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Calculation of Electromagnetic Fields Underneath A Proposed HVDC Transmission Line Interconnected Egypt and KSA

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OUTLINES

- Objectives
- Historical Background
- Advantages of HVDC Transmission.
- Construction and Types of HVDC Lines
- The Proposed Line tying Egypt and KSA.
- Research Methodology
- Simulation results and discussions
- Conclusions

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Objectives

- The main objective of this presentation is to introduce calculating values for electromagnetic fields underneath a proposed HVDC transmission line tying Egypt and KSA.
- The Right Of Way (ROW) of the proposed line is to be calculated.
- Two numerical methods are used for calculating both electric and magnetic fields. The Charge Simulation Method (CSM) is used for electric field calculation, while the Current Simulation Technique (CST) is used for magnetic field calculation.

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Historical Background

Electric power transmission was originally developed with direct current.

The world's first DC transmission is supplied directly to the DC load with a DC generator. 1882, French physicist Pule used DC generators installed in Miesbach mine, with 1.5 ~ 2.0kV voltages, along 57km of telegraph lines, supply the electric power to the international exhibition held in Munich, he completed the first ever DC transmission test.

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Historical Background (Cont.)

An early method of high voltage DC transmission was developed by the Swiss engineer Rene Thury.
This system used series-connected motor generator sets to increase voltage.
The line was operated in constant current mode, with up to 5 kV on each machine. An early example of this system was installed in 1889 in Italy by the Acquedotto de Ferrari-Galliera Company. This system transmitted 630 kW at 14 kV DC over a distance of 120 km .

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Historical Background (Cont.)

The first commercial HVDC line built in 1954 was a 98 km submarine cable with ground return between the island of Gotland and the Swedish mainland.
Thyristors were applied to DC transmission in the late 1960's and solid-state valves became a reality. In 1969, a contract for the Eel River DC link in Canada was awarded as the first application of solid state valves (diodes and thyristors) for HVDC transmission.

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Historical Background (Cont.)

Today, the highest functional DC voltage for DC transmission is ±1100 and 800 kV for the 2000 km transmission line in China . DC transmission is now an integral part of the delivery of electricity in many countries throughout the world.

Advanteges of HVDC Transmission

1. Cost less than AC transmission.

2. Submarine cables have no limitation in length.

3. Communicate two different AC systems with different frequencies

4. Greater power per conductor.

5. Simpler line construction.

6.Ground return can be used, hence each conductor can be operated as an independent circuit.

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Advanteges of HVDC Transmission (Cont.)

7. No charging current and no skin effect.
8.Cables can be worked at a higher voltage gradient.
9. Line power factor is always unity; line does not require reactive compensation.
10. Less corona loss and radio interference, especially in foul weather.
11. Less ROW comparing AC Transmission.
12. HVDC lines have no stability problems.

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Advanteges of HVDC Transmission (Cont.)

13. More reliable comparing than AC Lines.
14. With DC, Overhead Line Losses are typically 30-40 % less than with AC
15. HVDC can be integrated into the AC System
16. HVDC supports AC in Terms of Stability
17. For underground Cable Transmission (over 80 km), HVDC is the only Solution

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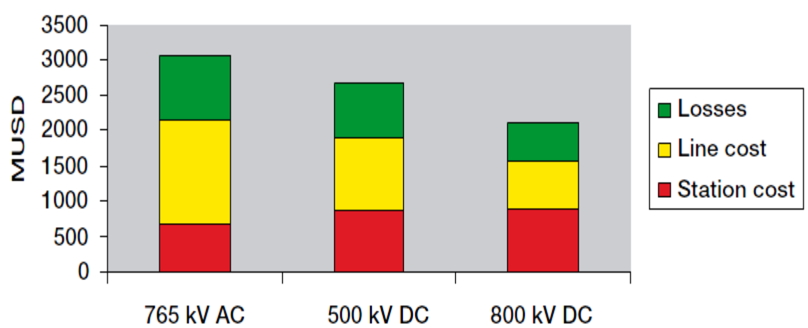
Advanteges of HVDC Transmission (Cont.)

Transmission of 6000 MW over 2000 km.
Total evaluated costs in MUSD



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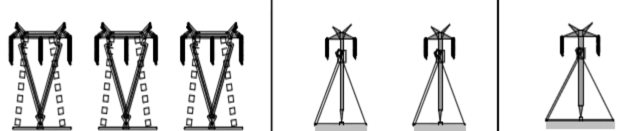
Advanteges of HVDC Transmission (Cont.)

	765 kV AC	500 kV DC	800 kV DC
Number of lines:			
Right of way (meter)	~ 240	~ 110	~ 90

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New HVDC Projects for (2013~2015)

Enormous investment in HVDC construction

No.	Commercial operation	Project name	Voltage (kV)	Capacity (MW)	Distance (km)	EPC/User	Remarks
1	2015	Northern Hami-Chongqing	±800	8000	2223	SGCC	Planned
2	2015	Ningdong-Zhejiang	±800	8000	1900	SGCC	Planned
3	2015	Ximeng-Jiangsu (Taizhou)	±800	8000	1690	SGCC	Planned
4	2015	Gansu(Jiuquan)-Hunan	±800	8000	2490	SGCC	Planned
5	2015	Mengxi-Hubei	±800	8000	1400	SGCC	Planned
6	2015	**Zhundong-Sichuan**	**±1100**	**10000**	**2600**	**SGCC**	Planned
7	2015	Humeng-Shandong	±800	8000	1600	SGCC	Planned
• 8	2014	Xiamen island in-feed	±320	1000	Approx. 10 Subsea cable	SGCC	Planned
• 9	2014	Zhoushan multi-terminal (5)	±200	1000	141 Subsea cable	SGCC	Ongoing
10	2014	Xiluodu-Zhejiang	±800	8000	1688	SGCC	Ongoing
11	2014	Southern Hami-Zhengzhou	±800	8000	2200	SGCC	Ongoing
• 12	2013	Nan'ao multi-terminal (3)	±160	200	9	CSG	Ongoing
13	2013	Nuozhadu-Guangdong	±800	5000	1451	CSG	Ongoing
14	2013	Xiluodu-Guangdong	±500	6400	1251	CSG	Ongoing
• 15	—	Dalian city in-feed	±320	1000	47.6 Subsea cable	SGCC	Postponed

! • represents the VSC-HVDC projects

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±800, ±1100 HVDCs During (2010 ~2015)

The largest UHVDC market in the world

No.	Commercial operation	Project name	Voltage (kV)	Capacity (MW)	Distance (km)	EPC/User	Remarks
1	2015	Northern Hami-Chongqing	±800	8000	2223	SGCC	Planned
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3	2015	Ximeng-Jiangsu (Taizhou)	±800	8000	1690	SGCC	Planned
4	2015	Gansu(Jiuquan)-Hunan	±800	8000	2490	SGCC	Planned
5	2015	Mengxi-Hubei	±800	8000	1400	SGCC	Planned
6	**2015**	**Zhundong-Sichuan**	**±1100**	**10000**	**2600**	**SGCC**	**Planned**
7	2015	Humeng-Shandong	±800	8000	1600	SGCC	Planned
8	2014	Xiluodu-Zhejiang	±800	8000	1688	SGCC	Ongoing
9	2013	Southern Hami-Zhengzhou	±800	8000	2200	SGCC	Ongoing
10	2013	Nuozhadu-Guangdong	±800	5000	1451	CSG	Ongoing
11	2012	Jinping-Sunan	±800	7200	2090	SGCC	Commissioned
12	2010	Xiangjiaba - Shanghai	±800	6400	1980	SGCC	Commissioned
13	2010	Yunnan - Guangdong	±800	5000	1418	CSG	Commissioned

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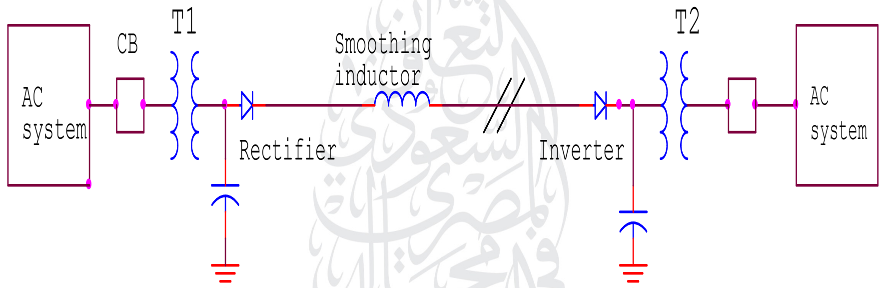
Construction of HVDC Line



Some writers claim that a two conductor dc line provides the same reliability as a two circuit three phase line having six line conductors, for either conductor of the dc line can be used with ground return continuously or for limited periods, say, a few days per year.

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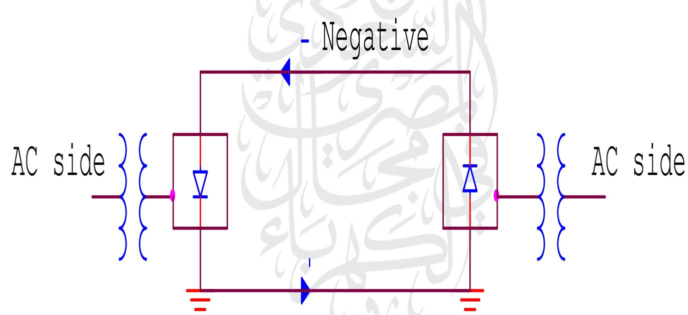
Types of DC Links

1- The monopolar line (link) has one conductor, usually of negative polarity, and ground or sea return



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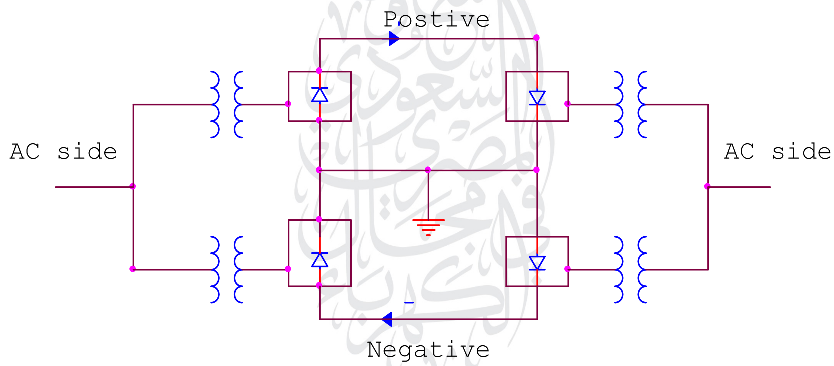
Types of DC Links (Cont.)

2- The bipolar line (link) shown has two conductors one positive, the other negative



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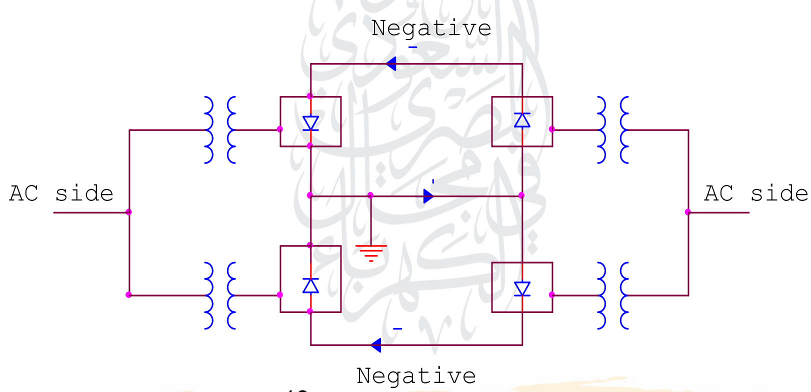
Types of DC Links (Cont.)

3- The homopolar line (link) shown in the following Figure. link has two or more conductors all having the same polarity, usually negative, and always operates with ground return



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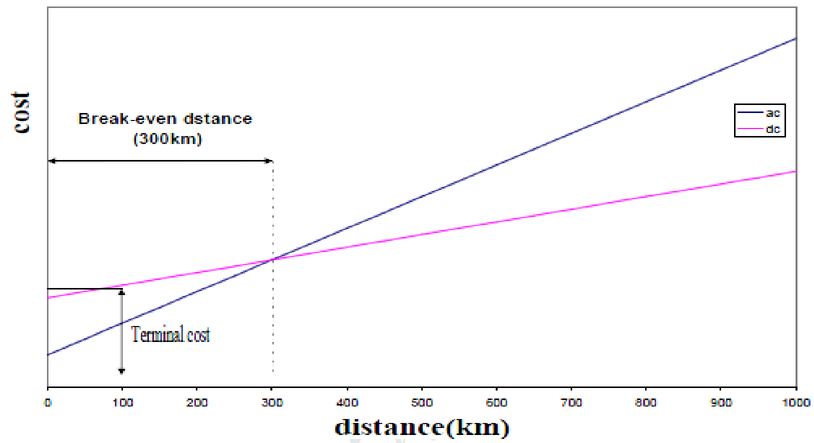
Economic Operation



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Environment Effects

1. For a given power transfer requiring extra high voltage transmission, the DC transmission line will have a smaller tower profile than the equivalent AC tower carrying the same level of power. This can also lead to less width of ROW for the DC transmission option.
2. The steady and direct magnetic field of a DC transmission line near or at the edge of the transmission right of way will be about the same value in magnitude as the earth's naturally occurring magnetic field. For this reason alone, it seems unlikely that this small contribution by HVDC transmission lines to the background geomagnetic field would be a basis for concern.

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Environment Effects (Cont.)

3. The static and steady electric field from DC transmission at the levels experienced beneath lines or at the edge of the ROW have no known adverse biological effects.
4. The ion and corona effects of DC transmission lines lead to a small contribution of ozone production to higher naturally occurring background concentrations. Exacting long term measurements are required to detect such concentrations

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Environment Effects (Cont.)

5. If ground return is used with monopolar operation, the resulting DC magnetic field can cause error in magnetic compass readings taken in the vicinity of the DC line or cable. This impact is minimized by providing a conductor or cable return path (known as metallic return) in close proximity to the main conductor or cable for magnetic field cancellation.

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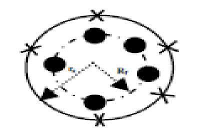
Calculation Methodology

1- Electric Field Calculation using Charge Simulation Method (CSM)

$$\sum_{j=1}^{N} P_{ij} Q_j = V$$



$$E_{x,j} = -\sum_{j=1}^{N} \frac{\partial P_{ij}}{\partial x} Q_j = -\sum_{j=1}^{N} F_{x,ij} Q_j$$

$$E_{y,j} = -\sum_{j=1}^{N} \frac{\partial P_{ij}}{\partial y} Q_j = -\sum_{j=1}^{N} F_{y,ij} Q_j$$

$$E_{z,j} = -\sum_{j=1}^{N} \frac{\partial P_{ij}}{\partial z} Q_j = -\sum_{j=1}^{N} F_{z,ij} Q_j$$

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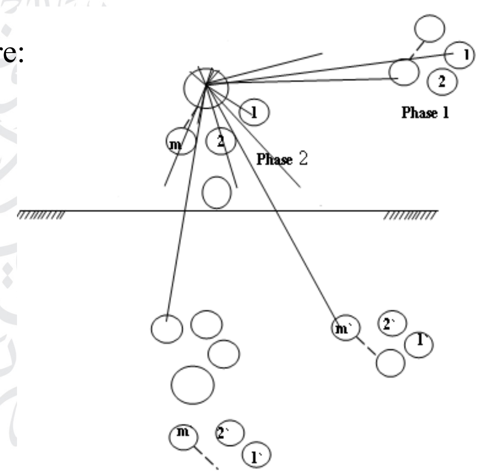
Boundary Potentials for High Voltage Transmission Lines

The boundary point potentials are:

+V on the positive pole,

-V on the negative pole,



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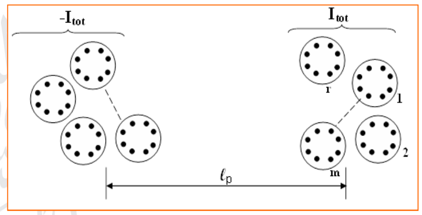
2- Magnetic Field Calculation using Current Simulation Technique (CST)

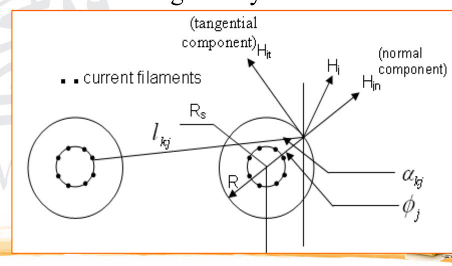
$$\sum_{k=1}^{2nm} p_{kj} i_k = 0, j=1,2,3,\ldots\ldots\ldots 2m(n-1)$$

$$\sum_{k=(q-1)n+1}^{nq} i_k = I_{cq}, q=1,2,3,\ldots\ldots\ldots 2m$$



where P_{kj} is the normal magnetic field coefficient determined by the coordinates of the j^{th} boundary point and the k^{th} filamentary line current and is given by:

$$P_{kj} = \frac{1}{2\pi l_{kj}} \sin\theta_{kj} \qquad \text{where} \quad \theta_{kj} = \alpha_{kj} - \phi_j$$



$$\bar{H} = \frac{1}{2\pi} \sum_{k=1}^{nm} i_k \left[\frac{-(y-y_k)\bar{a}_x + (x-x_k)\bar{a}_y}{(x-x_k)^2 + (y-y_k)^2} - \frac{(y-y_k)\bar{a}_x + (x+x_k)\bar{a}_y}{(x-x_k)^2 + (y-y_k)^2} \right]$$

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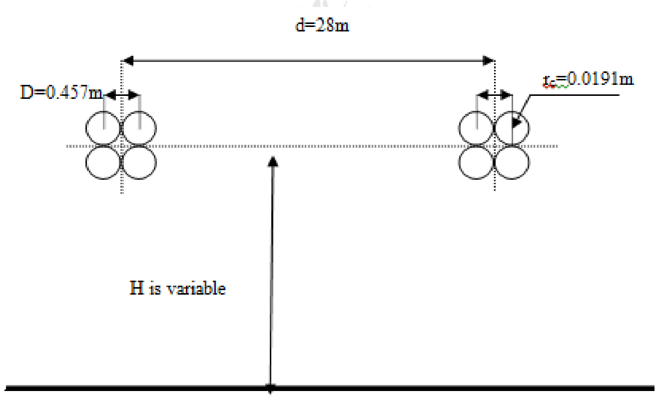
Results and Discussions



Typical construction of a ±500kV Transmission line

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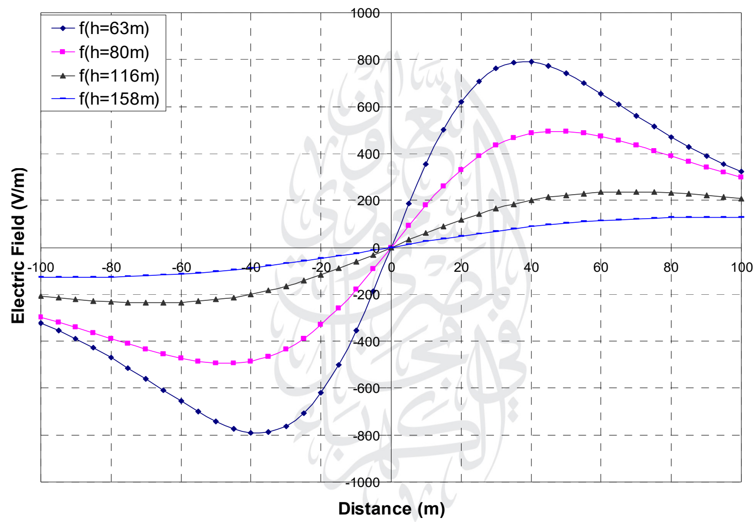

Typical Electric field values for ±500kV Transmission line at different heights

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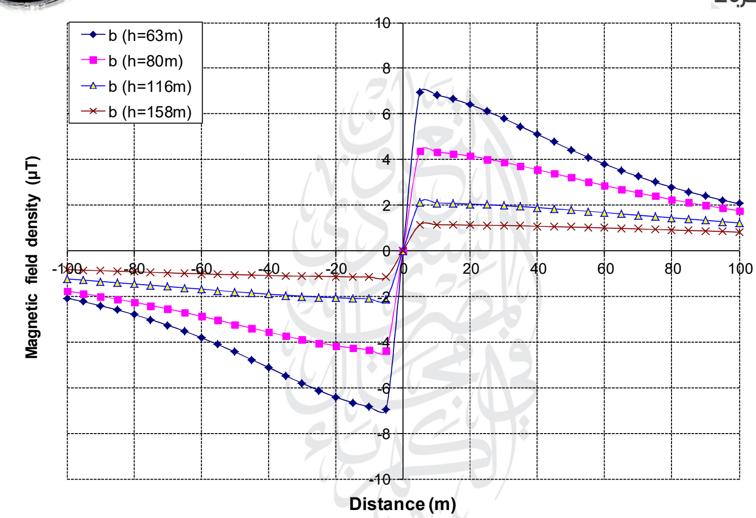

Typical Magnetic field values for ±500kV Transmission line at different heights

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Results and Discussions

In this presentation a charge simulation method (CSM) is used to calculate the electric field underneath HVDC transmission lines while the current simulation technique (CST) is used to calculate the magnetic field . Due to the harmful effect of the electric field, ion current and magnetic fields of these lines, these approaches were applied to ±500kV bipolar Extra High Voltage DC Transmission Line.
From the present analysis, one can conclude the followings:

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1- The ROW of the proposed transmission lines decreases with the increase of the line height..
2- The maximum electric field at the ground level (1m above ground surface) for proposed transmission line decreases with the increase of the height of the tower.
3- The maximum magnetic field at the ground level (1m above ground surface) for proposed transmission line decreases with the increase of the height of the tower.

تم بحمد الله

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السعودي المصري
في مجال الكهرباء

Reference

[1] http://www.energy.siemens.com/br/en/power-transmission/hvdc/hvdcclassic.htm (March 2016)

[2] http://www.energy.siemens.com/br/en/power-transmission/hvdc/hvdcclassic.htm (March 2016)

[3] https://en.wikipedia.org/wiki/Direct_current (March 2016)

[4] https://en.wikipedia.org/wiki/High-voltage_direct_current (March 2016)

[5] http://mentalfloss.com/article/30140/acdc-tesla%E2%80%93edison-feud (March 2016)

[6] http://www.safetytech.cn/1932.html (March 2016)

[7] http://www.safetytech.cn/1942.html (March 2016)

[8] http://new.abb.com/systems/hvdc/references/the-gotland-hvdc-link (April 2016)

[9] http://www.cepri.com/ (April 2016)

[10]http://xueshu.baidu.com/s?wd=paperuri%3A%286b70a4ef45a5daa1101d98882d4 16
108%29&filter=sc_long_sign&tn=SE_xueshusource_2kduw22v&sc_vurl=http%3A%2F%2Fwww.doc88.com%2Fp-94351327681.html&ie=utf-8 (April 2016)

[11] http://www.doc88.com/p-508834633373.html (April 2016)

[12]HVDC transmission technology [M]. Wang GuanJie.ChongQing University Press.

التـــعـــــــــاون
السعودي المصري
في مجال الكهـرباء

[13]http://datacenter.chinabyte.com/274/8877274.shtml (April 2016)
[14]Simulation of commutation failure in HVDC transmission system [J].Yang Xiu.Vo1.34 NO.2.Feb.2008 (April 2016)
[15]Research on traveling wave protection of HVDC transmission lines [D].Ai Lin. North China Electric Power University, 2002 (April 2016)
[16]AutoCAD2006 tutorial [M].Zhu Longzhu.Science Press, 2007 (April 2016) 41 [17]http://datacenter.chinabyte.com/274/8877274.shtml (April 2016)
[18]Study on operation and control of HVDC-VSC transmission system [M].Wang Zhaoan.Machinery Industry Press, 2000 (May 2016)
[19]Fundamentals of Electrical Engineering [M].Wen Buying. China Electric Power Press, 2006 (May 2016)
[20]http://wenku.baidu.com/link?url=ZAWzu0BKugJX4X1xFmIlP5gGsBGlc22aKOtEq_rb
5fmjkGXTQShGXmvmf0IEAZN7mN2w6vvBzWvZlKmd6wcCjETdvVp4L4Oj Wr3HAM65LG (May 2016)

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