
ISGF White Paper

FEASIBILITY STUDY FOR CONVERTING AIR INSULATED SUBSTATIONS TO GAS INSULATED SUBSTATIONS

Abstract

- The objective of this paper is to highlight the feasibility for converting Air Insulated Substations (AIS) to Gas Insulated Substations (GIS) by commercialising the land that would be saved. GIS requires as little as 15% to 20% of the land required by conventional AIS. GIS also has the advantage of huge savings in annual operation and maintenance expenditure which is only 20% of a comparable AIS. The final conclusions of this study is: (1) If 132 kV AIS is located at a place having land rates of around 450 lakh rupees (4.5 Cr rupees) per acre and above then NPV will be positive with payback period of 3 to 4 years and it would be beneficial to convert it into GIS; (2) If 220 kV AIS is located at a place having land rates of around 750 lakh rupees (7.5 Cr rupees) per acre and above then NPV will be positive with payback period of 3 to 4 years and it would be beneficial to convert it into GIS; and (3) If 400 kV AIS is located at a place having land rates of more than 700 lakh rupees (7 Cr rupees) per acre and above then NPV will be positive with payback period of 3 to 4 years and it would be beneficial to convert it into GIS.*

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About India Smart Grid Forum

India Smart Grid Forum (ISGF) is a public private initiative of the Ministry of Power (MoP), Government of India for accelerated development of smart grid technologies in the Indian power sector. ISGF was set up in 2010 to provide a mechanism through which academia, industry, utilities and other stakeholders could participate in the development of Indian smart grid systems and provide relevant inputs to the government's decision making.

Table of Contents

1. Introduction	3
1.1 Air Insulated Substation (AIS).....	3
1.2 Difficulties with Air Insulated Substations (AIS)	3
1.3 Gas Insulated Substation (GIS)	4
2. Feasibility Analysis of converting AIS to GIS	5
2.1 Assumptions.....	5
2.2 Operation & Maintenance Expense	5
2.3 Capital Cost of GIS.....	6
2.4 Calculation Method.....	6
2.5 NPV including land cost.....	7
2.6 Payback Period.....	8
3. Conclusions	9

1. Introduction

The target for power generation capacity addition in the 12th Five Year Plan in India (2012-2017) is fixed at 88,000 MW and in 13th Five Year Plan in India (2017-2022) is fixed at around 1,00,000 MW. This will require humungous transmission capacity addition as well. During the ¹financial year 2013-14, at the transmission level substation capacity addition was 13,700 MVA at 220 kV, 9630 MVA at 400 kV and 34000 MVA at 765 kV. The total transformation (substation) capacity in India as of May 2014 is 257614 MVA at 220 kV, 179727 MVA at 400 kV and 83000 MVA at 765 kV levels. The minimum land required for setting up conventional substations of 132 kV and 220 kV is 12 acres and land required for that of 400 kV substations is 20 acres. New transmission capacity will further need more and more land to meet the ever increasing demand of electricity.

Economic growth will propel demand for electricity as well as cost of land. Cost of the land is the major factor to be considered now if a utility wants to set up a new substations or upgrade the existing ones. Apart from the cost of land, right of way acquisition is a very cumbersome process and consumes a lot of time and money.

Gas Insulated Substation (GIS) provides the benefit of land savings as it requires as little as 15% to 20% of the comparable land required by conventional Air Insulated Substation (AIS). GIS has the biggest advantage of very little operation and maintenance expenditure with respect to conventional substations and GIS also provides very high reliability.

1.1 Air Insulated Substation (AIS)

An AIS uses atmospheric air as insulation between ground and the electrical phase which require certain minimum distances to be kept at different voltage levels. The equipment of an AIS substation is easily sourced and has a short lead-time; this means that the required future expansion bays need not be built immediately, unlike GIS where it must be considered. The main disadvantage of the AIS substation is its overall size.

1.2 Difficulties with Air Insulated Substations (AIS)

Severe environmental conditions listed below result in high maintenance costs for AIS:

- In costal sites, saline deposits can cause corrosion to the contacts of the switchgears and insulators
- If AIS is in the vicinity of industrial zone then heavy industrial particles get deposited on the insulators, metallic components, flanges and electrical joints which will require frequent/regular cleaning or hot line maintenance
- If AIS is in the remote rural areas then also the burning of residues from crops after harvest can cause the same problem as mentioned above

¹ http://www.cea.nic.in/reports/proj_mon/pspm/exec_summary_sub.pdf

- If AIS are at very high altitudes than it will require additional costly insulation to prevent breakdown due to low air density, snow loading and sub-zero temperature
- Extreme climatic conditions and seismic considerations would require additional measures such as extensive mechanical support and bracings while physical design of GIS allows seismic criteria to be more easily achieved at lower cost

1.3 Gas Insulated Substation (GIS)

A Gas Insulated Switchgear substation (GIS substation) uses sulphur hexafluoride gas (SF₆ gas) whose dielectric strength is higher than air, to provide the phase to ground insulation for the switchgear. The conductors and contacts are insulated by pressurised SF₆ gas, meaning clearances required are much smaller than that of AIS substations.

GIS with SF₆ gas is now a well-established technology and numerous GIS substations have been in service since the 1960's. The first GIS substations were installed in Switzerland and Germany in the year 1967. The one installed in Germany is still under operation while that in Switzerland has been dismantled after successful operation for 35 years.

GIS are used where there are constraints for space or land is very expensive. World over all new substations in urban areas are being constructed as GIS. Existing AIS in urban areas in India are now in prime locations where land has huge commercial value. If these are converted to GIS, 70% of the land can be freed and that value can fund the cost of the substation modernization. Moreover the commercialization of the excess land can bring in alternate revenue streams for the utilities. The overall size of a GIS is about 15% to 20% of the comparable AIS. Adding on to it, there are various advantages of GIS over AIS, such as:

- GIS is more reliable and safer
- It is aesthetically superior to AIS
- GIS is not affected by atmospheric pollution
- GIS required very low maintenance

2. Feasibility Analysis of converting AIS to GIS

The decision of converting existing AIS into a GIS depends mainly on the following factors:

- The location where the AIS is situated i.e. urban or rural area
- The price of the land where it is situated
- The age of the AIS i.e. condition of the substation and the extent of renovation and modernization required to keep the substation in running condition
- Existing load of the substation, spare load handling capacity of the substation and the future estimation of the increase in load Or additional BAYS in the substation
- The criticality of the substation i.e. whether the substation is transmission substation or an industrial substation of a cement factory/steel plant etc.
- Operation and maintenance cost of the substation

2.1 Assumptions

Following assumptions have been made in the financial model:

- Interest on long term loan is taken as 13% (SBI base rate + 300 base points)
- Interest During Construction (IDC) is considered as 13%
- Conversion period of AIS to GIS is considered as 3 years
- It is assumed that commercial value of the land vacated will be realized in 4th year
- 4 cases are considered for land rates depending upon classification of cities (Metro, Class A1, Class B1 and other cities)
- Depreciation on substation as 5.28%
- Feasibility analysis is done for the AIS of voltage levels:
 - 400 kV
 - 220 kV
 - 132 kV

2.2 Operation & Maintenance Expense

Operation & Maintenance (O&M) cost of the AIS is taken as per the Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations, 2014 as shown in the table below. The following normative O&M expenses shall be admissible for the transmission system:

Norms for substation (Rs Lakh per bay)	2014-15	2015-16	2016-17	2017-18	2018-19
400 kV	60.30	62.30	64.37	66.51	68.71
220 kV	42.21	43.61	45.06	46.55	48.10
132 kV and below	30.15	31.15	32.18	33.25	34.36
400 kV Gas Insulated Substation	51.54	53.25	55.02	56.84	58.73

Table 1: O&M expense of AIS as per CERC norms

- The AIS under consideration is believed to be more than 25 years old and hence the applicable normative O&M expenses per bay of different voltage levels are taken as it is from the CERC regulations
- The O&M expenses of GIS for 400 kV are also specified in the CERC regulations as shown in the table above. After interaction with several stakeholders like Reliance, Sterlite Grid, Siemens and other researchers, it is found that the actual O&M expense for GIS are about 10% to 20% of the admissible O&M expenses of AIS specified in the CERC regulations.
- Hence, following things are considered for calculation of O&M expense:
 - As per vendor experience O&M expenses of GIS are about 10% to 20% of admissible O&M expenses of AIS; hence in this study it is taken as 20% of the admissible O&M expense of AIS for the calculation purpose.
 - O&M escalation rate as 5.72% per annum (as per CERC norms)

2.3 Capital Cost of GIS

Capital cost of GIS has been taken as flows after discussion with various vendors (without IDC):

Voltage Level	Switch Gear cost in Rs. Crores (per bay)	EPC and Civil Cost in Rs. Crores (per bay)	Total Cost in Rs. Crores (per bay)
132 kV	2	1	3
220 kV	3	2	5
400 kV	5	3	8

Table 2: Capital cost considered for GIS

2.4 Calculation Method

Net cash flow is calculated in the excel sheet. The method adopted is as follows:

Cash Outflow:

- O&M expense is considered as 20% of AIS O&M expense given in CERC guidelines
- Total capital cost considered is given in table 2. Phasing of capital cost is considered as 20% in year 1, 40% in year 2, 20% in year 3 and 20% in year 4

Cash Inflow:

- Savings in O&M expense if AIS is replaced with GIS
- Land cost (case wise) which is included in 4th year as it is assumed that land will be commercialized in 4th year

2.5 NPV including land cost

NPV is calculated including land cost for each voltage level with 5 different land rates:

Voltage Level	Land Rate (Per Acre) (Rs. Crore)	NPV (Rs. Lakhs)
132 kV		
	50 (Metro Cities)	291.35
	25 (Class A1 Cities)	131.80
	15 (Class B1 Cities)	67.98
	4.5	9.73
	1 (Other Cities)	-21.36
220 kV		
	50 (Metro Cities)	273.45
	25 (Class A1 Cities)	113.91
	15 (Class B1 Cities)	50.09
	7.5	2.22
	10 (Other Cities)	-39.26
400 kV		
	50 (Metro Cities)	459.33
	25 (Class A1 Cities)	193.42
	15 (Class B1 Cities)	87.03
	7	1.97
	1 (Other Cities)	-61.84

Table 3: NPV for different land rates

 Minimum land rates required for NPV to be positive

2.6 Payback Period

In a 10 bay substation, total capital cost including IDC (interest during construction), area of land saving, its approximate value (in Metro cities, class A1 cities, class B1 cities and other cities) and payback period are summarized below:

Voltage Level	Typical land area of a 10 bay s/s (Acres)	Area of land saving by GIS (Acres)	Value of land saved (Rs Crore/Acre)				Cost of conversion to GIS (Rs Lac) including IDC	Payback Period (Years)			
			Other Cities	Class B1 Cities	Class A1 cities	Metro cities		Other Cities	Class B1 Cities	Class A1 cities	Metro cities
132 kV	12	9.6	1	15	25	50	3239.26	NF	3 to 4	3 to 4	3 to 4
220 kV	12	9.6	1	15	25	50	5398.76	NF	3 to 4	3 to 4	3 to 4
400 kV	20	16	1	15	25	50	8638.02	NF	3 to 4	3 to 4	3 to 4

Table 4: Payback period for various cases

NF: Not Feasible (Life considered for substation is 25 years and payback was not received till that time, hence it is considered as not feasible)

3. Conclusion

NPV for 132 kV, 220 kV and 400 kV workout out to be very convincing when cost of land saved is above X crore/Acre for 132kV, Y crore/Acre for 220kV and z crore/Acre for 400kV substations.

Internationally multi-storeyed buildings have GIS in their basements for meeting the power requirements. India should also start adapting to the change in technology to make the Indian grid smarter, more reliable and with less environmental footprint.

Final conclusion is:

- ***If 132 kV AIS is located at a place having land rates of around 450 lakh rupees (4.5 Cr rupees) per acre and above then NPV will be positive with payback period of 3 to 4 years and it would be beneficial to convert it into GIS.***
- ***If 220 kV AIS is located at a place having land rates of around 750 lakh rupees (7.5 Cr rupees) per acre and above then NPV will be positive with payback period of 3 to 4 years and it would be beneficial to convert it into GIS.***
- ***If 400 kV AIS is located at a place having land rates of more than 700 lakh rupees (7 Cr rupees) per acre and above then NPV will be positive with payback period of 3 to 4 years and it would be beneficial to convert it into GIS.***