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► To cite this version:

Thi Thu Nga Vu, Tùng Trần Anh, Thanh Son Tran, Séverine Le Roy, Gilbert Teyssedre, et al.. Prospects for HVDC links in electricity network of Vietnam. 10th International Conference on Insulated Power Cables, Jun 2019, Versailles, France. hal-02396354

HAL Id: hal-02396354

<https://hal.science/hal-02396354v1>

Submitted on 12 Nov 2020

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Prospects for HVDC links in the electricity network of Vietnam

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ABSTRACT

Opportunities and challenges for the power network of Vietnam are presented with as objective to identify cases where cable links could be applied. As a rapidly developing country and with the changes in the primary source of energy, the electrical grid of Vietnam will deeply evolve and strengthen in the next decades with a demand in energy estimated to twice as today in a twelve year time. The development of renewable energy sources, the upgrade of HVAC to HVDC lines, the introducing of MVDC links once mature and accessible technology could be the successive steps in the future evolutions.

KEYWORDS

Energy grid, HVDC, energy sources.

INTRODUCTION

HVDC technologies will certainly represent a growing part of energy transmission systems owing to the new sources of energy introduced, especially renewable energy, and to the need for strengthening energy networks with the decarbonation of the energy. To cite an example of such an evolution, in prospects proposed by Cigre working group C1.35 on global energy network, 99% of the lines would be HVDC, either submarine between continents or overhead on the land [1]. China is also developing extra high voltage corridors to transmit energy from the east of the country where most of the hydropower is concentrated to the consumption area of megapoles of the west of the country with some innovative challenges of hybrid LCC and VSC technologies in the same 'branched' network [2].

This massive introduction of DC links is a reality today for example in Europe with the France-Spain 320kV line made with extruded insulation cables, the construction of the Savoy-Piemont line, the building of offshore windfarms connected to the shore with DC link, and the decision to build HVDC corridors through Germany fully made with buried cables. All these examples are with HVDC cables. The switch from HVAC to HVDC systems has this great advantage that there is virtually no limit to transmission length, even for cable technology owing to the fact that the compensation of the capacitive current is no longer a necessity. Besides, for off-shore cables, at equivalent capacity, DC cables technology constitutes a great simplification in manufacture, reducing the cable from a 3-core for HVAC to a single core, and also reducing the weight and facilitating transport and laying of the cables [3].

Today, it seems that the main limitation to the development of cable links is the cost itself when compared to overhead solutions. So, in developing countries, overhead lines will certainly be preferred for a while but when technologies will be mature no doubt that cable technologies will spread.

However, still with DC cables, some issues remain. The progressive switch from oil-filled insulation to extruded insulation that has been operated over the last 40 years for HVAC cables is much more recent for HVDC. The behavior of extruded cables under DC stress, regarding space charge build-up and field redistribution, particularly at polarity reversal stages as used in converter technologies using IGBT, is not fully under control [4]. Materials improvement, characterization and modelling are still intensively researched, both for cables and accessories.

The paper is a summary report of a workshop [5] organized in Hanoi in September 2018 on green energy and networks. The objective was to present opportunities and challenges with HVDC cable links and to put it in relation to the current situation of the energy network in Vietnam and to the evolution forecasted for the energy generation and management in the country and at its borders. It was also a milestone of a joint project in which a relevant case study of energy transmission link that could be turned to HVDC. We report herein mainly on the current evolution of the Vietnamese electricity network.

FACTS AND FIGURES FOR THE ENERGY SOURCES AND DEMAND IN VIETNAM

Vietnam has a relatively late development of electricity systems compared to other countries in the world due to the historical impact of the wars. The power system only really developed when the 500 kV lines is put into use, along with the strong opening of the economy. This late development is illustrated in Fig. 1 with the evolution in terms of energy consumption over the last 17 years [6]. The peak power follows the same trend. The growth rate is of the order 10-15%/year over the whole period.

In 2018, the total electricity consumption of Vietnam was nearly 215 TWh, increased by 11% compared to 2017 with 198 TWh. Vietnam power system now is ranked a 2nd among ASEAN countries (after Indonesia) and 25th in the world. Demand for electricity is largely driven by factors such as GDP, pricing, wealth and population size. In a near future, Vietnam power system could face a lot of difficulties to secure the supply, especially with the reduction of fuel sources supply (domestic coal, natural gas...). According to the demand forecast, Figure 1, the growth rate should remain at 11 ~ 13% per year up to 2020, decreasing to 8 ~ 8.5% per year for the period of 2021 – 2030.

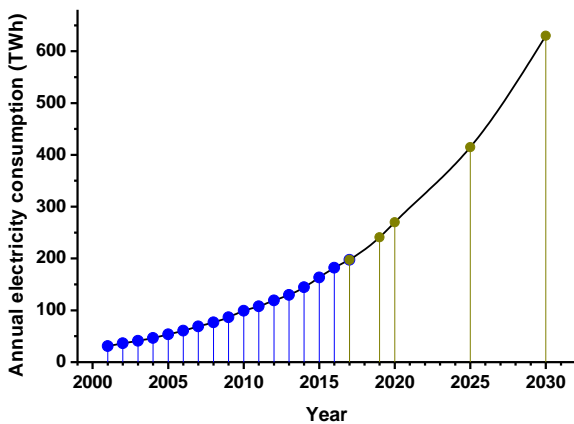


Fig. 1: Evolution of the annual power demand over the last 15 years and forecasted figures.

The fast increase in demand is due to the current trend of using a wide range of technological equipment, especially electrical appliances, and devices such as air conditioners and refrigerators in all households. In addition, there is a gradual shift from heat engine vehicles to electrical ones. Therefore, the peak load growth rate may continue to stay high, and even increase in the future. This increase in the demand poses challenges for adapting the electrical network as discussed in the next section.

The split in energy sources

By the end of 2016, the total electricity generation output is up to 180 TWh (Figure 2a) [6]. Hydropower and coal-fired thermal power have equivalent contributions at 36%. The production of electricity has increased by nearly 80% between 2011 and 2016. As reflected in the installed capacity, there has been significant increase in production from coal fired power plants.

Figure 2b considers the forecasted distribution of power sources according to the revised Power Master Plan VII (PDP7) for the period from 2016 to 2030 [7]. From 2020 to 2030, the total installed capacity for the country would be increased from 60 GW to 130 GW and the production from 265 TWh to 572 TWh. It can be seen that coal - fired thermal power is projected to be the main source for electricity production. The capacity of hydropower does not evolve substantially during the period. Other renewable energies are showing an upward trend. The specificities for these 3 different energy sources are detailed below.

Contribution from hydroelectricity

With sloping areas of relief and many rivers, a tropical climate with high annual rainfall, a rainy season lasting from June to December, Vietnam has a huge hydropower potential. With a total current capacity of 19.7 GW, hydro power accounts nearly for a half (42%) of the total installed capacity of the country. Hydro-power plants represent a major and indispensable part of the system. Hydropower plants are spread throughout the country, but are still concentrated in the Northern and the Central Highlands. Some big hydro-power plants like Son La (2400 MW), Hoa Binh (1920 MW), Lai Chau (1200 MW), Ialy (720 MW) play multiple roles, supplying the water and reducing floods, controlling the frequency and voltage of the entire system and contributing to a large amount to electricity production. With incitation from the government,

many small hydropower plants (with power under 30 MW) have been built and operated, with a total capacity of around 4 GW. With concerns about the effects of hydropower on the environment as well as the dependence on natural conditions, the planning and construction are now under more strict operating regulations. Besides many advantages, the optimization of operation is complex in regards of the long dry/wet seasons and the characteristics of agriculture which rely heavily on irrigation.

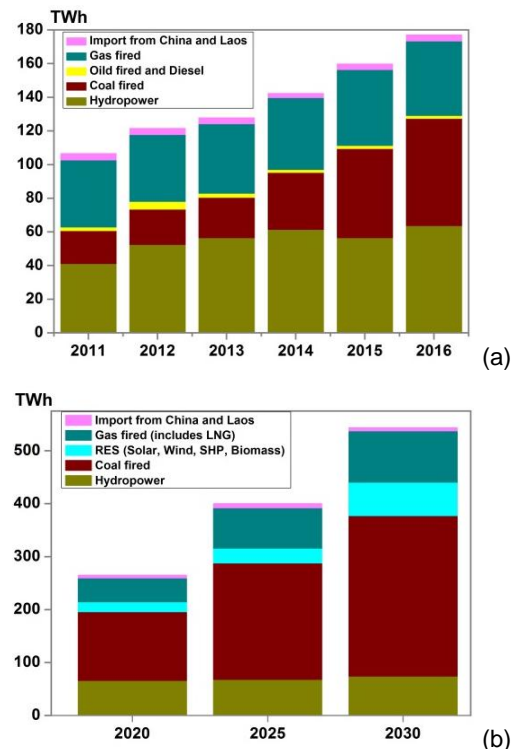


Fig. 2: Power generation output portfolio during 2011 – 2016 and planned production according to PDP7 [6, 7]

Dependence on coal

Vietnam's electricity system is mainly dependent on three primary sources of energy: hydropower, natural gas and coal. With the controlling and tightening hydropower development policies decided recently, hydropower development will not be as high as it is now. In addition, with the decline in supply of natural gas as well as delays in the construction of gas turbine power plants, the power supply of the system will mainly rely on coal alone. Currently, coal-fired power plants constitute the main development strategy with lower investment cost and shorter construction time compared to the same capacity of hydro-power. According to PDP7, Vietnam will have 26 GW of coal-fired in 2020 and 48 GW in 2025. Nowadays, most of new constructed coal-fired power plants are located in Southern area, where the demand in electricity is high. They have larger unit capacity (~ 600 MW/unit), like in the thermal power complexes of Vinh Tan or Duyen Hai. Existing and future plants in Southern Vietnam will use imported coal, often from Australia or Indonesia.

Wind and solar energy

Located in the tropical area, close to the equator with hot climate and long sunshine duration (~3000 h/year), a 3 400 km long coastal line with an average wind speed of 6

m/s, Vietnam has enormous potential for renewable energy, especially with solar and wind. But for now, solar and wind power is still relatively modest: with only about 300 MW of wind power and same of solar, it accounts for less than 1% of the all electrical power production. To promote the development of renewable energy while declining traditional energy sources, the government has recently (September 2018) guaranteed purchase prices to attract investors. The goal is that by 2020, renewable energy will account for 10% of the total electricity production, 16 TWh of wind and 36 TWh of solar energy in 2030.

Vietnam's wind energy potential is considerably high in comparison to Thailand, Laos or Cambodia [8]. According to a report by the GIZ Vietnam [9], the potential of wind power is about 27 GW. Currently, the actual installed capacity is about 190 MW of wind power plants. In the PDP7, the total capacity of installed wind power is expected to reach 800 MW in 2020, 2 GW in 2025 and 6 GW in 2030, which account for 0.8% of the share of produced electricity in 2020, 1% in 2025 and 2.1% in 2030.

Vietnam has also a high potential in solar energy, particularly in its central and southern regions [10]. The intensity is lower in the North due to the annual winter-spring cloudy and drizzle sky. A theoretical potential was estimated to about 2 – 5 GW for residential and commercial rooftops, and 20 GW for solar Photovoltaic (PV) plants. However, the deployment of solar power is still modest, as well as studies related to grid-connected PV systems are still limited in the demonstration phases. An ambitious development of solar is proposed in PDP7: the capacity of solar PV shall increase from around 7 MW in 2016 to 850 MW by 2020 and 12 GW by 2030.

With the support policies, the number of renewable energy projects has increased sharply in the past 2 years. At present, 110 renewable energy projects with as total capacity 7.5 GW of solar and 2 GW of wind power were approved. However, besides many advantages that are zero operating costs, low emissions and support from the government, renewable energy also has many drawbacks. As wind and solar energy production are indeterminate and difficult to predict, the system needs to have a corresponding power supply in case of renewable energy production affected by the weather. In addition, the increase of renewable energy in the system will cause impacts on grid operations such as grid congestion, power quality, redundancy and system reliability. Therefore, to manage the increase in global energy demand and exploit safely renewable sources, the electrical network has to evolve. We present below the current network structure and the needs for strengthening it.

CURRENT ENERGY GRID AND EVOLUTION

The structure of the network

Vietnam electricity grid system, affected by history and natural topography, is divided into separate regions: North, Central and South, which have their own standards and technologies. Over time, with the unification of the country and its economic development, it was necessary to unify into a unique standard, to connect separate regional electrical systems, and to transmit a large amount of capacity from the North to the South. The first

500 kV line with 1500 km, put into operation in 1994, integrates the 3 regional systems (previously operated independently), thereby enhancing the support of the strength, increasing the stability and the general reliability of the whole system. Since then, after 25 years of operation and expansion, the system has nearly 7500 km of 500 kV and nearly 40.000 km of 110 and 220 kV (Figure 3), contributing to an important part in the economic development of Vietnam.

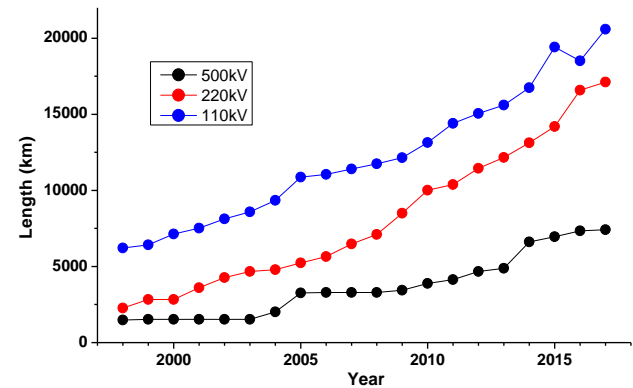


Fig. 3. Evolution of grid transmission line length from 1998 to 2017

Being not only an internal grid, the system also connects with neighboring networks to import and export electricity, see Figure 4 [11] and Table 1. Since 2005, to minimize the risk of power shortage in peak periods (usually in the dry season), Vietnam has begun to connect and import electricity from China Southern Grid. The annual purchase volume is about 1.5 TWh through two 220 kV lines with 800 MW peak. The connection to Laos is to take advantage of abundant hydropower resources. With agreement of the two governments, some hydropower plants were built, connected for selling power to Vietnam through two 220 kV lines since 2015. A plan is agreed to increase the number of power-plants in Laos. In the Southern Vietnam, a 220 kV transmission line with 200 MW peak connects to Cambodia's grid since 2000, for selling about 1 TWh/year to Cambodia.

Nation	Line	Capability (MW)	Annual Vol. (MWh)
China	Malutang / Ha Giang	450	750 ~ 800
	Xinqiao / Lao Cai	350	700 ~ 750
Laos	Xekaman 1 / Thanh My	290	900 ~ 1100
	Xekaman 3 / Thanh My	250	900 ~ 1200
Cambodia	Takeo / Chau Doc	200	700 ~ 800

Table 1: Capability and annual volume of import and export transmission lines

The congestion is also seen on the regional grid due to a large concentration of residents in cities. The local transmission network connecting from the substations, to the power plants and to the cities are often heavily loaded, especially in the two biggest cities that are Hanoi and Ho Chi Minh City. In addition, the natural topography divides the Northern region in two areas: east place where most of the largest hydropower plants are located, and west

where a number of coal-fired thermal power plants are installed. With that configuration, the transmission lines linking these two areas often carry high loads.

The impact of renewable energy

Along with above problems, the strong increase of renewable energy in the system has also brought many challenges. Technically, wind or large solar power plants are often installed in areas far away from the load so the transmission line is heavy and expensive. This power

source is unstable and fluctuates in very large capacity in the short term and needs backup resources for this change such as hydropower or electrical storage devices while Vietnam has little operational experience integrating the wind and solar power. For renewable energy integration, Vietnam should address important issues that are network infrastructure development, incorporation of energy storage systems and precise and agile management of the system through grid automation.

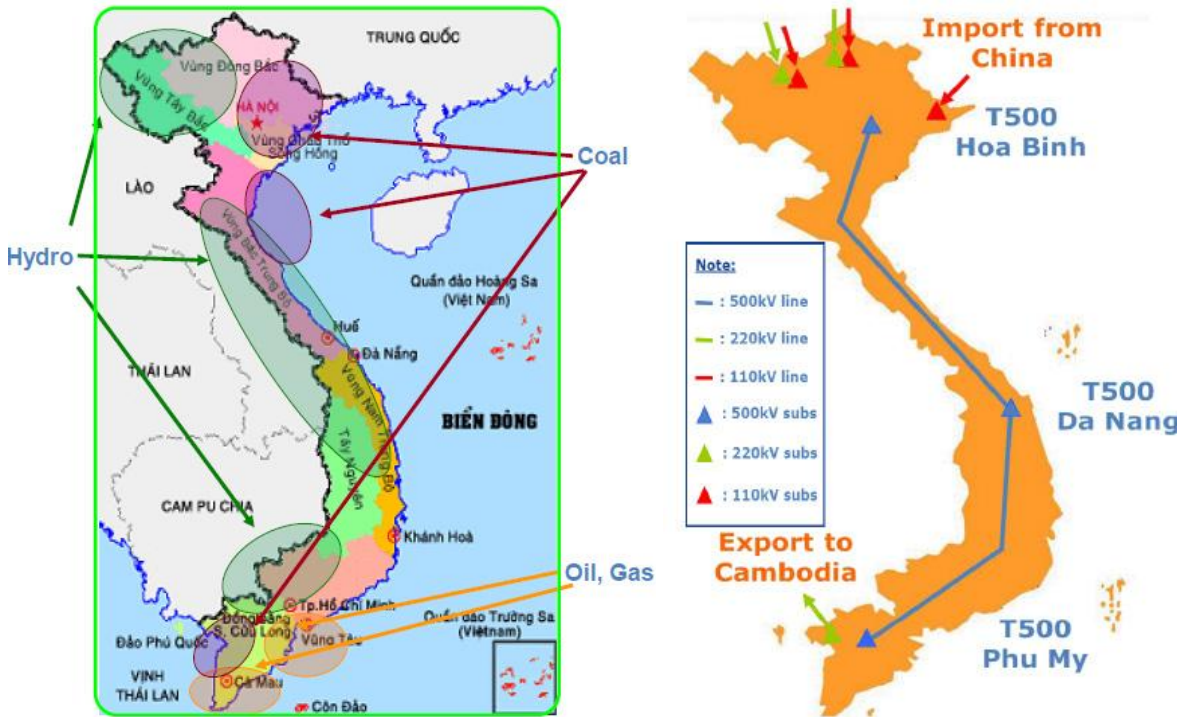


Fig. 4: The broad distribution of energy sources and network structure [11].

The grid system, that presently receives 300 MW from solar power plants, could face an increase of the installed capacity to over 4 GW in 2019 from plants concentrated mainly in the Southern and Central regions, where the transmission grid system (110 and 220 kV) has not been developed to meet such a large capacity. According to EVN report [6], the current grid can only absorb for 2000 MW of renewable energy. Therefore a large part of the capacity would be curtailed and the situation could be worse in the coming years.

In addition to investing in the upgrade and building of new transmission lines to release all the power from renewable power plants which licensed for construction, EVN expects to build and put into operation new energy storage systems, apply a smart grid to control and optimize the system.

The massive incorporation of renewable energy has to go with a strong transmission and distribution grid with strong interconnections to neighboring power markets. Denmark for example has the majority of his power from wind, but this goes with interconnectors to Norway and Sweden making it possible to balance wind power and hydro power [12]. To the North of Vietnam, the energy exchange with China could be strengthened by building a 500 kV line (Honghe – Soc Son project with 400 km transmission line) [13].

Besides the development of production and transmission infrastructures, energy storage constitutes one strategy for smoothing the needs in maximum power, optimizing the inputs from renewable and smoothing the transmission congestion. Because of its strong infrastructure in hydropower, hydraulic energy storage could be a solution for Vietnam. The other solution to storage could be with using batteries: from the fleet of electrical vehicles on the one hand, and with dedicated ESS – Electrical storage systems. Although the huge potential for development and the market seems to be booming, yet the ESS is still in its early stages, so the investment to own and operate the system is still relatively high. This will require improvements in performances as well as a reduction in initial investment costs so that ESS can be easily accessible to the majority of users.

Master plan and uncertainties

As for many other countries, with today's rapid evolution in this field, the future of electricity network will substantially depend on evolutions in the demand, on the national and internal policies and on the technical and economical progresses in power engineering.

The incorporation of electrical vehicles will have a strong impact on the network but the speed of market penetration is difficult to anticipate. The impact is not only on the consumed power; it can also contribute to the

general equilibrium of the network with providing a storage capacity. For electrical vehicles, besides cars, the marked of motorbikes (representing actually one of the main transport means in VN) is developing fast [14]. High speed train projects have been postponed several times. Despite competition from budget airlines and the unpopularity of rail travel, developing a modern high speed railway system between Hanoi and Ho Chi Minh City may just be more a matter of pride for Vietnam.

The choice of compensating the demand by massive incorporation of coal exposes to two uncertainties of international nature. First, although more efficient technologies are coming, it is not in favor of the compliance to the national committed target at COP21 about CO₂ emission reduction and it can be affected by carbon tax policies. Second, it brings some dependence to other countries for primary energy as the coal will be imported e.g. from Australia or Indonesia. By 2030 and beyond, with the increase of price of fossil energy and progress for cheaper renewable, it can be anticipated that new orientation in favor of the renewable energy will emerge.

Potentialities for HVDC and cable energy transmission

As stated previously, the massive introduction of renewable energy requires strong inter-regional cooperation. In this perspective, power lines at the boarder should be viewed no more as a one-way transmission of energy from source to charge but as an exchange with energy flux that can be reversed on a daily basis.

The fast increasing in demand of electrical energy poses a challenge to the supply capacity. Interconnection links with foreign countries to import energy are considered as a solution. The 220 kV HVAC Malutang (China) – Ha Giang – Thai Nguyen transmission line was thus built and put into operation in 2007. The capacity could be increased in the future with either switching to DC or realizing higher voltage line. However, for the massive exchange in electricity in the future, HVDC links tend to be preferred. Examples of increase in the power flow of existing overhead 380kV AC lines are available notably in Germany [15]. In a previous study [13] in 2011, Nguyen-Mau *et al.* analyzed some of the weaknesses of the power grid such as the interconnection with Chinese and Laos power systems, the power swing protection (especially at Hatinh – Danang 500 kV transmission line), or over-voltages occurring when tripping heavily loaded lines. HVDC technologies could be a solution to those features. It was shown by simulation that, due to the capability of fast and independent active and reactive power control, VSC HVDC can greatly improve the stability of a power network. According to Lerch *et al* [16], strengthening the power transmission system by a separate 500 kV transmission system or HVDC connection between North and South can avoid the system separation at single faults. An alternative is to distribute more power generation across the country.

DC energy transmission has application also in the Medium Voltage domain (MVDC). Beyond renewable energy transmission, several applications are targeted ranging as DC microgrids, electric ships, data centers powering, etc. [17]. The expansion of wind power and solar energy systems has huge consequences for the

transmission and distribution of electricity making it more complicated and decentralized, with risks for power quality and grid stability. Solutions are provided in the 30-150 kV range [18, 19] that are suited for instance, to connect wind turbines installed on offshore islands or medium-sized solar plants to the AC grid and sensitive, weak distribution networks can be stabilized. There are indeed several PV plants projects of medium size capacity, such as Hong Phong 1A-B at Binh Thuan (250 MWp), BIM 2 at Ninh Thuan (250 MW) provinces, etc. that are planned to be built and connected to the 110 kV transmission lines.

The above analysis shows that DC energy transmission is a possibility for improving the quality of the grid in Vietnam, especially at a time where a strong strengthening and stabilization of the network is necessary. As to HVDC cables the investment it represents is certainly still an issue for today. The first step will be to integrate more power electronics and upgrading existing overhead HVAC lines for HVDC. The MVDC links are still in the infancy, and have not yet penetrated the market. Perhaps in the far future, offshore windfarms with effective resources of the country along the very long coast could benefit from these technologies.

CONCLUSIONS

As a rapidly developing country and with the changes in the primary source of energy, the electrical grid of Vietnam will necessary evolve and strengthen in the next decades with a demand in energy estimated to twice as today in a twelve year time.

The short term energy provision is thought with development of fired coal-based electricity with advantages of agility, localization of the production on demand and low investment cost. In parallel, an ambitious development of renewable energy is planned, and it can be forecasted an amplification effect once technologies are well implanted, provided the grid can be conveniently managed. HVDC energy links will certainly be integrated on a middle term basis, as a way to stabilize the network. The last pillar of the grid will be the implantation of ESS, in which hydraulic or battery solutions will probably contribute. Though identification of best suited application of HVDC cable links is probably a bit early, a case as the 220 kV HVAC Malutang (China) – Ha Giang – Thai Nguyen transmission line could be considered as case study for equipment modeling.

Acknowledgments

We would like to acknowledge the C.N.R.S. for financial support to the ModHVDC project n° PICS07965.

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GLOSSARY

HVDC: High Voltage Direct Current
HVAC: High Voltage Alternative Current
IGBT: Insulated Gate Bipolar Transistor
MVDC: Medium Voltage Direct Current
ESS: Energy Storage System