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Current Trends in High Voltage Products & Overlook in Transmission Capacity After 5 Years

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Abstract:*Rapid advances in high voltage products are redefining the transmission system. Switchgear is a most important part of every substation and various advances has been taken for the efficient power transmission. This paper gives brief idea about the new technologies coming up into the market for the high voltage switchgear products in terms of their insulation mediums used and their operating mechanisms. This paper also discusses the current transmission capacity of India as per their regions and overlook in the transmission capacity after 5 years. By taking reference from various single line diagrams of different substations, paper gives idea about the number of switchgear products used according to the particular transformation capacity of substations and this may help to the manufacturers of high voltage switchgear products to estimate future demands for their products.*

I. Introduction

Electrical energy is must for a development of a nation. The basic condition for good and safe power supply is a reliable power system network all over the nation. For an ideal functioning of a transmission network all the switchgear like circuit breakers, power transformers, relays, surge arresters, busbar, isolators, conductors and insulators must work properly as per their operation. Hence, Switchgear plays an important role in electrical power system network, so at most priority must be given while selecting these products to get a reliable electrical power supply for a well-functioning of transmission system. Almost all the Power Transmission network and generating plant are running closer to their limits in such a condition it becomes essential to establish a high system availability and reliability for maintaining the power supply withappropriate operation of all the equipments to their rated values thus leading to less chance of failure.

As, it is well known phenomenon thatwhen an equipment is operated in overload condition or above its rated values then there are chances of damaging the equipment, hence it affects the reliability of a system. Principle cause of failure of power system network a decade ago was due to Overloading and Short-circuiting which would lead to damage of whole network leading to blackouts in those areas. So, when thesekinds of conditionarise then electrical equipments and appliances should be isolated from the whole network. The job of isolating the equipment and appliance from the network is done by the equipments like relay and circuit breaker. Relay sense the fault and circuit breaker operates during abnormal condition,the band of conditions under which it has to operate is very large. The operation of circuit breaker is affected by nature of circuit. Different types of fault are there like line to line(L-L), line to ground(L-G), double line to ground(L-L-G) all these are unsymmetrical faults out of which line to ground occurs 65-70% of time. But the most serious type of fault is symmetrical fault in which voltage may be of thousands of volts and which can damage the whole system. Hence, there is a great need to isolate the system when these kinds of abnormal conditionsoccur. The isolation of all such equipment from the system is done by circuit breaker.

Due to continuous usage and growing demand for electricity in the era of restructuring and deregulation the power utilities are striving for improvement in productivity and efficiency. New inventions are upgrading the conventional technologies by facilitating the development inultra-high voltage that is by increasing the operating voltage so that bulk amount of power can be transferred which will enable smart grid and enhancing eco-efficiency with a huge area of network of commercial, industrial and residential areas. Also, in addition to this, utilities try to provide service centre across the world offering life cycle support market of high voltage equipment and product, starting to era of new technologies.

This paper will focus on high voltage switchgear product like circuit breaker and instrument transformer, total installation capacity present all over India, and at the last estimation of the number of focused product require in upcoming 5 years and what will be the new technologies arrive to replace the old ones.

II. Methods & Technology

Currentinstalled capacity of India is 349.288GW is equal to one billion (10^9) watts or 1 gigawatt = 1000 megawatts as on 31 December 2018.Out of which renewable power plant Contribute about 33.60% of total installed capacity, but then also India is largely depending on Fossil fuel for power generation and they dominate the electricity sector. India got sufficient amount of power generating capacity but as the infrastructure is not operating to its full efficiency that's why sometimes they need to import electricity from other nation with high tariff.

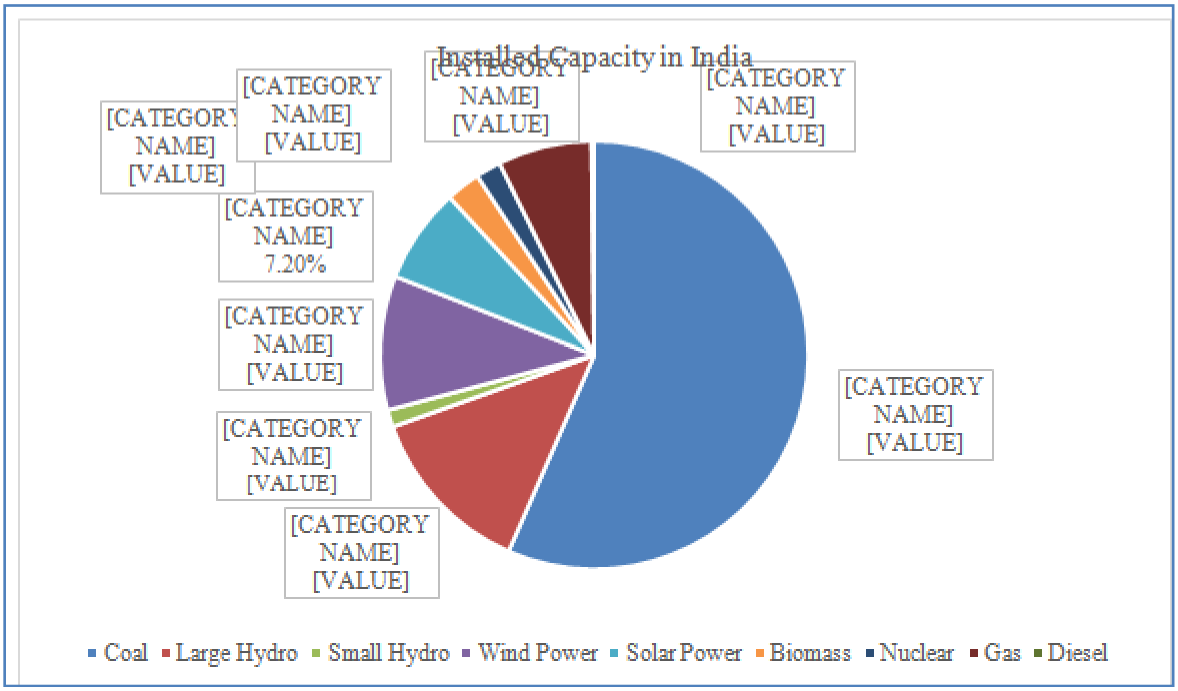

Figure no 1. Installed Capacity in India as per Central Electricity Authority (As on 31.01.2019)

The total installed power generation capacity is sum of utility capacity, captive power capacity and other non-utilities. Captive power plants are a form of distributed generation, generating power close to the source of use. Distributed generation facilitates the high fuel efficiency along with minimizing the losses associated with the transmission of electricity from centralized power plants.

Current Trends & Future Technologies for focus Products: Considering, 3 focus products in the switchgear industry as Circuit Breakers, Current Transformer, Potential Transformer.

Circuit Breakers: Switchgear manufacturing companies like ABB,Siemens, General Electric (GE), Schneider Electric,Bharat Heavy Electricals Limited (BHEL), etc are manufacturing live tank circuit breakerand also dead tank circuit breaker according to the requirement circuit for applications. Siemens have manufactured and commission a SF6 circuit breaker of 1200kV which is the world's highest ever system voltage till this date. According to requirement circuit breakers are classified as athree-pole circuit breaker which means one drive for three poles, another one is single pole which means three drives for three poles. Single pole operation is reliable and safe that's why above 145kV we use single pole operation only due to its various advantages over a three-pole circuit breaker operation.

While manufacturing circuit breaker they should be manufactured such that they should withstand all the climatic condition like extreme temperature to earthquake condition so they must be mechanically stable during such circumstances. Depending on the environmental condition in which circuit breaker is to installed the different type insulators are used like Porcelain or Composite insulator. Spring Drive mechanism is mostly used in all circuit breaker but we can use other drive mechanism like electro-hydraulic operating mechanism as per the required application. Control cabinet is the heart of circuit breaker which contains current transformer connection, controls, tripping units, motor and heating power supplies are which are placed according to the required specifications All these elements together forms a control system of a circuit breaker.During the operation of a circuit breaker an arc is produced between the terminal so to quench the arc different type of dielectric medium are used but now a day's SF6 gas as a dielectric medium is most commonly used due to its various properties like SF6 is five times heavier than air with a specific gravity or density of about 6 grams/litre, it liquefies at -40 degree Celsius at 3.6 atmosphere's temperature, it is colourless, odourless,non-toxic, non-combustible, chemically extremely stable and inert up to 500 degree Celsiusthat's whys SF6 is used as a dielectric medium in circuit breaker for arc quenching principle.but there is some limitation to use SF6 because it emits greenhouse gas due to which it is harmful for the environment.Companies are trying to find an alternative for SF gas and they are concentrating on adopting clean air and vacuum for a dielectric medium.

Instrument Transformers: Electrical instrument transformers transform high currents and voltages to standardized low and easily measurable values that are isolated from the high voltage. When used for metering purposes, instrument transformers provide voltage or current signals that are very accurate representations of the transmission line values in both magnitude and phase. These signals allow accurate determination of revenue billing. When used for protection purposes, the instrument transformer outputs must accurately represent the transmission line values during both steady-state and transient conditions. These critical signals provide the basis for circuit breaker operation under fault conditions, and as such are fundamental to network reliability and security.

Calculation of Number of Switchgear Products Present in Substation:

This paper referred different single line diagrams of various transformation capacity which gives the approximate number of high voltage products installed in the particular substation and here, paper focused on only circuit breakers, current transformers and capacitor voltage transformer/voltage transformer. In 132KV & 220KV substations most of the secondary side is below 66KV.So here,neglecting secondary voltage level for the calculations of switchgear products because this paper is only focused on the calculation of switchgear products for more than 132KV voltage level.

i. 132 KV Substations: Number of outgoing bays are calculated as per the particular transformation capacity of substation. But, transformation capacity of substation is not same for all 132 KV substation. It is variable as per the load on substation. So here by using thumb rule and taking references from different single line diagrams, we have distributed total number of substations which are available in the region in 4 parts like 25%-25%-25%-25%. Various SLDs shows that transformation capacity of 132KV substation is maximum up to 100 MVA. So, considering 25% Substation of 25 MVA, 25% of 50 MVA, 25% of 75 MVA & remaining 25% of 100 MVA.

Table no 1. Distribution of 132KV Substation as per different transformation capacity

25%	25%	25%	25%
25MVA	50MVA	75MVA	100MVA
12×2	25×2	50×1, 25×1	50×2
2 incoming line bay for up to 75MVA			4 incoming line bay

Table no 1. Shows, for the 25 MVA Capacity of substation two transformers will be required each of 12 MVA. So, there will be total 2 incoming line for 25 MVA Capacity. Similar concept can be implemented to all other MVA Capacities and one will get the total incoming line bay which will be helpful to calculate number of switchgear products installed or need to install in that particular substation. Circuit Breakers are placed at the incoming line bay (3 pole), at the Bus Coupler (3 pole) and at the HV LV side of Transformer (3 pole). Also, Single pole CTs are placed at the incoming bay, bus coupler and at the transformer HV LV side. As mentioned above, neglecting LV side.

For up-to 75MVA Capacity Transformers,

- 2 Incoming bay + 1 Bus coupler + 2 HV side CB = Total 5 CB
- (2 Incoming bay + 1 Bus coupler + 2 HV side) × 3=15 CT (for single pole CT)
- 2 Incoming Bus + 2 Outgoing Bus = 4 CVT

For 100MVA Capacity Transformers,

- 4 Incoming bay + 1 Bus coupler + 4 HV side CB = 9 CB
- (4 Incoming bay + 1 Bus coupler + 4 HV side CB) × 3=27
- 2 Incoming Bus + 2 Outgoing Bus = 4 CVT

ii. 220 KV Substation: Similar to above concepts, maximum capacity available for 220 KV substations is 200 MVA. Distributing total number of substations in 4 parts as 30%-30%-30%-10%.

Table no 2. Distribution of 220 KV Substation as per different transformation capacity

30%	30%	30%	10%
50MVA	100MVA	150MVA	200MVA
50×1	50×2	100×1, 50×1	100×2
2 incoming line bay	4 incoming line bay		

For up to 50 MVA Capacity Transformers –

- 2 Incoming bay + 1 Bus Coupler + 2 HV Side CB = 5 CB
- (2 Incoming Bay + 1 Bus Coupler + 2 HV Side) × 3 = 15 CT
- 2 Incoming Bus + 2 Outgoing Bus = 4 CVT

Between 100MVA – 200MVA –

- 4 Incoming Bay + 1 Bus Coupler + 4 HV Side CB = 9 CB
- (4 Incoming Bay + 1 Bus Coupler + 4 HV Side) × 3 = 27 CT
- 2 Incoming Bus + 2 Outgoing Bus = 4 CVT

iii. 400/220 KV Substation: Maximum capacity available for 400/220 KV substation is 1500 MVA, Distributing total number of substations in two parts as 60%-40%.

iv.

Table no 3. Distribution of 400/220KV Substation as per different transformation capacity

60%	40%
1000MVA	1500MVA
300×3, 100×1	300×3, 167×3
4 incoming line bay	4 incoming line bay

In 400KV substations, considering secondary side as 220KV and calculating the number of switchgear products for both voltage levels considering one & half breaker scheme.

For 1000MVA Capacity Transformers,

a. For 400KV
- (4 incoming line + 1 bus coupler) × 3 = 15 CT
- 4 + 1 + 3 CB in one & half breaker scheme = 8 CB
- 2 incoming bus = 2 CVT

b. For 220KV
- (7 outgoing + 1 bus coupler) × 3 = 24 CT
- 7 outgoing + 1 bus coupler = 8 CB
- 3 outgoing bus = 3 CVT

For 1500MVA Capacity Transformers,

a. For 400KV
- (8 incoming line + 1 bus coupler) × 3 = 27 CT
- 8 + 1 + 3 CB in One & Half Breaker Scheme = 12 CB
- 2 Incoming Bus = 2CVT

b. For 220KV
- (8 outgoing line + 1 bus coupler) × 3 = 27 CT
- 8 outgoing line + 1 bus coupler = 9 CB
- 3 Outgoing Bus = 3 CVT

v. 765 KV Substation

Maximum transformation capacity considered for 765 KV Substation is 3000 MVA and considering secondary side as 400 KV

a. For 765KV
- (7 incoming line + 1 bus coupler) × 3 = 24 CT
- 7 incoming line + 1 bus coupler = 8 CB
- 2 Incoming Bus = 2 CVT

b. For 400KV
- (7 incoming line + 1 bus coupler) × 3 = 24 CT
- 7 Outgoing+ 1 Bus Coupler = 8 CB

- 3 Outgoing Bus = 3 CVT

III. Result

Above method can be implement to calculate the number of switchgear products that will be required in upcoming 5 years. Table no 4. shows the outlook in transmission capacity of India after 5 years. Data collected from the authorized source Central Electricity Authority of India. Region wise substations are given below which are going to install in upcoming year.

Table no 4. Outlook in Transmission Capacity After 5 Years

Northern Region				
State	**132**	**220**	**400**	**765**
Haryana	0	0	1	0
Himachal Pradesh	1	3	8	0
Jammu & Kashmir	0	1	2	0
Punjab	1	1	1	0
Rajasthan	0	0	2	0
Uttar Pradesh	0	0	4	2
Uttarakhand	0	4	3	0
Western Region				
Chhattisgarh	0	0	13	0
Gujrat	0	0	2	0
Maharashtra	0	1	7	0
Madhya Pradesh	0	0	6	3
Arunachal Pradesh	0	0	8	0
Karnataka	0	0	4	0
Tamil Nadu	0	1	7	3
Telangana	0	1	5	0

Eastern Region				
State	**132**	**220**	**400**	**765**
Bihar	0	1	3	0
Jharkhand	0	0	2	0
Orissa	0	1	6	1
Sikkim	2	5	1	0
Western Bengal	1	2	4	0

North - Eastern Region				
State	**132**	**220**	**400**	**765**
Arunachal Pradesh	1	2	5	0
Assam	0	0	1	0
Nagaland	0	1	0	0
Bhutan	0	0	2	0

Easily, from table no 4. one can calculate total number of switchgear products require in upcoming 5 years.
Future demand of high voltage products can be given below,

132KV	Product	Demand up to 2022-23
	Circuit Breakers	41
	Current Transformers	123
	Capacitor Voltage Transformer	24
220KV		
	Circuit Breakers	208
	Current Transformers	624
	Capacitor Voltage Transformer	92

400KV	Product	Demand up to 2022-23
	Circuit Breakers	1506
	Current Transformers	4518
	Capacitor Voltage Transformer	480
765KV		
	Circuit Breakers	128
	Current Transformers	384
	Capacitor Voltage Transformer	40

IV. Conclusion

The objective of this research paper is fulfilled very well by introducing the current technologies and future technologies for the focus product which are Circuit Breaker, Current Transformer and Potential Transformer. This paper includes has given total installed capacity of India, operation and application of high voltage products,insulating medium and working mechanism of these products.State wise growth in transmission capacity of India is also shown in this paper. We have calculated the total number of high voltage switchgear products will require in the upcoming 5 years by considering different transformation capacity for a particular substation.

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