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Fault current analysis and its effects comparison on HVDC and HVAC of 660kV Matiari to Lahore project (Pakistan)

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Abstract Fault current is the flow of abnormal current in transmission system. It occurs in three states i) Sub-transient state ii) Transient state iii) Steady-state. They have an impact on power loss and power system physical parameters. This paper describes a special case of HVDC transmission simulated in ETAP installed at 660kV and performs fault current analysis of HVDC and HVAC. The results show that HVDC gives less value of fault current in case of longer transmission lines..

Keywords: Fault current analysis, HVAC system, HVDC system, longer transmission lines

I. Introduction

The whole power system is based on HVAC currently. HVAC reliability and economics need to be analyzed for very long distances [1][2]. This article explores how HVDC is more favorable in comparison of HVAC at very long distances. In this case study analysis a real time National Transmission Dispatch Company, Pakistan project 660KV 4000MW Bipole HVDC Matiari-Lahore which is in under construction phase [3]. This project has 878KM length of project which will connect the power generation in north of Pakistan with the generation of south Pakistan [4][5]. It has power converter stations at both end of HVDC transmission to convert HVDC in to HVAC for the usage [6]. It will connect the Thar coal power generation block at 500 KV high voltage AC with 500 KV grid station after it further it will connect at Matiari HVDC converter station which will convert the HVAC into HVDC through rectifiers and it will transmit to Bi-pole transmission line at 660 KV, it will cross the 878 KM distance at 660KV to Lahore converter station and it will again convert into HVAC through Inverters and it will connect with 500KV grid and transmission system in Lahore. This article simulates the fault current for both HVAC and HVDC for comparison [7][8]. In this paper unsymmetrical fault current (single-line to ground) case has been discussed. The simulation will be performed in ETAP 16.0 software which is powerful tool to for the simulations of power system [9]. In this simulation all the conductors, transformers and generators are used with the real time and actual data as per Water and Power Development Authority rule and regulations

II. Types of Transient

A. REACTANCE Sub transient reactance:

The flux crossing the air gap is massive all along a primary no of cycle .so the reactance through 2 to 3 cycles is least and short circuit current is high. The reactance is named sub transient reactance.

B. Transient reactance:

After a primary few cycles, the decrement within the R.M.S. value of short current is a smaller amount accelerate than the decrements during the primary few cycles.

C. Steady state reactance

Finally the transient dies out and also the current reaches a gradual curving state referred to as the Steady State.

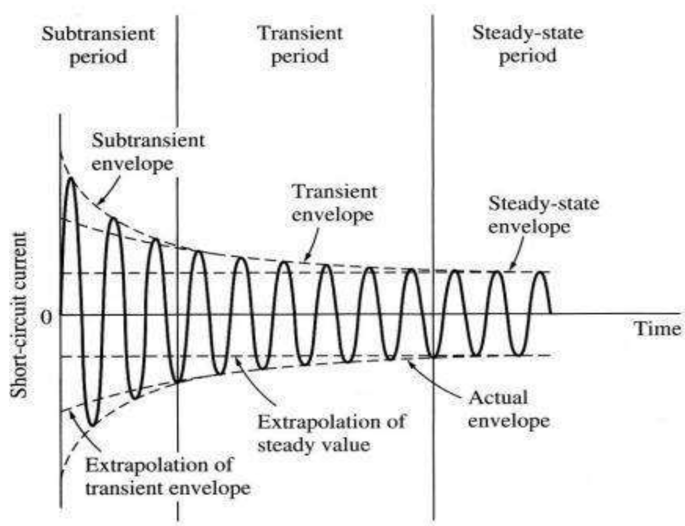

Figure.1 Transient /sub transient and steady state condition

III. SIMULATION CONDITIONS

A. Simulation in ETAP:

The simulation will be performed in ETAP 16.0 which considers in new versions of ETAP which can easily determine losses by load flow analysis and fault current through fault current analysis in HVDC and HVAC transmission lines. In the

proposed project the conductor used in this project is rail conductor which is heavy duty low resistance conductor. For generation purpose synchronous generators are used which are built in feature of ETAP. For the flow of power transmission line module is used and for the consumption of electric power lumped load is used.

B. Single Line Diagram in ETAP:

The proposed HVDC and HVAC system is designed in ETAP. The HVDC transmission system is simulated from Matiari to Lahore with same length and parameters. From Matiari side it's is connected with Thar coal block power generation.

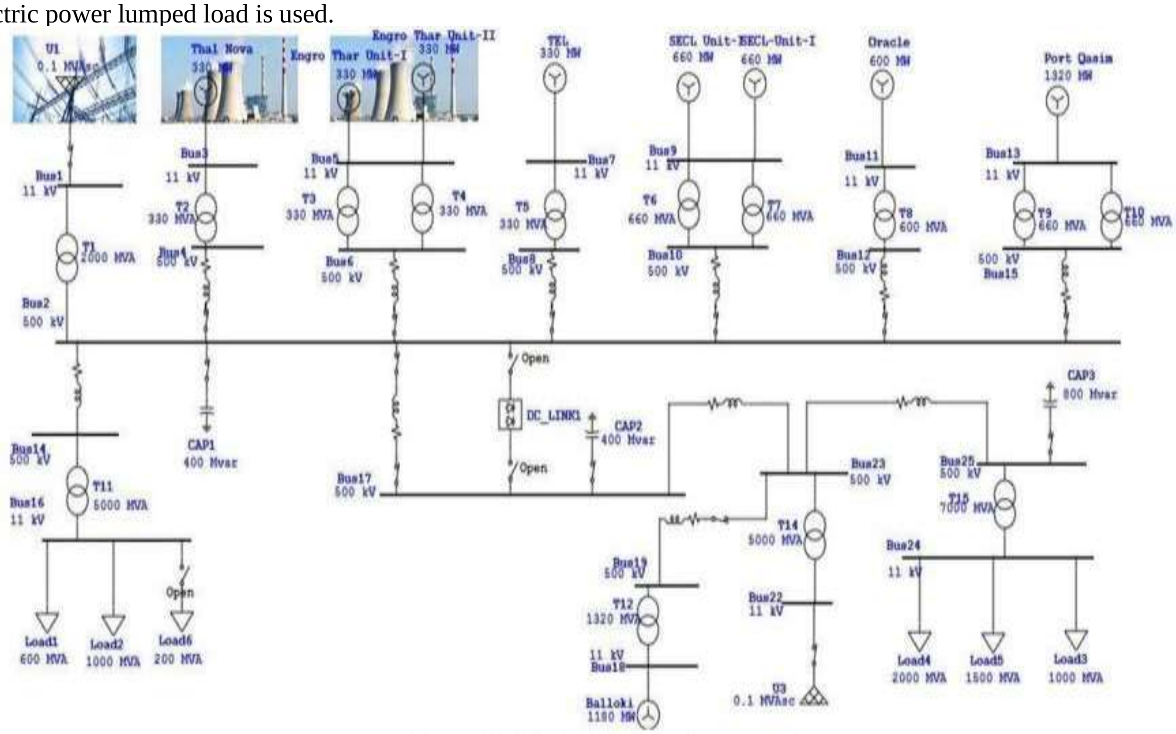

Figure 2. (ETAP Simulation of HVAC &HVDC)

IV. IV.HVDC BLOCK SECTIONS:

HVDC block has two sections

- Rectifier Section
- Inverter Section

A. Rectifier Section

Rectifier section has rectifier transformer which step up the voltage from 500 kV to 660 kV HVAC and then feed to rectifier's for the conversion from HVAC to HVDC through silicon control rectifier's (SCR) or power diodes and then feed to transmission line.

B. Inverter Section

Inverter section firstly comprise with DC to AC inverters which convert the 660KV DC voltages into AC voltages and then Inverter transformer to meet the voltage level of HVAC side which is 500 KV. The Matiari to Lahore line is simulated with the both side power plants for desired power generation and loads connected for power consumptions. For voltage step-up unit transformers are also installed at power generation generators.

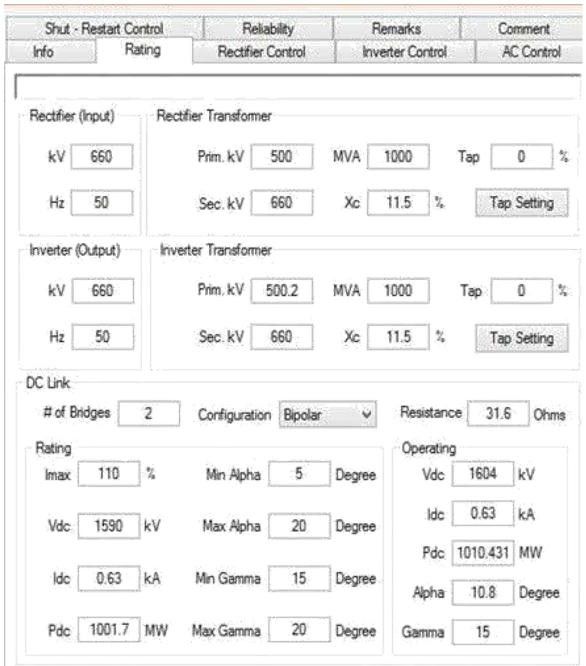

Figure 3. Values for HVDC Block

V. FAULT CURRENT ANALYSIS AT DISTANCE 878 KM

Case 1: Analysis of fault current at 878 Km HVDC

In this case study fault current analysis is made on 878 Km high voltage dc transmission line with the power flow of 1010 MW from Bus-2 to Bus-17.In this simulation it is depicted that HVDC can be applicable for the flow of bulk power from one side of power network to other side of network. The put up values in the DC block has shown in figure 3.

After putting the values in DC-Link of ETAP for HVDC. The load flow analysis have to be performed for the confirmation of simulation and to check the normal parameters of transmission line and other power system components. In load flow analysis all the power system components, bus voltages, rated power generations on rated voltages, power flow in transmission lines, transformers transformation ratio and their losses, consumption of electrical energy across the loads and other power system parameters should be in nominal ranges. Here in this simulation lumped loads are used for the flow of electrical power from transmission line to electric loads. In this simulation lumped load are used to consume large amount of power. Lumped load is the built in block in the ETAP. Which is the static load and can be used for large power consumption. Just like the load 4 which has power rating of 2000 MVA.

Fault Current Analysis of Case-1.

Fault current analysis of HVDC transmission line at 878 km is further divided in three types

- **Fault Current in Sub-Transient state (1/2 cycle)**
- **Fault Current in Transient (1.5- 4 cycle)**
- **Fault Current in Steady State (30 Cycle)**

Fault Current in Sub-Transient state (1/2 cycle): When there is short circuited in any element of power system. There is three-phase current rise up with the value of 10 to 18 times of full load current during first half cycle. The impedance reactance during this half cycle is very least and that's why short circuit is very high. This reactance is called sub-transient reactance denoted by X". This state is denoted by sub-transient state. The fault current analysis has made on case-1 at sub-transient state at bus- 2 and bus-17 the busses which are connected with high voltage DC transmission. In fault condition the every source feed the fault current at fault location. In this case fault current has to be determine on HVDC DC_Link which is connected with Bus2 and Bus17.

Fault Current in Transient (1.5-4cycle):
In this state reactance of the fault increased and during this state fault current decreases but in this state the decrement in fault current is not fast as in sub-transient state. This is called transient state and denoted as X'. The fault current analysis has made on case-1 at transient state at bus-2 and bus-17 the busses which are connected with high voltage DC transmission.

Fault Current in Steady State (30 Cycle): After transient state the fault current reaches to steady state. In this state the current is very less then sub-transient state and reactance is high in this state. But the decrease in current is slow from all previous states. This reactance is known as steady state reactance which is denoted as X. The fault current analysis has made on case-1 at steady state at bus-2 and bus-17 the busses which are connected with high voltage DC transmission.

Comparison of fault current analysis in Case-1 HVDC at 878 km.

The comparison of fault currents in all three states has been made on Bus-2 and Bus-17. The fault current in transient state is very high on Bus-2 and Bus-17 while in steady state the fault on Bus-2 and Bus-17 is quite less than transient state. So these are the current values in HVDC transmission line.

Table 1:(Fault current analysis in HVDC in three transient states)

Fault States	**Case 1: HVDC 1010MW System at 878 KM**

Fault Current in Sub-Transient state (1/2 cycle)	Bus 2: 20.924 KA Bus 17: 12 KA
Fault Current in Transient (1.5- 4 cycle)	Bus 2: 20.924 KA Bus 17: 10.1 KA
Fault Current in Steady State envelop (30 Cycle)	Bus 2: 18.988 KA Bus 17: 8.498 KA

Losses in HVDC transmission line in case-1.

The load flow analysis shows the following results of losses in HVDC transmission line in following table.

Table 2: (Power Losses in Case-1)

Transmission Length	Case 1 HVDC 1010 MW Power flow losses
878 km	12.542 MW

Case 2: Analysis of fault current at 878 KM:

In this case study fault current analysis is made on 878 Km high voltage ac transmission line with the power flow of 1010 MW from Bus-2 to Bus-17.

In this simulation it is depicted that HVAC can also use for the transfer of bulk power from one side of power network to other side of network. In this case same three types of faults will be analyzed at 878 km.

Fault Current in Sub-Transient state (1/2 cycle) The fault current analysis has made on case-2 at sub-transient state at bus-2 and bus-17 the busses which are connected with high voltage AC transmission line. The results shows that there is 25.109 kA at Bus-2 and 17.329 kA at Bus-17 which is in very large value than in case-1 in sub-transient state.

Fault Current in Transient (1.5- 4 cycle):

The fault current analysis has made on case-1 at transient state at bus-2 and bus-17 the busses which are connected with high voltage DC transmission. Here in this result we can see that the fault current is same as in sub-transient state on bus-2 and bus-17 which is 25.109 kA and 17.329 kA respectively.

Fault Current in Steady State envelop (30 Cycle):

The fault current analysis has made on case-1 at steady state at bus-2 and bus-17 the busses which are connected with high voltage AC transmission line.

In this case the fault current in more than sub-transient state of case-1. So it can be easily determine that the fault current in steady state of HVAC is more than the fault current in sub-transient state of HVDC. So in HVAC the fault current is very high and for interrupting this fault current large capacity circuit breakers have to be need and strong quenching media is required.

Comparison of fault current analysis in Case-2 HVAC at 878 km.

The comparison of fault currents in all three states has been made on Bus-2 and Bus-17. The fault current in transient state is very high on Bus-2 and Bus-17 while in steady state the fault on Bus-2 and Bus-17 is quite less than transient state. So these are the current values in HVAC transmission line.

Table 3: (Fault current analysis in HVAC in three transient states)

Fault states	Case 2 HVAC 1010 MW At 878 km
Fault current in Sub-Transient state	Bus2: 25.109 KA Bus17: 17.329 KA
Fault current in Transient state	Bus2: 25.109 KA Bus17: 17.3 KA
Fault current in Steady state	Bus2: 22.884 KA Bus17:15.56.498 KA

Losses in HVAC transmission line in case-2 The load flow analysis shows the following results of losses in HVAC transmission line in following table. Table 4 clearly show that power loss in HVAC system is very high making it in-efficient for very long distance.

Table 4: (Power Losses in Case-2)

Transmission Length	Case 2 HVAC 1010 MW Power flow losses
878 km	43.2 MW

VI. FAULT CURRENT ANALYSIS AT 500 KM:

Case 3: Analysis of fault current at 500 Km HVDC:

In this case study fault current analysis is made on 500 Km high voltage dc transmission line with the power flow same as in previous case from Bus-2 to Bus-17. In this simulation the fault current analysis will be analyzed on the basis of distance. In this case same three types of faults will be analyzed at 500 km.

Fault Current in Sub-Transient state (1/2 cycle): The fault current analysis has made on case-3 at sub-transient state at bus-2 and bus-17 the busses which are connected with high voltage DC transmission line. The results shows that there is 20.924 kA at Bus-2 and 12 kA at Bus-17 in sub- transient state.

Fault Current in Transient (1.5- 4 cycle):

The fault current analysis has made on case-3 at transient state at bus-2 and bus-17 the busses which are connected with high voltage DC transmission. In transient state the fault current is less than sub-transient state which is 10.1 kA at Bus-17.

Fault Current in Steady State envelop (30 Cycle): The fault current analysis has made on case-3 at steady state at bus-2 and bus-17 the busses which are connected with high voltage DC transmission line. In steady state it's depicted that in all cases the peak fault current has reduced to some extent than other states.

Comparison of fault current analysis in Case-3 HVDC at 500 km.

The comparison of fault currents in all three states has been made on Bus-2 and Bus-17. The fault current in transient state is very high on Bus-2 and Bus-17 while in steady state the fault on Bus-2 and Bus-17 is quite less than transient state. So these are the current values in HVDC transmission line.

Table 5: (Fault current analysis in HVDC in three transient states)

Fault states	Case 3 HVDC 1010 MW At 500 km
Fault current in Sub-Transient state	Bus2: 20.924 KA Bus17: 12 KA
Fault current in Transient state	Bus2: 20.924 KA Bus17: 10.1 KA
Fault current in Steady state	Bus2: 18.988 KA Bus17: 8.498 KA

Losses in HVDC transmission line in case-3:

The load flow analysis shows the following results of losses in HVDC transmission line at 500 km in following table.

Transmission Length	Case 3 HVDC 1010 MW Power flow losses
500km	7.14 MW

Case 4: Analysis of fault current at 500 Km HVAC

In this case study fault current analysis is made on 500 Km high voltage ac transmission line with the power flow same as in previous case from Bus-2 to Bus-17. In this simulation the fault current analysis will be analyzed on the basis of distance. In this case same three types of fault states will be analyzed at 500 km.

Fault Current in Sub-Transient state (1/2 cycle): The fault current analysis has made on case-4 at sub-transient state at bus-2 and bus-17 the busses which are connected with high voltage AC transmission line. The results shows that there is 25.698 kA at Bus-2 and 18.555 kA at Bus-17 in sub- transient state .

Fault Current in Transient (1.5- 4 cycle):

The fault current analysis has made on case-4 at transient state at bus-2 and bus-17 the busses which are connected with high voltage AC transmission. In transient state the fault current is 18.55 kA at Bus-17.

Fault Current in Steady State envelop (30 Cycle): The fault current analysis at steady state on bus-2 and bus-17 has performed. These are the busses which are connected with high voltage AC transmission line. In steady state it's depicted that in all above cases the peak fault current has reduced to some extent than other states.

Comparison of fault current analysis in Case-4 HVAC at 500 km.

The comparison of fault currents in all three states has been made on Bus-2 and Bus-17. The fault current in sub-transient state is very high on Bus-2 and Bus-17 while in steady state the fault on Bus-2 and Bus-17 is quite less than sub-transient state. So these are the current values in HVAC transmission line.

Table 7: (Fault current analysis in HVAC in three transient states)

Fault states	Case 4 HVAC 1010 MW At 500 km
Fault current in Sub-Transient state	Bus2: 25.698 KA Bus17: 18.555 KA
Fault current in Transient state	Bus2: 25.698 KA Bus17: 18.555 KA
Fault current in Steady state	Bus2: 23.371 KA Bus17: 16.541 KA

Losses in HVAC transmission line in case-4: The load flow analysis shows the following results of losses in HVDC transmission line at 500 km in following table. Table 8 shows that even at 500 km HVDC system is more efficient than HVAC system.

Table 8: (Power Losses in Case-4)

Transmission Length	Case 4 HVAC 1010 MW Power flow losses
500 km	24.7 MW

VII. CONCLUSION:

This paper shows a fault current analysis and comparison between HVAC and HVDC at 660kV transmission system. For better analysis and comparison, both simulation environments are kept same and distance is changed to 878km and 500km.

Fault current in HVAC transmission system is much higher than HVDC system. Also the effects of fault current in HVAC transmission system are highly destructive. But in HVDC, these effects are comparatively small and less harmful for longer transmission system.

POWER FLOW LOSSES COMPARISON FOR HVAC AND HVDC AT 878 KM & 500KM

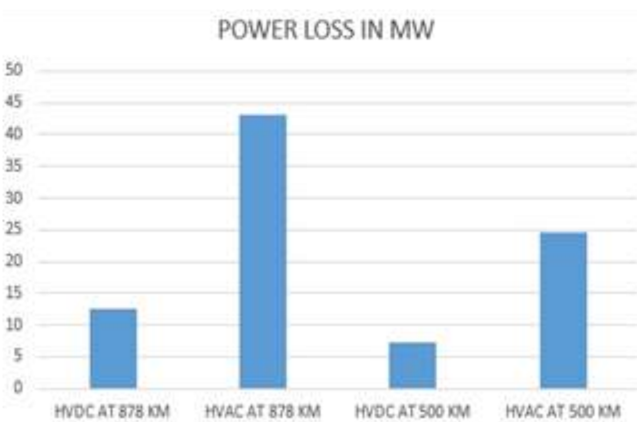

Figure 4: Power flow loss comparison

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