voltage stability.

TABLE 2. SHORT CIRCUIT ANALYSIS RESULTS

Type of Faulty	kAmps
3-Phase	7.183
Line-to- Ground	8.135
Line-to-Line	6.087
Line-to-Line-to-Ground	8.186

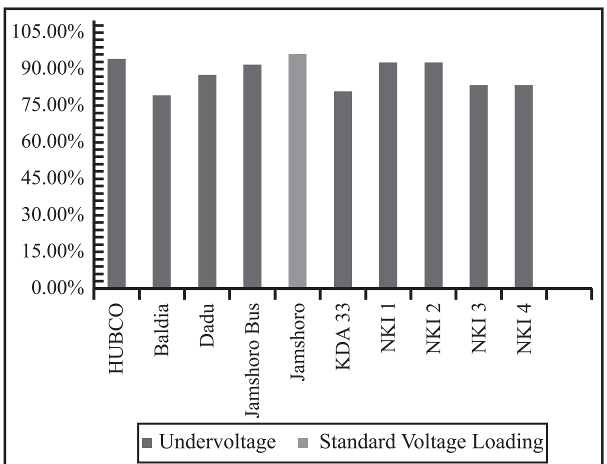

FIG. 9. VOLTAGE LOADING OF BUSES WITH STATIC LOADS

The AEDB (Alternative Energy Development Board) has allotted some 33,700 acres of land for establishment of 17 wind-turbine power generating plants of 50 Megawatts each in Jhimpir, Sindh [10], whereas three projects will be setup in Gharo, Sindh [11]. Here we connect 6 wind power generating plants of 50MW each Jhimpir and 3 wind power generating plants of 50MW each at Gharo and analyze the contribution of these wind power generating plants on network under consideration [12-13]. The block diagram is shown in Fig. 11.

Short circuit calculations with fault at Hubco bus are shown in Table 4 while voltage loadings of buses are shown in Fig. 12. It is thus found that both Jhimpir and Gharo generators contribute in short circuit currents although they are far away from point of fault. Also the voltage loading of buses have been improved. Thus the future projects Jhimpir and Gharo will be very useful for improvement of voltage stability.

TABLE 3. SHORT CIRCUIT ANALYSIS RESULTS USING LUMPED LOADS

Type of Faulty	kAmps
3-Phase	8.467
Line-to-Ground	9.515
Line-to-Line	7.302
Line-to-Line-to-Ground	9.155

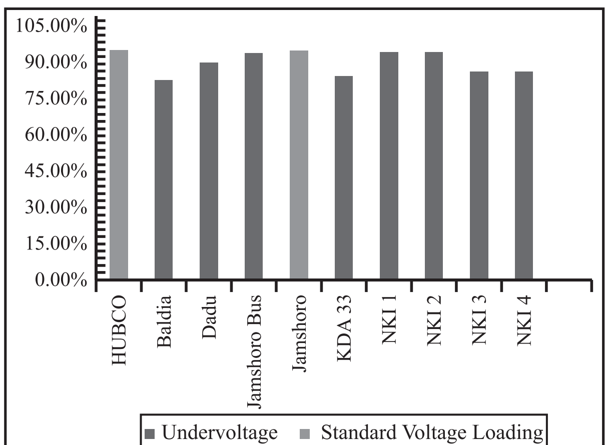

FIG. 10. VOLTAGE LOADING OF BUSES WITH LUMPED LOADS

6. CONCLUSION

The present 500KV Hubco-Jamshoro transmission network of NTDC (National Transmission and Dispech Company) in Pakistan is suffering from a number of under voltage bus loadings hence certain remedial measures are required to be taken in this regard. Moreover, short circuit current values show that ratings of switchgear and protection equipments which were designed and installed in 1980's need to be revised for withstanding fault currents and operating satisfactorily without damage. Proposed Wind Power generating Plants of Jhimpir and Gharo in near future would help in reducing under voltage problems of the network. The method used in the simulation is reasonably accurate to identify short circuit results for all four types of faults, voltage loading of buses as well as it can be used for selection of future projects and benefits in strengthening existing system towards stability.

7. FUTURE WORK

We are working to extend this work by incorporating the real case of fault in same transmission network and comparing the results of designed model with experimental data to validate our work. Moreover we are working to improve the voltage stability and reliability of existing network using FACTS (Flexible AC Transmission System)b devices.

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TABLE 4. SHORT CIRCUIT ANALYSIS RESULTS WITH STATIC LOADS AFTER INTEGRATION OF WIND POWER PLANTS

Type of Fault	kAmps
3-Phase	7.799
Line-to-Ground	6.588
Line-to-Line	6.590
Line-to-Line-to-Ground	8.724

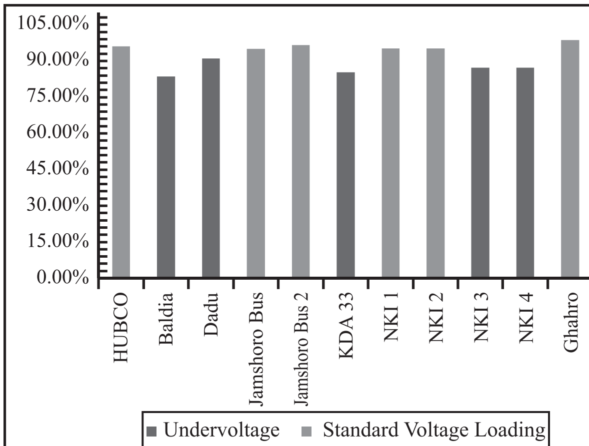

FIG. 12. VOLTAGE LOADINGS AFTER INTEGRATION WITH WIND POWER PLANTS

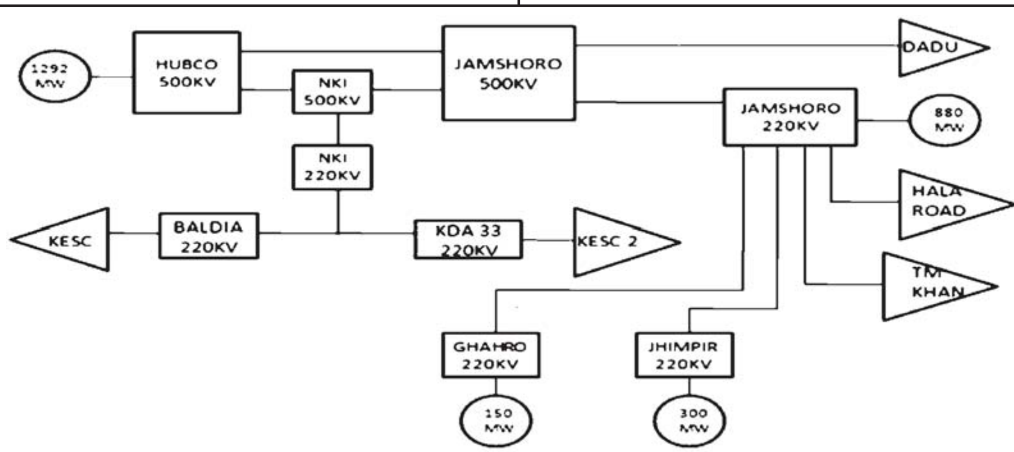

FIG. 11. BLOCK DIAGRAM OF HUBCO-JAMSHORO TRANSMISSION NETWORK WITH INTEGRATION OF JHIMPIR AND GHARO WIND POWER PLANTS

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