

SWOT Analysis of Indian Power System

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Abstract

The paper reviews the present status of Indian power system and its salient feature looking from the point of view of fresh engineering graduates who would like to take up the career in the power system sector. The paper also gives the important roles being played by the Indian transmission systems within India and also providing interconnections to its neighbouring countries. Two of the improvements which have become essential in EHV transmission system (series and shunt compensation systems) have been given briefly. One important contribution of the present paper is the SWOT analysis of Indian power system, which is normally not covered in technical literature on power systems. The paper gives at the end some recommendations for the engineers to concentrate upon to improve the situation in Indian power sector.

Keywords: SWOT Analysis, Indian Power System, Present Status, Salient Features, Recommendations for Power System Engineers

1.. INTRODUCTION

In a power system, it has to be ensured that the power generation matches with the power demand. There are two elements in between the generation and loads. First one is power transmission system, which transmits power up to the high power receiving substations located at a number of locations around a large city. The second element is distribution systems, which form a network within a city and supply power to millions of domestic, commercial, industrial and other consumers.

A few years after the Independence of India, new industries were being set up all over India and there was also increase in the domestic and commercial power

consumptions. This demanded new power stations and corresponding new transmission systems. But, at that time, the power business (generation, transmission and distribution) in a State was managed by the State Electricity Board (SEB) of that State. With deteriorating financial health of most of the SEBs, the growth in generation and transmission could not match the power demand. That situation resulted in power shortages, with frequent scheduled or unscheduled power cuts for all the consumers in most parts of India.

With the establishment of NTPC Ltd (formerly National Thermal Power Corporation Ltd) in Nov 1975 and Power Grid Corporation of India Ltd (PGCIL) in Oct 1989, there were continuous additions of new power stations and transmission systems, resulting in gradual reduction in the power shortages [1] – [2]. Presently, the situation is much better, with power cuts mostly confined to the rural areas because of a number of political and financial factors. India is the third largest producer of electricity and also the third largest consumer of the electricity. According to the International Energy Agency, India's energy demand grew by 4 per cent in 2018, outpacing the global demand of 2.3 per cent, and is expected to surpass China as the world's largest energy growth market by 2020 [3]. But because of a large population in India, the per capita energy consumption (1,122 kWh in 2016-17) is low.

The present paper would like to discuss about the power sector in India; starting with its present status and roles played by it within the country and also as required by its neighbouring countries. Then, after covering briefly the two essential improvements required in EHV transmission system, the paper analyzes the strengths, weaknesses, opportunities and threats for the Indian power sector. The paper concludes with a few recommendations for the power system engineers to concentrate upon.

2. ROLES OF TRANSMISSION SYSTEMS IN INDIA

2.1 Enabling Setting up of Large Capacity Power Stations

Large capacity power generating sets have higher efficiency, giving lower cost of power generation. Also, the large capacity thermal power plants produce lower air pollution and waste. Mostly with automatic operations and controls in modern large capacity power stations, the number of operating and maintenance personnel required is lower, giving lower running cost. In order to save cost of coal transportation, it is preferable to set up large capacity coal-based power stations near the coal mines (known as pit-head power plants). For example, India has a large number of pit-head super thermal power stations: Vindhyachal 4,760 MW, Talcher 3,000 MW, Sipat 2,980 MW, Ramagundam 2,600 MW etc [4]. Also, large hydro power plants will mostly be located at remote locations having large flow of water and / or high water head. The disadvantage of having large capacity generating units is that there will be sudden shock on the power system if there is outage of one unit. However, it has been observed that the shock is not much if the unit capacity is very small per cent of the

grid capacity. The transmission systems enable the transfer of power from these large power plants to the load centres. Lower cost of power generation will result in lower cost of power supply to the consumers.

2.2 Interconnection of Power Stations and Load Centres in India

The objective of transmission systems is to have interconnection of all the generating stations with all the load centres. With this, the cost of generation can be made minimum and the consumers will have 24 x 7 availability of quality power at the lowest cost.

On Dec 31, 2013, India got one synchronously connected “National Grid”, interconnecting five regional grids (Northern, Eastern, Western, North-Eastern and Southern Grids). This made it possible to pool together the total installed power generation capacity (as on March 2019) of about 356 gigawatt (GW), consisting of 226 GW (63.5 per cent) of thermal; 7 GW (2 per cent) of nuclear; 45 GW (12.6 per cent) of large hydro; and 78 GW (21.9 per cent) of other renewable energy sources (RES). Along with generation, there were also additions of large networks of extra high voltage (EHV), high voltage (HV) and high voltage DC transmission (HVDC) systems. As on March 2019, there were 41,809 circuit km of 765 kV transmission lines, 180,746 circuit km of 400 kV transmission lines, and 175,296 circuit km of transmission lines of various voltage levels up to 220 kV. For HVDC, there were 6,124 circuit km of \pm 800 kV transmission lines and 9,632 circuit km of \pm 500 kV lines [4]. Thus, with excellent additions of transmission networks, it became possible to have transmission of surplus electricity between different regions in India, resulting in reduction in the power shortages in all the regions of India. It was due to these interconnections by transmission systems that the power deficit Southern Region started receiving power from the other regions of India. Another advantage of interconnection is that the system operators do not have to plan for the reserve capacity in each region. In case of increase in power demand or the loss of generation in one region, the power can be transferred from the other regions.

It may be mentioned that, due to separation by long distance through sea, the Union Territories of Andaman and Nicobar Islands and Lakshadweep are not connected to the National Grid of India. Andaman and Nicobar Islands do not have any coal or gas-based power generation; they have 40 MW of diesel-based generation and 17 MW of RE. Lakshadweep has only about 1 MW of RE generation.

Government of India (GoI) is going ahead with installation of large solar PV power parks and wind energy parks at many locations all over India. There has been an excellent growth in RES during the last one decade. It is well known that both solar PV power and wind energy have hourly, daily and seasonal variations. Solar PV power is available during day time, whereas the winds are strong during night hours. Different regions in India have different behavior of solar PV and wind energy

generations. But, with the interconnections of all the different regions as exists now, it can be estimated that the variations in power generation over all India basis would get smoothed out, making it easier for the system operators to have integration of these RES into the power system.

Today, the situation in Indian power system is that there is sufficient generating capacity. But, due to shortage of Indian coal in a few power stations and due to unavailability of costly imported coal, many thermal power stations are running at low plant load factors. Also, due to the non-availability of domestic gas and high cost of imported gas, a large number of gas-based power stations (of about 14,000 MW) are not operating for the last few years. Further, there are adequate transmission lines in operation or under commissioning. But, some areas have power shortages or power cuts due to the financial problems of the distribution companies (DISCOMs).

2.3 Connection of Indian Power System with Neighbouring Countries

2.3.1 Interconnection with Bhutan

Bhutan has the potential to generate 30,000 MW of hydro power, but presently has only 1,490 MW of total installed power capacity. Hydro power exports to India provide more than 40 per cent of Bhutan's domestic revenues, and constitute 25 per cent of its gross domestic product (GDP). India has provided in the past and is continuing to give technical assistance to Bhutan in the installation of a number of hydro electric projects. Almost all the power projects in Bhutan have been constructed by the Indian power and construction organizations. For many projects, India has also provided part funding along with Asian Development Bank and the other financing agencies. There is already an agreement between Bhutan and India to import up to 10,000 MW of power from Bhutan. There are a number of 400 kV, 220 kV and 132 kV transmission lines already existing between the two countries and many more are under construction. With the commissioning of new hydro power stations in Bhutan and new transmission lines between the two countries, the power import to India would reach about 4,250 MW by the end of 2019.

2.3.2 Interconnection with Nepal

India is connected with Nepal through 11 kV, 33 kV, 132 kV and 220 kV transmission lines. Also 400 kV transmission line is there but being operated at 220 kV, as the power transfer is not much. While presently about 550 MW power transfer takes place, it is expected to reach up to about 950 MW. Nepal is interconnected with Bihar, Uttar Pradesh and Uttarakhand States of India.

2.3.3 Interconnection with Bangladesh

Bangladesh was importing about 660 MW power from India. With a number of 400 kV transmission lines and 2x500 MW back-to-back HVDC transmission systems, about 1,500 MW of power is expected to be supplied shortly by India to Bangladesh. The two countries have interconnections at West Bengal and Tripura States of India.

3. HIGHER POWER TRANSFER WITH HIGHER LINE VOLTAGE

In India, the first 400 kV transmission line was started in 1997 and the first 765 kV in 2007. The power transfer over a transmission line is proportional to the product of “sending-end voltage” and “receiving-end voltage”. The sending-end voltage is maintained at the nominal value, while the receiving-end voltage is lower than the sending-end voltage by the voltage drop in the line (which is very small in EHV transmission lines). Therefore, with increase in voltage from 220 kV to 400 kV, the power transfer can be increased by about 3 times; and with increase in voltage from 400 kV to 765 kV, the increase in power transfer can be about 3.7 times. That is the reason for going to higher voltage level for transmission systems. But, the construction of new higher voltage transmission lines is becoming difficult because of the requirement of “right of way” (ROW) and getting the environmental clearance for acquiring the land. The ROW for 400 kV AC transmission tower is 46 m, and the last conductor is required to be away from the nearest trees by 5.5 m; these values are 64 m and 9.0 m respectively for 765 kV AC tower, and 69 m and 10.6 m respectively for \pm 800 kV HVDC tower. Getting so much land over hundreds of km is gradually becoming difficult for PGCIL.

PGCIL has already operationalized the ultra-high-voltage (UHV) 1200 kV National Test Station in Bina (Madhya Pradesh State of India); which will be subjected to various testing for 2 – 3 years before taking up the commercial power transfer using 1200 kV transmission systems in India.

4. IMPROVEMENT IN PERFORMANCE OF EHV TRANSMISSION LINES

With the development of power electronics controllers, there have been great efforts towards improving the performance of EHV transmission lines transferring GW level of power over distance of 1,000 km or more. This led to the birth of a new branch of power system engineering, called as “Flexible AC Transmission Systems” (FACTS); where the term flexible implies controllability of transmission lines parameters or their operation by means of power electronics-based controllers [5]. There have been a number of FACTS devices developed on pilot scale, of which a few have been put on commercial scale. But, most of the commonly applied FACTS devices are series compensation systems and shunt compensation systems, particularly in the context of Indian power system. These are discussed below.

4.1 Series Compensation of EHV Transmission Lines

Presently, there are many operating EHV transmission lines and many are under erection or planning with transmission distance of 1,000 km or more. The power transfer over a line is inversely proportional to its inductive reactance (X_L); and X_L increases with increase in the line length. Therefore, the power transfer capability of the EHV transmission line decreases with increase in the line length. The solution lies in decreasing the effective inductive reactance of line by connecting a capacitive reactance in series with the line, known as “Series Compensation System”. For example, consider EHV transmission line transferring power P_1 with inductive reactance of X_L . If the inductive reactance (X_L) is compensated (that is, effective inductive reactance is decreased to $X_L - X_c$) by connecting a capacitive reactance (X_c), then for the same values of voltages of the sending and receiving ends, the power transfer over the line gets increased by a factor = $X_L / (X_L - X_c)$. For a given power transfer over the line, the reduction in effective inductive reactance of line also results in lower line voltage drop, improving the voltage at the receiving end.

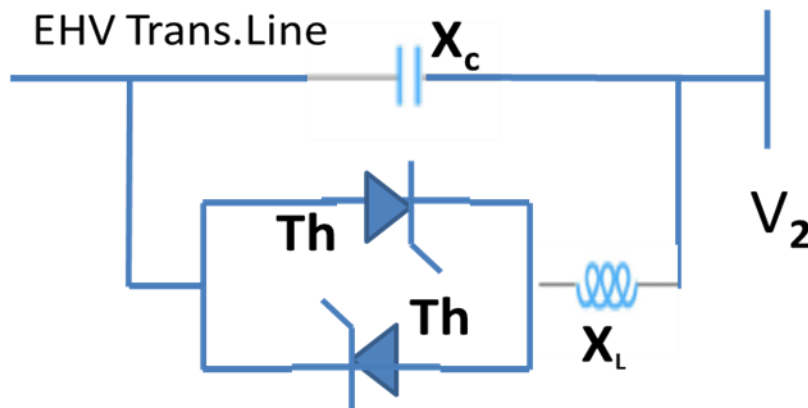


Fig.1 Schematic of thyristor-controlled series capacitor (TCSC)

In most of the EHV transmission lines, the capacitive reactance connection in series with each line has the scheme shown in Fig.1, called as thyristor-controlled series capacitor (TCSC). The fixed capacitor bank (X_c) is connected in parallel with a thyristor-controlled reactor (TCR) [5]. By controlling the control angle of the reverse-parallel connected thyristors (normally from 180° to 150°) in series with an inductor, the current taken by the inductor (X_L) is varied. For example, when thyristors have a control angle of 180° , there will be no current flow through the inductor, resulting in the maximum value of capacitive reactance in series with the EHV transmission line. On the other hand, when the control angle is 150° , there will be current flow through the inductor, which will reduce the effective value of capacitance in series with the line. Thus, by using TCSC, the line inductive reactance can be varied as per the

requirement by varying the compensating series capacitance by TCSC, giving the desired power flow over the EHV transmission line. One point to be brought out here (as seen from Fig.1) is that all the components in TCSC are at line voltage (of 400 kV or 765 kV). Therefore, the complete TCSC in an installation is required to be insulated for the full voltage and kept on an insulated platform as shown in Fig.2.



Fig.2 Thyristor-controlled series capacitor (TCSC) installation

4.2 Shunt Compensation Systems in EHV Transmission Lines

Shunt compensations systems are used mostly as a combination of shunt capacitive compensation and shunt inductive compensation; and are usually connected at the receiving-end of a transmission line. As is well known, the main objective of the shunt capacitive compensation branch is to compensate a part of inductive current drawn by all the loads connected to the receiving-end substation of the transmission line, so as improve the power factor of total receiving-end current in the transmission line to more than 0.95 for reducing the line power losses. The shunt inductive compensation is made effective only when the transmission line is lightly loaded; because then, the line charging current becomes predominant, resulting in the receiving-end voltage becoming higher than the sending-end voltage (known as Ferranti effect) [6].

Fig.3 shows the schematic of a shunt compensation system, commonly known as “Static VAR Compensator” (SVC). As defined by IEEE, “SVC is a shunt-connected static VAR generator or absorber, whose output is adjusted to exchange capacitive or inductive current, so as to maintain or control specific parameters of the electrical power system (typically bus voltage)”. World’s first small capacity SVC was installed in an industry in the year 1972; and the first SVC in transmission system was used in the year 1979. Since then, hundreds of SVCs have been used all over the world; and dozens of SVCs exist in India. Each phase of SVC (Fig.3) consists of a thyristor-controlled reactor (TCR) in parallel with a bank of capacitors. The current taken by the inductor is varied by varying the control angle of the reverse-parallel connected thyristors. When control angle is 90° , the RMS current taken by the inductor is maximum and is designed to be more than the current taken by the capacitor bank ($I_L > I_C$), so as to provide inductive compensation ($I_T = I_L - I_C$) to reduce the effects of capacitive charging current taken by the transmission line. On the other hand, when the control angle is 180° , the RMS current taken by the inductor (I_L) is zero, so that the SVC provides the full capacitive compensation ($I_T = I_C$). Thus, the compensation required can be varied smoothly by the SVC between the two limits discussed above. At some value of control angle in between these two limits, the current taken by the inductor is designed to be equal to the current taken by the capacitor ($I_L = I_C$), so that there is no compensation ($I_T = 0$) provided by the SVC. A transformer is always connected at the line, so that the voltage ratings of all the components of SVC are lower.

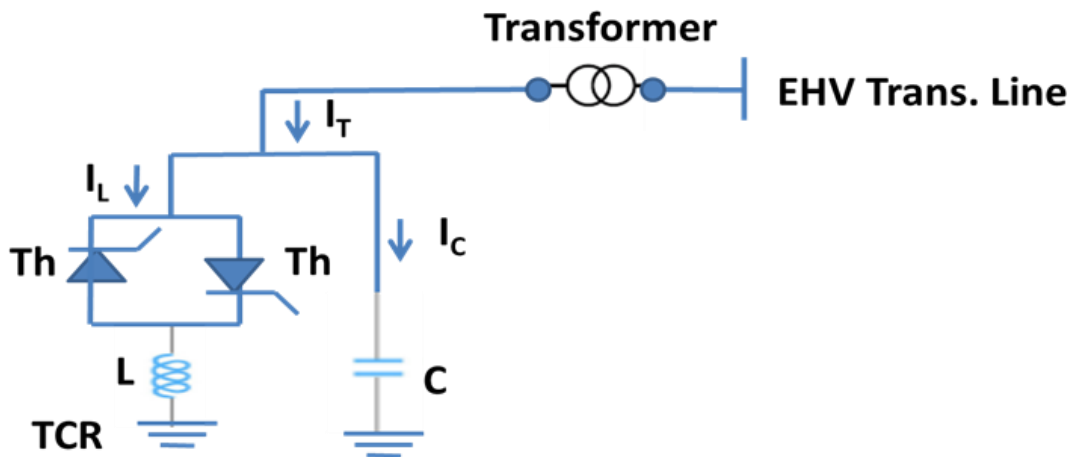


Fig.3 Schematic of static VAR compensator (SVC)

One of the India’s largest SVC installed at 400 kV receiving-end sub-station at Ludhiana in the Punjab State is shown in Fig.4, called as 1000 MVAR SVC. It provides inductive compensation of 400 MVAR (shown as -400 MVAR) and capacitive compensation of 600 MVAR (shown as $+600$ MVAR). A large number of

air-cored inductors and banks of capacitors can be seen in the installation shown in Fig.4.



Fig.4 Static VAr compensator at Ludhiana (- 400 MVar / + 600 MVar)

5. STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS FOR INDIAN POWER SECTOR

Having presented the status of power system in India, it is now proposed to discuss the “Strengths, Weaknesses, Opportunities and Threats” (SWOT) for the Indian power system, a topic which is normally not covered in any technical literature.

5.1 Strengths

The Indian power sector has strengths in many areas. One “National Grid” with 356 GW installed power capacity distributed all over India is the biggest strength. With 800 MW as the largest generating set, even if one unit develops some problem and is taken out, it is hardly 0.2 per cent loss of power capacity in the grid. Further, if a complete power station with a total capacity of 4000 MW goes out because of some reasons, even then also, it is only 1.1 per cent reduction in power generation. Similarly, India has a total of more than 400,000 circuit km of transmission lines. Even if there is loss of 4,000 circuit km of lines due to problems in any geographical area, it is only 1 per cent of the total; and there would be power outage in the specific areas served by those lines. Presently, every large / metro city is served by a number of transmission lines; therefore, any problem on one line may not cause major disturbance to the city.

India has a large reserve of indigenous coal, which is required for thermal power

generation; and as per rough estimates, the coal reserves can serve the demand of thermal power stations for many decades. Further, during last one or two decades, India has gone for a large scale use of renewable energy generation, based on both PV power and wind energy. Therefore, having sufficient energy sources is a major strength for Indian power sector.

Many experienced and financially strong public sector undertakings are the backbones of the Indian power sector. NTPC Ltd is able to install large capacity thermal power stations with latest technologies; it has also erected many small capacity hydro power stations and is venturing into renewable energy generation. PGCIL has commissioned thousand of circuit km of EHV / HV / HVDC transmission systems and has a large number of these under “work-in-progress” or planning stages. Further, there are a number of reputed and experienced manufacturers producing latest equipment required for generation, transmission and distribution of power. Thus, India has strengths in all the areas of power sector: manufacturing and erection of power stations and transmission lines. India has also the availability of large skilled and semi-skilled manpower required for the production, erection, operation and maintenance of equipment in the power sector.

5.2 Weaknesses

One weakness commonly mentioned for India is the dependence on imported gas for the gas-based power stations. As of now, because of non-availability and high cost of imported gas, gas-based power stations of about 14,000 MW have not been operating for the last many years. But now, GoI has decided not to encourage the installation of large gas-based units. Also, for nuclear power station, India is dependent on the supply of nuclear fuel from a number of countries. Fortunately, nuclear power capacity is only 2 per cent of total installed capacity and power production will not be affected so much even if there is disruption of supply of nuclear fuel.

Major weakness of power sector has been the poor financial position of most of the DISCOMs. The energy rates are not been raised by the State Electricity Regulatory Commissions (SERCs) due to political pressures. Further, although the DISCOMs are able to collect the revenue for the energy supplied to the cities or towns; the collections have been poor from the rural areas. Aggregate Technical and Commercial (AT&C) power losses are very high in most of the States, due to theft of power, pilferage and non-collection of bills. In most of the rural areas, the power supply is free or the people do not make payments. Thus, the DISCOMs are running into losses. Ujjwal DISCOM Assurance Yojana (UDAY) was launched by GoI in 2015 with the intent to find a permanent solution to the financial mess that the power distribution was in. It allowed State Governments, which owned the DISCOMs, to take over 75 per cent of their debt as of Sept 30, 2015, and pay back lenders by selling bonds. DISCOMs were expected to issue bonds for the remaining 25 per cent of their debt [7]. It temporarily made the financial position of the DISCOMs better. But, again after that, due to the non-receipts of amount has again brought them back to the situation of financial losses.

5.3 Opportunities

The number of good sunny days gives opportunity of tapping solar PV power generation in India; and also, there are large areas in many States having sufficient potential for the development of wind energy. Therefore rightly, India has planned to tap 175,000 MW of RE by 2022 [8].

India has also a potential for the development of large hydro power, particularly in the North-Eastern region. But, in the recent years, there has not been much progress in the development of hydro power due to the problems of land acquisition, re-settlement of the people (displaced by the submergence of land by the construction of dam) and delays or not getting environmental clearances (due to the issues raised by people regarding loss of green land and its effects on the birds and animals located in that land).

5.4 Threats

The main problem in India is that there are no new developments and the country is dependent on import of new technologies or new products. For example, for RES, the Indian suppliers have to import the PV cells for building the PV panels. For stationery battery storage, the manufacturers are dependent on the import of lithium-ion cells. Further, for FACTS devices, the large power semiconductor devices have to be imported. Thus, the dependence of India on supplies from the other countries for the latest technologies and products is a great threat for the Indian power sector.

5.5 SWOT Analysis

On the basis of the details discussed above, it can be said that the Indian power sector is in a good position because of its strengths and great opportunities of future growth (particularly in RES). The overall situation would become much better if the Central and State Governments are able to concentrate on the distribution systems to make them financially strong.

6. RECOMMENDATIONS

The paper gives the status of Indian power sector and briefly brings out the topics which are relevant under this sector and which a new electrical engineering graduate must brush up if he / she would like to take up the career as power system engineer. Two excellent books on the subjects of FACTS and Power Electronics have been included in the reference and more information is available these days on the internet. The following are some of the recommendations for improving the performance of the Indian power sector.

(a) A large per cent of energy is consumed by the industries and the recovery of energy bills from them has not been any problem. Therefore, the DISCOMs must be provided with proper support so that the industries are able to have 24 x 7 availability

of quality power. If this is ensured, then the industries would not try to go for the captive power using inefficient and costly diesel-based generation. This would be a “Win-Win” situation for both; industries not required to use costly captive power, and improved revenue for DISCOM.

(b) There are a number of old and inefficient coal-based power plants of low capacities inside the cities. These must be scrapped. Some alternative use of buildings can be thought of (if possible), but large open space must be cleared of all the items and used for the generation of solar PV power.

(c) So far, there has not been much application of stationary battery energy storage in India. For integration of RES in the distribution system at local level, it would become necessary to go for a large scale installation of battery energy storage of MW level and also the software support in the form of battery energy management.

(d) There have not been many successful stories in India for making small distribution areas as “Smart Grids” [9]. One major investment would be the installation of pre-paid smart meters in all the premises of domestic, commercial and industrial consumers, so that (apart from the other benefits) the collection efficiency would become higher, reducing the AT&C losses. Making smart grids would also involve changing the overhead distribution lines to high voltage underground cables in order to prevent theft / pilferage of power, apart from giving reduced line power losses and lower disruption of supply. DISCOMs have also to concentrate on reducing the unbalance in the line currents, and on improving the power factor and voltage in all the areas using commonly available power electronics based controllers for reducing the line power losses. Apart from many other advantages of the smart grids, the idea here is reducing the line power losses, theft / pilferage, and improving the collection efficiency etc for DISCOM, with the overall aim of reducing the AT&C losses.

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