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COMPARATIVE STUDY OF ANALYSIS & DESIGN OF DOUBLE STOREY 400/220KV GIS CUM GANTRY (TOWER) BUILDING AND CONVENTIONAL GIS BUILDING

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***Abstract*— Construction of High Voltage substations in the heart of city is becoming more and more difficult. The difficulty in getting land, complex entrance and exit of high voltage overhead lines, increasing protest of neighbours, high priority of projects and short schedule to energize these substations are some of the common problems for those working in design and execution departments of power utilities.**

The land available for 400/220 KV sub-station projects in urban cities is very small and irregular. The complete project cycle of the GIS project from planning to commissioning stage is very time consuming and complex. Thus, the planned time to build GIS (Gas Insulated Substations) equipment is too long and could not satisfy the project's schedule. Under such conditions, to save space, time & cost, a Double Storey GIS building with 400 KV Gantry on the top of the building in 400/220 KV GIS substation can be evolved. This is a new way to solve problem of space in urban areas although there may be already other proven solutions. With this type of arrangement, we are expected to solve the land associated problem for the GIS substations.

***Keywords*— GIS Substations, Transmission Lines, Pre-Engineered Buildings, Staad Pro, utilization ratio, tapered section.**

I. INTRODUCTION

Power transmission industry is growing rapidly in most of the parts of the world. Considering the increasing use of electricity in a developing country like India, voltage drop of the domestic and commercial electricity users and inability to support the local substations with the existing system of transmission network, construction of high voltage transmission system along with associated substations in the country is felt highly important. The first step is to find a land with suitable conditions to construct a 400/220 KV GIS substation is the initial activity of any project. During the process of land acquisition and finalization, various pieces of lands is considered; the one with the low cost and no legal issue is preferred. But in urban areas in cities like Delhi, Mumbai etc the land prices are very high and also many associated legal issues are there.

In general practice of power transmission, the GIS substations buildings are built of RCC frame or steel frame having single storey. In a substation having two voltage level there is requirement to construct two different buildings accommodating equipment of different voltages. Considering the land availability in urban area, the conventional normal layout of 400/220KV GIS can be converted to double storey GIS building with 400KV Gantry on the top. So, this type of arrangement is needed for saving the land foot print. This building is of steel structure due to various technical and economic factors.

The use of steel structures is not only economical but also eco-friendly at the time when there is a threat of global warming. Here, "economical" word is stated considering time and cost. Time being the most important aspect, steel structures (Pre-fabricated) is built in very short period and one such example is Pre-Engineered Buildings (PEB). Pre-engineered buildings are simply, steel buildings in which excess steel is avoided by tapering the sections as per the requirement of bending moment. However, one may think about its prospects, but it's a fact about which many people are not aware of. Consider if we go for regular steel structures then time frame will be more, cost will be more, and both together will make it costlier project. Thus, in pre-engineered buildings, the total design is done in the factory, and as per the design, members are pre-fabricated and then transported to the site where they are erected in a time less than 6 to 8 week.

The structural performance of these buildings is well understood and, for the most part, adequate code provisions are currently in place to ensure satisfactory behaviour in high winds. Steel structures also have much better strength-to-weight ratios than RCC and they also can be easily dismantled. Another advantage of using Pre-Engineered Buildings is that, they have bolted connections and hence can also be reused after dismantling. Thus, pre-engineered buildings can be shifted and/or expanded as per the future requirements. In this paper we shall discuss the various advantages of using pre-engineered buildings in GIS substation and, with the help of example, a comparative study shall be made between pre-engineered Double Storey GIS building and conventional two single-storey GIS building with steel structure.

A. *Double Storey GIS (400/220KV) cum Gantry Pre-Engineered Buildings .*

Presently, large column free area is the utmost requirement for any type of industry and with the advent of computer software it is now easily possible.

With the improvement in technology, computer software's have contributed immensely to the enhancement of quality of life through new researches. Pre-engineered building (PEB) is one of such revolution. "Pre-engineered buildings" are fully fabricated in the factory after designing, then transported to the site in completely knocked down (CKD) condition and all components are assembled and erected with nut-bolts, thereby reducing the time of completion.

In our study, we have studied the comparison between buildings used in GIS substations. The building considered here is a two storeyed Pre-engineered building with 400KV GIS area on the bottom floor and 220KV GIS area on the second floor. Further to this the columns of the building has been extended above the top floor to further height to serve the purpose of the 400KV Gantry tower. Thus, the complete building served the purpose of the GIS hall as well as 400KV gantry tower. This building concept has been considered for comparison with the conventional type of buildings where it a two separate steel building with 400KV GIS hall at some distance from 200 KV GIS hall with the electrical connections in between the buildings.

i) ***Advantages of PEB in GIS Building.*** Following are some of the advantages Pre-Engineered building structures-

a) ***Construction Time***: Buildings are generally constructed in just 6 to 8 weeks after approval of drawings. PEB will thus, reduce total construction-time of the project by at least 40%. This allows faster occupancy and earlier realization of revenue.

This is one of the main advantages of using Pre-Engineered Building.

b) ***Lower Cost:*** Because of system approach, considerable saving is achieved in design, manufacturing and erection cost.

c) ***Flexibility of Expansion:*** As discussed earlier, these can be easily expanded in length by adding additional bays. Also, expansion in width and height is possible by pre-designing for future expansion.

d) ***Large Clear Spans:*** Buildings can be supplied to around 90m clear spans. This is one of the most important advantages of PEB giving column free space.

e) ***Quality Control:*** Buildings are manufactured completely in the factory under controlled conditions, and hence the quality can be assured.

f) ***Low Maintenance:*** PEB Buildings have high quality paint systems for cladding and steel to suit ambient conditions at the site, which in turn gives long durability and low maintenance coats.

g) ***Energy Efficient Roofing:*** Buildings are supplied with polyurethane insulated panels or fiberglass blankets insulation to achieve required "U" values (overall heat transfer coefficient).

h) ***Erection:*** Steel members are brought to site in CKD conditions, thereby avoiding cutting and welding at site. As PEB sections are lighter in weight, the small members can be very easily assembled, bolted and raised with the help of cranes. This allows very fast construction and reduces wastage and labour requirement.

From the numerous advantages of Pre-engineered building, in the present study, the points b and d are considered for the study, i.e. to save the steel, reducing cost and providing large clear spans, while all the other points are self-explanatory.

II. ANALYSIS AND DESIGN OF DOUBLE STOREY 400/220 KV GIS CUM GANTRY PRE-ENGINEERED BUILDING.

At present, Staad Pro software has been used to analyse and design Pre-Engineered Building structures and conventional structures. In the first example, a 3D model of a Hostel building has been designed and compared with conventional structure using conventional steel. In the second example, a 2D plane frame of width 44m for both PEB and conventional has been designed and comparison has been made in terms of weight of steel. In the third example, a 2D plane frame of width 88m has been designed with tapered sections for PEB, this example is not solved with conventional sections as it is neither possible by using only conventional steel sections nor it is economical. This frame has been designed for different bay spacing to choose the most economical.

A. *Double Storey 400/220 KV GIS cum Gantry Pre-Engineered Building by Staad Pro*

The power tool for computerized structural engineering STAAD Pro is the most popular structural engineering software product for 3D model generation, analysis and multi-material design. It has an intuitive, user-friendly, visualization tools, powerful analysis and design facilities and seamless integration to several other modelling and design software products. The software is fully compatible with all Windows operating systems. For static or dynamic analysis of Pre-engineered building, STAAD Pro has been the choice of design professionals around the world for their specific analysis needs.

B. *Structural Analysis and Design*

STAAD Pro software can be used for analysing and designing of the pre-engineered buildings. It gives the Bending Moment, Axial Forces, Shear Forces, Torsion, Beam Stresses of a steel structure so that the design can be done using tapered sections and check for the safety.

i) *Static Analysis*- At present, using the Staad Pro software, 2D/3D analysis has been done using Stiffness Matrix Method. All the components of Pre-engineered building are tapered using the in-built option of the Software. The software provides options for hinged, fixed, and spring supports with releases so as to analyse as per our requirement. Herein this work, fixed supports are assigned to the structures. It also facilitates Linear, P-Delta Analysis, and Non-Linear Analysis with automatic load and stiffness correction. Multiple Analyses can also be done simultaneously which reduces the time. It also has an option of assigning members as tension-only members and compression-only members for truss structures.

ii) *Dynamic Analysis*- Dynamic analysis has been done in the present work taking seismic loads and wind loads into consideration. The software provides automatic load generation for seismic and wind forces; however, the seismic loads and wind loads are calculated manually for the present work as per IS codes. The software also provides Loading for Joints, Members/Elements including Concentrated, Uniform, Linear, Trapezoidal, Temperature, Strain, Support Displacement, Prestressed and Fixed-end Loads. It also provides the facility of Combination of Dynamic forces with Static loading for subsequent design.

III. GAP IN STUDY

Various studies have been made earlier where the Pre-Engineered Buildings were found to be more economical than Conventional Steel Buildings in GIS Substations, especially for GIS with less number of bays spanning up to 60m with eave height up to 30m. But where there is less space and we cannot construct two separate buildings for 400KV and 220KV GIS Hall separately then there is lot of issue in layout optimization. In this no studies have been made so for to accommodate two GIS halls one above another with the gantry at the top. So, there is the need of developing a new layout of GIS substation to achieve the economical construction of GIS Building in the terms of cost and erection.

IV. COMPARISON BETWEEN THE CONVENTIONAL GIS STEEL BUILDING AND DOUBLE STOREY GIS CUM GANTRY BUILDING

Properties	Conventional GIS Building	Double storey GIS cum Gantry Building
Design	Requires heavy detailing with modifications	Requires specialized computer design
Foundation	Widespread foundations are required	Easy to manage and light design work
Structural weight	Conventional steel section is used which are heavier than pre-engineered section	Efficient use of steel at different components of section which reduces the weight from 20% to 40 %
Erection	Sections are needing to be modified as per site conditions	Pre-casted sections are designed as per the site necessity
Erection cost and time	It takes time up to 10-12 weeks for erection and expensive as compared to PEB	Over all Erection time is less than 6 weeks which makes it cost effective
Overhead space	Use of standard sections limits the overhead space	It may vary according to convenience
Inside space	Large spans CSB with interior columns reduces the inside space.	Interior columns are eliminated due to which the inside space increases
Aesthetic	Average in terms of aesthetic experience	Aesthetically nice
Seismic resistance	Rigid and heavy structural members do not perform well against the seismic reactions	Light structural members can perform well against seismic reactions
Safety and responsibility	Multiple supplier units result in inefficient management of building materials and sections	Order is fulfilled by a single supplier leads to better management of materials and sections
Performance	Faulty connections may lead to poor performance	Higher performance due to efficient bracing system
Economy	Economical in terms of cost but uneconomical in terms of erection time	Economical in terms of erection time and economy
Demount ability	May take more time for demounting	Less time required for demounting

V. COST COMPARISON BETWEEN THE CONVENTIONAL GIS STEEL BUILDING AND DOUBLE STOREY GIS CUM GANTRY BUILDING

	Conventional Building	Proposed Building
Land Required (hectare)	12	4
Land Cost for Urban Area (INR in Cr.)	26.28	8.76
Weight of Structural Steel (ton)	300.00	610.00
Cost of Structural Steel (INR in Cr)	3.75	7.62
TOTAL COST (Cr.)	30.03	16.38
Savings in Primary Investment (Cr.)	13.65	

VI. CONCLUSION

As it is seen, wherever the required land for substation is not meeting the requirement and the available resources for establishing a GIS substation is not enough, the layout can be changed to double storey GIS building with gantry on the top. As it is can be clearly seen in the present work, the land requirement can be reduced by 66.6% for the double storey GIS cum Gantry building, providing lesser land footprint as against conventional GIS building. This type of solutions is relief for contractors of the project who are generally worried about the elongation of the time schedule due to time consumed in acquisition of large land area and thus delay in execution and commissioning of project.

The time schedule was reduced to 6 months from the base plan. The quality assurance, the workload and the functioning of the substation had increased in a feasible way. Comparison also clearly shows that even though structural steel weight required in the proposed building is two times the requirement of conventional building there is overall cost saving of about 49.9 %. The saving in the primary investment based on land and steel can be approx. 18,92,49,155.20 INR . With the right decision of Engineering this type of processes cab be introduced to other upcoming projects which will be a great success.

Hence the double storey GIS cum Gantry building is more advantageous over conventionally designed GIS buildings for two separate voltage level in terms of cost effectiveness, time saving, future scope, subtleness and economy. This paper of comparative study between conventional and double storey GIS cum Gantry building shows their experimental and analytical studies carried out in this field. The results show that the double storey GIS cum Gantry building are far more economical energy efficient and flexible in design than other type of buildings in GIS substations.

Further costs can be reduced by more detail analysis of the foresaid topic as it is also seen that the weight of PEB depends on the Bay Spacing, with the increase in Bay Spacing up to certain spacing, the weight reduces, and further increase makes the weight heavier.

For longer span structures like the one considered in this work, conventional buildings are not suitable with clear spans. Double Storey GIS cum Gantry Pre-Engineered Building are the best solution for longer span structures without any interior column in between as seen in this present work. With the advent of computerization, the design possibilities became almost limitless. Saving of material on low stress area of the primary framing members makes proposed building more economical than Conventional steel buildings.

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