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# HIGH VOLTAGE DIRECT CURRENT (HVDC) IN APPLICATIONS FOR DISTRIBUTED INDEPENDENT POWER PROVIDERS (IPP)

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**KEYWORDS:** HVDC Recently Research and Project, HVDC Transmission Configuration.

## ABSTRACT

Last some decades the increase the demand of electricity, now it is used mostly bulk power transmission system over long distances and it is interconnected to grid system. The generation of HVDC, the growth of power demand for consumption and utility. Now a day HVDC systemic good solution over HVAC system. My scope of this research on focused on use and development of HVDC and study the ac to dc and dc to ac converter this thesis the compression between HVDC and HVAC overhead transmission system and to study of network of HVDC system.

In this research HVDC system, mainly VSC-HVDC is used as interface to interconnected independent power provider system to grid system. There are some advantage due to fault accurse, it is independent of active power and reactive power. VSC-HVDC have advantages to protect integration of IPPs, interconnected to grid for stabilization. MATLAB/Simulink simulations for different grid connection for VSC-HVDC system. Due to IPPs technology model performs are studies due disturbance analysis of dynamic response with help of. MATLAB/Simulink simulations. So that the Simulation is satisfied condition and power quality improvement. And due to fault occur in VSC-HVDC system to prevent the propagation from grid to integrated IPPs units.

## INTRODUCTION

In1882first time Thomas Edison transfer hvdc power in transmission and distribution of electrical power in New York. After 1954 the establishment of 20 MW HVDC link between Swedish mainlands - Gotland Island. When invention of induction motor which is main part of industries and transformer's widely use of voltage level to high level to low level as required for our uses. AC system are used for commercial purpose but some limitation like power transmission capacity and inefficiency for long transmission. However increase the demand of electric power so that increase the voltage drop of transmission line, this is create problem in transmission line. This problem minimize busing power electronics component, this combined system known as HVDC system. In this system all problem is minimize for transmission system. There are some advantages of HVDC system over HVAC

| AC Cables | DC Cables |
|---|---|
| 1. Ohmic loss in conductor<br>2. Corona Loss In Surface Of Conductor.<br>3.Sheath Loss Of Cables<br>4.More conductor are required | 1.Ohmic Loss In Conductor<br>2.No Corona Loss<br>3.Not Sheath Loss Of Cables<br>4. Less Conductor Are Required |

1) Lower ohmic loss in HVDC line than HVAC line.
2) HVDC lines are more economical they are less required of conductor than HVAC line.
3) HVDC system easily control power and over voltage than HVAC system.
4) Easily transmitted power interlinks subsea over long distance.
5) At fault occur in one side of ac system, it is easily isolated from the system.
6) HVDC link system is not radio interface.

7) HVDC system is use in underground cables over long distance with high power.

There is some disadvantage in HVDC link system, so improved the techniques and component of HVDC system we can be summarized given below.

1) High cost and complicated circuit in converter station system.
2) Limited operation can be operated in HVDC system.
3) Capacitor bank and harmonics filter both AC and DC side converter station, in AC node received reactive power and it is convert itself 50 % to active power and transmitted it.

In HVDC system used in power electronics component. These components convert AC to DC power and DC to AC power. So that HVDC system is invention new high rated converter power station.
Now a day HVDC converter stations coziest of various type of semiconductor like IGBT, GTO and IGCT this is known as HVDC VSC "Voltage Source Control. This converter is more efficient to another classical HVDC converter.

**HVDC Recently Research and Project:**
The HVDC system important role of the grid system, to transfer electrical power one end to other end easily without loss of power. There is a HVDC system have different application, this application are given below.

1) HVDC system is use for large bulk power transfer to remote area.
2) High power transmitted reduce loss.
3) By using HVDC system to improve AC grid system and control easily.
4) HVDC system is interconnected regional and national.
5) HVDC current transmission many advantage like power system connected same frequency but different phase shift and eliminated corona loss.
6) HVDC system have uses less conductor's requirement to transfer the power than HVAC system.

Now a day the HVDC system is use planning and big scale of all over world. Tables 2,3 show lists of some operating HVDC systems with different technology.

| System | Year Commissioned | System's Capacity [MW] |
|---|---|---|
| Gotland | 1970 | 20 |
| Skagerrak | 1976 | 500 |
| Cahora Bassa | 1977 | 1930 |
| Inga-Kolwezi | 1982 | 560 |
| CU Project | 1979 | 1000 |
| Nelson River 2 | 1985 | 2000 |
| Itaipu | 1984-90 | 3150 |
| Pacific Intertie | 1970 | 1440 |
| Intermountain | 1986 | 1920 |
| Fenno-Skan | 1989 | 500 |
| Rihand-Delhi | 1990 | 1668 |
| Quebec-New England | 1992 | 2000 |

hangji-Guguan HVDC link in China, which will start operating in 2018, is expected to be break every
World record in HVDC systems in terms of system's ratings. It is the world's first 1100 kV UHVDC power link with a length of over 3000 km, and 5.5 kA in the conductors.
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HVDC link in Changji Guguan China which will be starting operation in 2018 world record in KVA rating of HVDC system, It is first rank of 1100 UHVDC link of power system with 3000 km and 5.5 Ka in the conductor.

| | | |
|---|---|---|
| Kriegers Flak Combined grid solution(KFCGS) HVDC | 2019 | 410 |
| FA2 HVDC Transmission Link | 2020 | 1000 |
| Nordlink | 2020 | 1400 |
| NSL | 2021 | 1400 |

## HIGH VOLTAGE DIRECT CURRENT SYSTEMS

HVDC system has two terminal and DC link between two terminals. Each terminal has converter stations of both ends. The main component of HVDC system has one end rectifier and other end inverter.

1) Converters: it has one and more than one thyristors bridges and each bridge has consists six thyristor valve which depends upon the size of HVDC system of each thyristor value.
2) Converter transformer: this is special type of transformer that designed to use of high harmonics current and high voltage rating. This transformer easily tape changer to optimization of HVDC operation. It is connected in the HVDC system in star-delta connection. The delta connection is provided to dc side to eliminate the zero sequence current $I_0$ .
3) Smoothing Reactor: This is use to protect the converter from overvoltage. It avoid the step impulsive wave due to fault accrue in dc system and failure communication system, it provide dynamic stability. it is provided smooth ripple of dc current.
4) Reactive Power Compensation**:** reactive power required at different dc power level. Line commutation converter require capacitive reactive power only ac power which is 50% converter rating.
5) Filter: the use of passive shunt filter in HVDC system for safety of $3^{rd}$ and $5^{th}$ harmonics. Most of filter are design they allow reactive power in MVAr rating in system.
6) DC capacitor: In present ac harmonics DC supply have harmonics due to PMW technology VSC system. So that DC capacitor gets free from ripple factor.
7) Communication and Control: To maintain the stability of HVDC system, the terminal will have control system as well as established communication link between terminals.
8) AC Circuit Breakers: AC circuit breaker are used to interrupt supply in HVDC system and stop feeding from ac side. VSC converter cannot interrupt fault current.

 

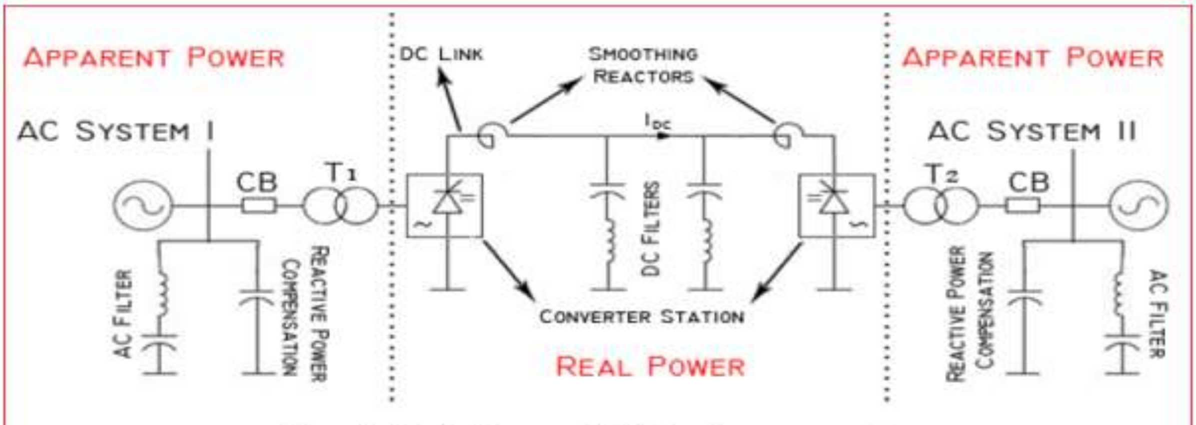


Figure 1: Block diagram of HVDC main components.

## HVDC TRANSMISSION CONFIGURATION

HVDC system is classified in two parts

i. Two terminal transmission system
ii. Multi terminal transmission system Different type of application and different configuration sche.

In both parallel and series connections, the regulation and distribution of active power depend on the direct voltage variation which can be maintained by controlling the firing angle or the transformer tap-changer [7].

## CHAPTER 3: HVDC CONVERTER STATİON

- Line Commutated Converter Most of HVDC systems are used current source converter CSC in past time. Now we are used mercury arc valve based on thyristor technology which known as thyristor valve. It consists of four layers of semiconductors which work on bi-stable switching. In HVDC system we are used high rating thyristor because line commutated converter technology work well performance in robust voltage in all other conditions.

The converter absorbed reactive power (50to 60% the transmitted active power) from surrounding system which produce low level harmonics. so that with the help of passive filter and reactive compensation unit we received stable signal. When we connected weak AC system the converter commutation system will fail. so we connected commuting capacitor to converter operator.

- Voltage Source Converter

HVDC VSC is self-commutating switching. This is like IGBT (insulated gate bipolar transistor) or GTO (gate turn off thyrisitor).the mai work of VSC minimizes converter loss and increase voltage level, power level. This self-commutation device is work on turn-on turn- off any time which is independent of ac system. This difference in construction offers many advantages over HVDC LCC., these advantages can be summarized as follows [6] [8] [9]:

1) The use of self-commutating system, VSC system will remove from failure commutation.
2) VSC system does not required reactive compensator. It is fully control active and reactive power. It is provided stability in all over the system.
3) it is minimize the higher frequency and it required filter size and loss ,cost are minimum.
4) VSC support to transmitted weak ac system.
5) In the fault occurs in power system it quick response and isolate faulty section.

- Converter Station Losses

HVDC system has two basic losses one is Converter station loss and another is DC cable losses. The converter station losses in HVDC transmission system most about 80% of all over losses. The converter station losses is depend upon size of system and voltage level. HVDC Line Commutated Converter losses varying between 0.5 to 1.0 % of rated over the system.

The main converter losses for both LCC and VSC are classified given below.

1) Switching losses
2) Semiconductor conduction losses
3) Converter valve
4) DC capacitor/reactor Losses.
5) Turn-on and off losses.
6) AC harmonic filters.

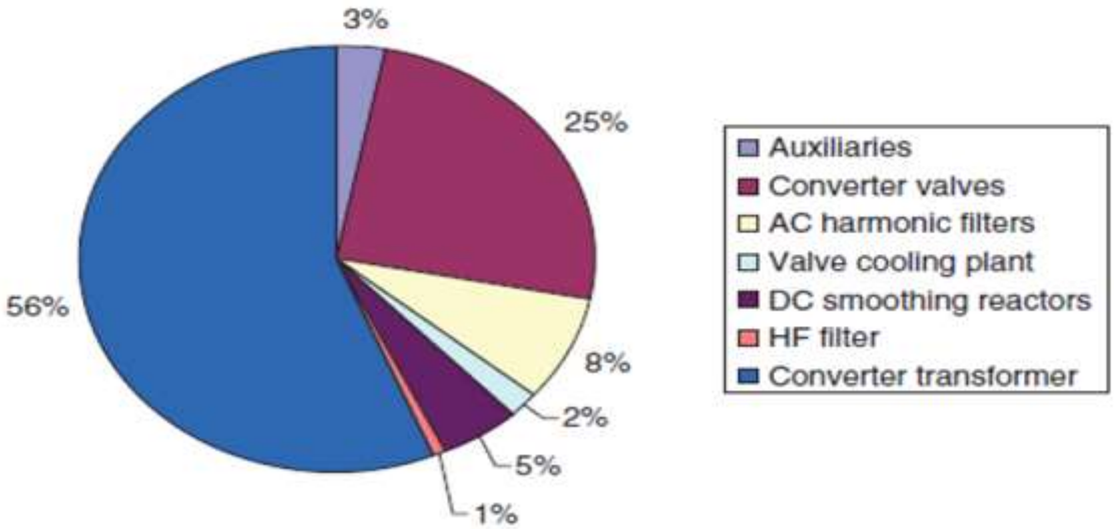


***Figure: 2 break down LCC converter Station loss***

## SYSTEM DESIGN

• AC system-

Power system can be represent two type one is dynamic model (changing model) and another is static model (steady state model). This study is easily for electrical system and distribution network on study state model which is good performance to understand variable load conditions.

The main campus Delhi University consisted 6 load via Rihand-Delhi HVDC system, each is connected bia 11kv-0.4kv step-down transformer. All transformer is fed from 33kv-11kv substation by via 11kV XLPE standard copper conductors. On 24 June 1990.it connecting the 3000MW coal based Rihand thermal power station in UP. The project has an 814 km long bipolar overhead line. The total distribution of data show the table given below.

| Transformer | | |
|---|---|---|
| Voltage Level | Quantity | Rating |
| 11-0.4 kV Step Down Transformer | 6 | 1500MVA |

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| | | |
|---|---|---|
| 33-11 kV Step Down Transformer | 1 | 10MVA |
| Cables | | |
| Cable type | Length | |
| 11 kV XLPE Standard Aluminum Conductor | 3 Km | |
| 0.4 kV XLPE/AWA/PVC Standard Copper Conductor | 20 Km | |
| Busses | | |
| Voltage Level | Quantity | |
| 33 kV Bus | 1 | |
| 11 kV Bus | 12 | |
| 0.4 kV Bus | 6 | |

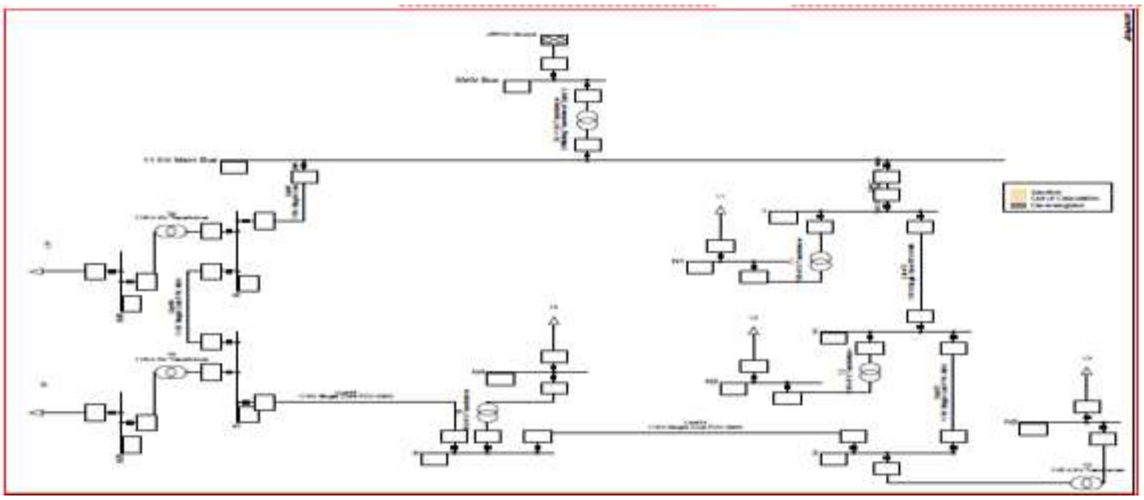

***Figure: 3 Conversion from AC to DC lines***

AC line has many problems to transmitted ac power from one place to another place. But in HVDC system more reliable for transfer bulk electrical power and HVDC system increase stability or overall capacity of the system. In HVAC system control the frequency and phase angle is very complicated

- DC System

In the given figure main 6 pulse AC-DC converter are used in campus so that all 6 loads are connected equal distance to each load. to required ac supply to meet 6 inverter are connecting each load.Furthermore, AC harmonics filters, Reactive power compensators were added to maintain the system stable performance and meet the grid standards for the THD .

Detailed description of the design of the main DC system components is discussed below.

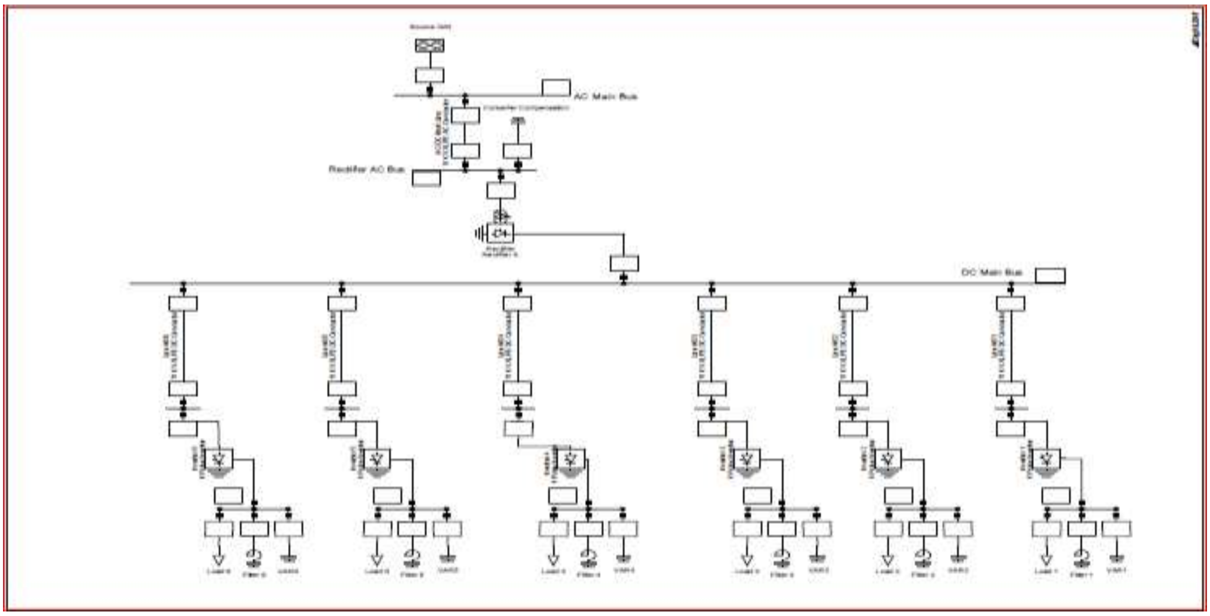


***Figure:4 Six Pulse Line Commutating Converter***

In the campus fed from 33/11kv transformer in figure by the optimization by converter station received 11kv ac. In ac system has higher power losses and the connection point was through the 0.4 kV AC voltage level
We received dc power is given formula-the main components of a six pulse line commutating converter (LCC), Where:

$$V_{DC}=s * q/\pi \sin\left(\frac{\pi}{q}\right) * \sqrt{\frac{2}{3}} *\sin(\alpha)*V_{AC}=1.35*\cos(\alpha)*V_{AC}$$

$V_{DC}$ : The DC output voltage of the converter.
$V_{AC}$ : The line to line AC input voltage of the converter.
α : The firing (ignition) angle; Alpha.
s=2, q=3.

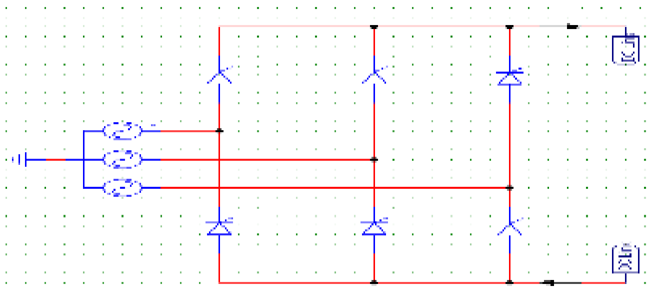

***Figure:5 6- pulse LCC circuited. DC Cables***

Same cable are use like ac cables main difference in dc content 70% of ac rated rms value.

### III. HP and LP Filters

When in HVDC system convert ac to dc supply some distortion harmonics is produce in supply system which is produce losses and power factor is low. So that with help of passive filter removes this problem. in the passive filter have both type of filter HP and LP filter. We use these filter series and combination of shunt filter. In the DU campus distortion is 6.5% TDH. The design of HP and LP passive filters was done on PSIM V9.0

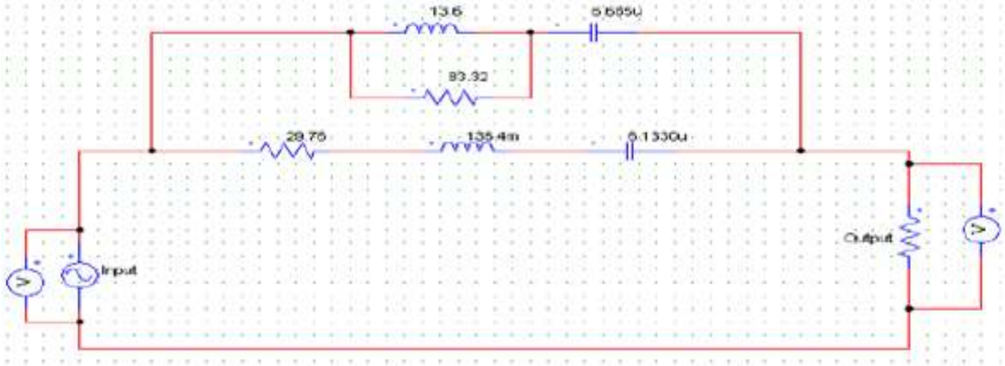


*Figure: 6 High pass and RLC damped filter design*

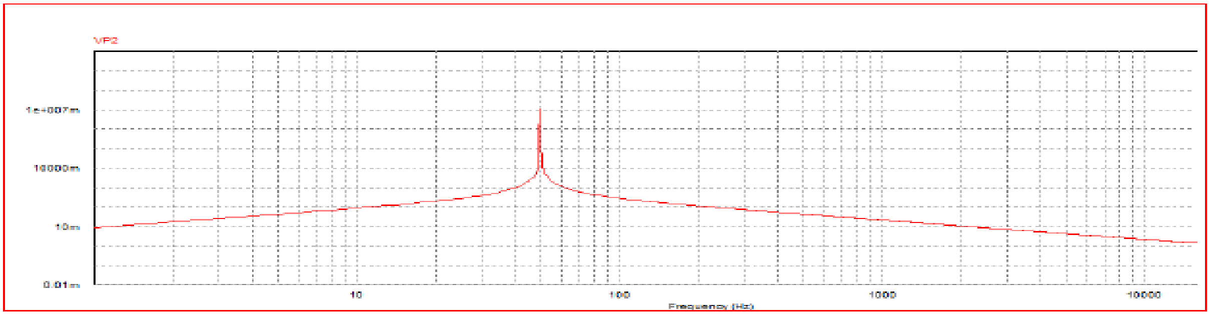


*Figure 7: Frequency response of the designed filters*

| Converter Station | | |
|---|---|---|
| ***Voltage Level*** | ***Quantity*** | ***Rating*** |
| ***33 kv*** | ***1*** | ***10MVA*** |
| ***11kv*** | ***6*** | ***1500KVA*** |
| ***Cables*** | | |
| ***Cable type*** | ***Length*** | |
| ***11 kV XLPE Standard Aluminum Conductor*** | ***1.2Km*** | |
| ***0.4kVXLPE/AWA/PVC Standard Copper Conductor*** | ***20Km*** | |
| ***Busses*** | | |
| ***Voltage Level*** | ***Quantity*** | |
| ***33 AC kV Bus*** | ***1*** | |
| ***14 DC kv Bus*** | ***1*** | |
| ***0.4 DC kv Bus*** | ***6*** | |
| ***Reactive Power Compensation*** | | |
| ***Rating*** | ***Quantity*** | |
| ***0.1 MAar Capacitor Bank*** | ***6*** | |

| Filters | |
|---|---|
| ***Type*** | ***Quantity*** |
| ***HP Damped Filte*** | ***7*** |
| ***RLC Filter*** | ***7*** |

***Table 6 shows the equivalent DC system electrical components***

## SIMULATION AND RESULTS

**AC System:**

My electrical model have 7 transformer, 19 busses, 1 external grid to meet 6 loads. Dig SILENT Power Factory provides a summary report of the studied network, which is shown in figure 20. This summary was exported from the simulation software under rated loading conditions.

We can understand at different loading conditions in AC system. The loads were study different loading percentage over rated 1500 MVA. We take two cases were study of different conditions. Some detail in different cases given below table.

| | | | | | |
|---|---|---|---|---|---|
| **Case 1: 50% Loaded** | | | **Case 5: 90% Loaded** | | |
| **S** | 4.60 | MVA | **S** | 8.45 | MVA |
| **P** | 4.15 | MW | **P** | 7.60 | MW |
| **Q** | 1.98 | Mvar | **Q** | 3.70 | Mvar |
| **Case 2: 60% Loaded** | | | **Case 6: 100% Loaded** | | |
| **S** | 5.47 | MVA | **S** | 9.38 | MVA |
| **P** | 4.90 | MW | **P** | 8.50 | MW |
| **Q** | 2.45 | Mvar | **Q** | 3.99 | Mvar |
| **Case 3: 70% Loaded** | | | **Case 7: 20% Upgrading** | | |
| **S** | 6.47 | MVA | **S** | 10.94 | MVA |
| **P** | 5.84 | MW | **P** | 9.84 | MW |
| **Q** | 2.80 | Mvar | **Q** | 4.79 | Mvar |
| **Case 4: 80% Loaded** | | | **Case 8: 50% Upgrading** | | |
| **S** | 7.46 | MVA | **S** | 14.10 | MVA |
| **P** | 6.70 | MW | **P** | 12.78 | MW |
| **Q** | 3.30 | Mvar | **Q** | 5.98 | Mvar |
| **load conditions to HVDC.pfd & DU System.pfd** | | | | | |
| **PF** | | | **0.85** | | |
| **PF Angle** | | | **27.126** | | |

We study both ac and dc network at different cases evaluated losses and performance all over efficiency of both system. in case 8 and case 9 upgraded all over system and to be implement in future in new load adding. Figure.
.

The AC and DC systems' losses are shown in figure 23,24 respectively. Moreover, both of the systems' losses are plotted in figure 25.

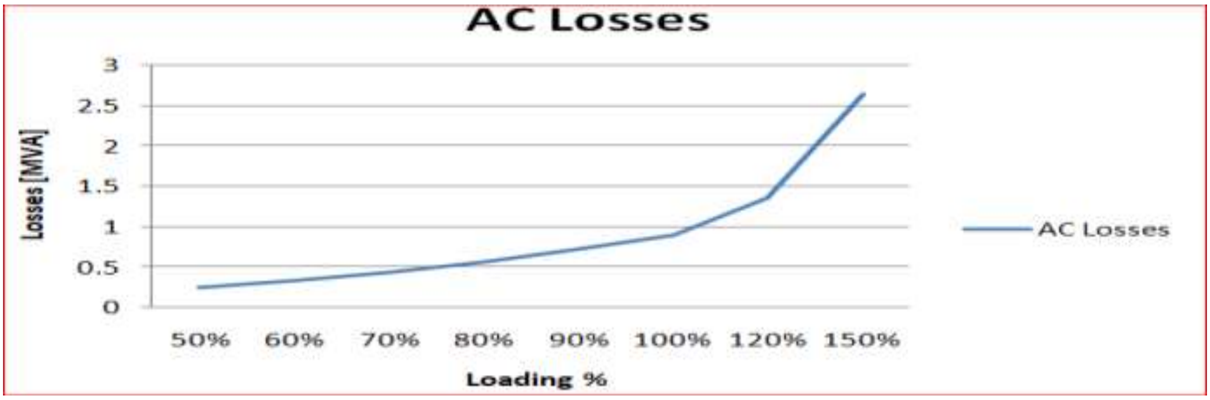


*Figure 8: AC System Losses under different loading conditions*

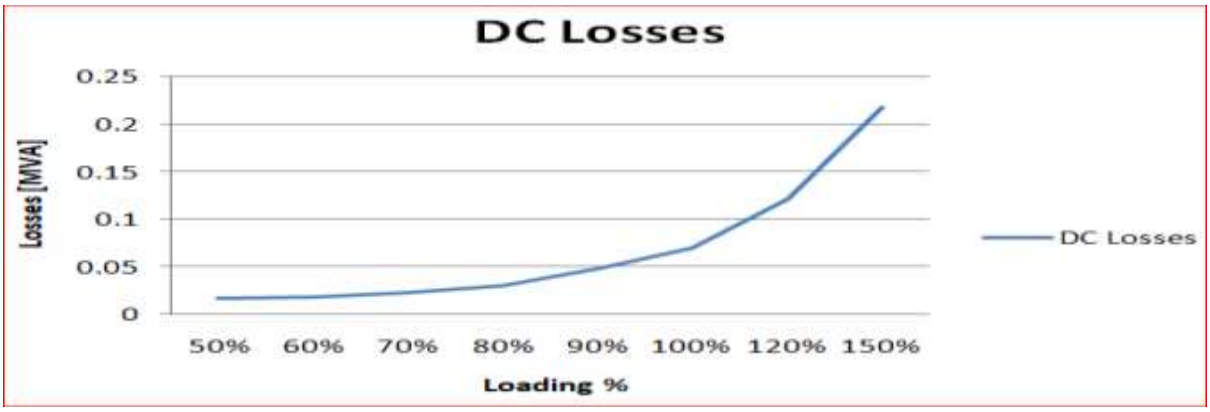


*Figure 9: DC System Losses under different loading conditions*

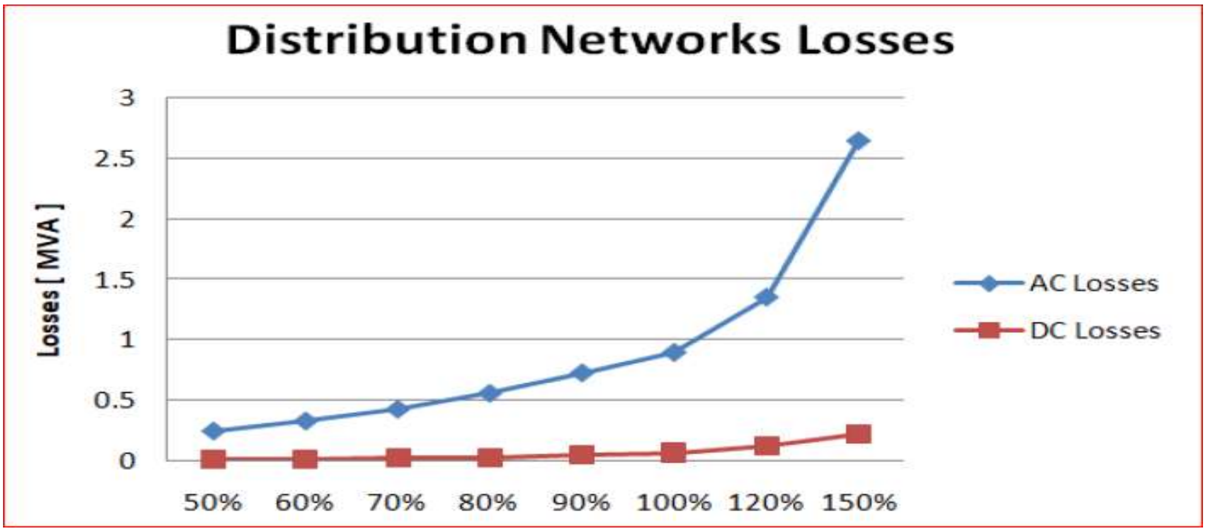


*Figure 10 : AC & DC Systems Losses under different loading conditions.*

***Table 8 shows the detailed systems' losses in different loading conditions***

| ***Case 1*** | | | | | ***Case 5*** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DC Network Losses | | | AC Network Losses | | DC Network Losses | | | AC Network Losses | |
| **P Diff** | 0.00925 | MW | 0.172 | MW | P Diff | 0.0320 | MW | 0.299 | MW |
| **Q Diff** | 0.01500 | Mvar | 0.190 | Mvar | Q Diff | 0.03700 | Mvar | 0.69 | Mvar |
| **S Diff** | 0.01762 | MVA | 0.2562 | MVA | S Diff | 0.04891 | MVA | 0.751 | MVA |
| **Case 2** | | | | | **Case 6** | | | | |
| **P Diff** | 0.0145 | MW | 0.198 | MW | P Diff | 0.03950 | MW | 0.360 | MW |
| **Q Diff** | 0.0132 | Mvar | 0.275 | Mvar | Q Diff | 0.05810 | Mvar | 0.830 | Mvar |
| **S Diff** | 0.01960 | MVA | 0.338 | MVA | S Diff | 0.07025 | MVA | 0.904 | MVA |
| **Case 3** | | | | | **Case 7** | | | | |
| **P Diff** | 0.01930 | MW | 0.230 | MW | P Diff | 0.05698 | MW | 0.475 | MW |
| **Q Diff** | 0.0150 | Mvar | 0.370 | Mvar | Q Diff | 0.10730 | Mvar | 1.30 | Mvar |
| **S Diff** | 0.02424 | MVA | 0.435 | MVA | S Diff | 0.12149 | MVA | 1.384 | MVA |
| **Case 4** | | | | | **Case 8** | | | | |
| **P Diff** | 0.02520 | MW | 0.265 | MW | P Diff | 0.08950 | MW | 0.725 | MW |
| **Q Diff** | 0.01810 | Mvar | 0.500 | Mvar | Q Diff | 0.19851 | Mvar | 2.550 | Mvar |
| **S Diff** | 0.03103 | MVA | 0.5658 | MVA | S Diff | 0.21774 | MVA | 2.651 | MVA |

## CHAPTER 8: CONCLUSION, RECOMMENDATIONS AND FUTURE WORK

In this analysis we study of both type AC and DC system show significante difference losses. We can see differences in table 8 the knee point where more difference about 70% nominal loading value, hance current become increasing,so that cables loss can be computed by following equations.

$$S=I^2*Z$$

Where:
S : The complex power losses in MVA.
I : The current flowing in the conductor.
Z : The impedance of the conductor.

Conductors impedance contains real (resistive) and imaginary (reactance) components, these impedance values are used to calculate voltage drop, power flow, and line losses. Typically, the reactance part of the impedance dominates the impedance of the conductor [32]. So in the case of DC network, the imaginary components (inductive part) will not be considered as a part of the conductor as the inductors will act as a short circuit for DC current. Moreover, this will eliminate the reactive power losses (Q) and thus reducing the system's overall losses.

The losses in the DC system were nearly 5.5% of the losses at the AC system at the same power transfer, this is a result of three key parameters which are:

1) The DC losses are only real power losses (active) and the conductors have a relatively low resistance values compared to the reactance values.
2) The current in each DC line (94 A) were about 75% of those at AC lines (126 A) at the same power level.
3) The existence of high reactive power losses in the AC line, where it's zero Mvar in the DC lines. As the university is still developing, increasing the load in the future will lead to a saving percentage of around 10.23%

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