

Feasibility Study to Implement 3D Printing in Transmission Power Substations

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Abstract: 3D printing technology have been recently widely used among many industries including but not limited to medical, building construction, aerospace, education, industrial and more. In this paper, the authors focus merely on the technology's application in the construction sector and specifically industrial buildings to put together a feasibility study to implement 3D Printing in Transmission Power Substations. The paper explains the methodology used to conduct the study and explores the outcomes which define the pros and cons of this technology when applied in this particular field.

Keywords: 3D Printing, Traditional Construction, Time, Cost, Quality

1. Introduction

Transmission substations in Dubai are usually built following the traditional construction method using reinforced concrete (cast in - situ or precast) and blockwork. The main objective of the study is to conduct a feasibility study to implement 3D printing technology in transmission power substations. Through this paper, the authors examine the benefits and setbacks of the 3D printing technology in terms of cost, quality and time.

The methodology adopted here is mainly following semi - structured interviews to gather the information needed from different 3D vendors in order to obtain the necessary input for the feasibility study. One of the main advantages of interviews is the possibility of collecting detailed information about research questions. Moreover, in this type of primary data collection, researchers have direct control

over the flow of process and they have a chance to clarify certain issues during the process since it is based on interactive meetings. Disadvantages, on the other hand, include the process being time consuming and challenges associated with arranging meetings with concerned group members based on their availability to conduct interviews.

2. Literature Survey

As a preliminary study, the authors selected a smaller scope of work to evaluate the construction advantages and disadvantages of 3D printing which was the security room and toilet. The table below includes the basic information of the studied area which will be referred to as "the base case scenario" in this paper. The average total cost estimation was obtained from one of the leading contractors who have worked in Transmission Power Substations in Dubai.

Area of study	Dimension	Architectural Plan (Base Case Scenario)	Estimated Avg. Total Cost
Security Room	3000L*3000W mm		<p>AED 196, 363 - Note: The cost is for the structure above the ground only.</p>
Toilet	3000L*2000W mm		

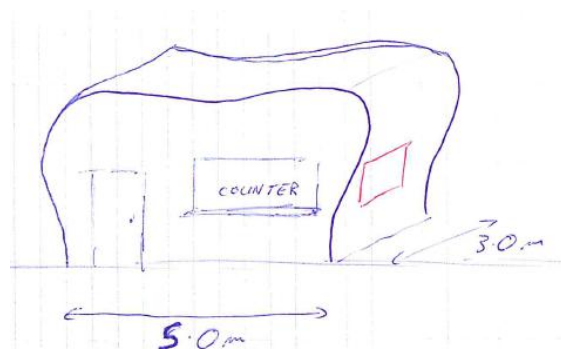
3. Methods and Approach

The authors interviewed three local 3D Vendors, briefed them about the purpose of the study and the anticipated outcome from it. In this paper, the vendors will be distinguished as Vendor (A), Vendor (B) and Vendor (C). After the initial interviews, all vendors agreed that the project's nature is well - suited for 3D printing technology. However, all agreed that in order to reap all the benefits that 3D printing has to offer over the traditional construction methods, a complexity is recommended to be introduced to the design instead of a rectangular room shape.

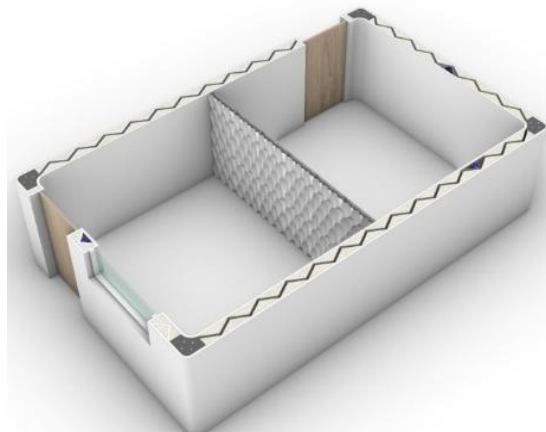
Vendor (A)

Vendor (A) recommended a curved walls and roof which, in traditional construction method, would require special

formwork, skilled manpower, special materials and longer time frame. Below is a conceptual sketch provided by Vendor (A) to show an example of a more complex/creative design.



However, in order for the authors to undergo a more accurate comparison between the 3D printing and the traditional construction method, the authors requested Vendor (A) to stick to a design shape similar to the base case scenario with minimal changes so that the authors can precisely compare both methods from cost, time and quality point of view, while fixing the design variable. Below perspective is the revised design proposed by Vendor (A) with very minor changes introducing a pattered/textured internal wall between the security room and toilet. Accordingly, Vendor (A) estimated the time to complete the project as two weeks and it would cost approximately AED 200, 000.



Vendor (B)

Vendor (B) was also excited for this project and informed the authors that the project nature is doable by 3D printing especially since they have already completed a project with a similar function (Guard Room). The vendor suggested proposing similar concepts to the security room and toilet.

Pictures of the Guard room project done by Vendor (B) is shown below.



The authors were impressed by the quality and level of design complexity produced by 3D printing. However, similar to what was conveyed to Vendor (A), Vendor (B) was requested to stick the basic design of the security room and toilet in the substation to obtain the most accurate comparison. The vendor complied with the request and

provided the time and cost estimation as approximately 2 weeks and AED 160, 000, respectively.

Vendor (C)

In addition to the vendors above, Vendor (C) also estimated the design time and cost using 3D printing for the exact design as 3 days and AED 174, 500, respectively.

4. Results and Discussion

3D Vendor	Approximate Cost	Time	Scope of work
Vendor (A)	200, 000AED	2 weeks	Including MEP and HVAC services as well as insulation and some civil works (above ground level)
Vendor (B)	160, 000AED	2 weeks	Excluding MEP and HVAC services as well as civil works and insulation
Vendor (C)	174, 500AED	3 days	Excluding MEP and HVAC services as well as civil works and insulation

Below is the summary of the information provided by the three 3D Vendors in terms of time and cost.

Based on the information gathered from the vendors, a comparison between 3D printing construction and conventional construction from time, cost and quality aspects is summarized below:

Method	Conventional Construction (Base Case Scenario)	3D Printing Construction
Time/ Duration	2 - 3 months. The construction completion is usually delayed for several weeks due to slow labor, process of poring and casting, shuttering removal and curing of concrete.	3days to 2 weeks The duration depends on the 3D Vendor and the equipment (type of 3D printer) used.
Cost	Approximately 196, 369AED (limited to construction works above ground level of Security Room and toilet)	180, 000AED on Average (limited to construction works above ground level of Security Room and toilet). The provided quotation is excluding the in - situ civil works.
Quality	The quality of the project/building depends on the labor skills during construction.	The quality of the building is completely determined and controlled by the 3D printer with minimal human interference. This results in higher quality and less formation of cracks or unwanted joints.

5. Conclusion

After careful consideration and comparison between the two different construction methods, the authors concluded that constructing the security room and toilet using 3D printing with the current design and specs is not feasible.

Although there is a significant time reduction using 3D printing over its superior method, there is minimal cost benefits. The time reduction, in this case, is not very beneficial since the main building of the substation will be constructed using the traditional methods and the construction of security room can be constructed traditionally (in parallel) with the construction of the main building. Using 3D printing for constructing the security room and complete the work within 2 weeks (excluding the in - situ civil works and services) will not add significant value to the overall project duration.

However, using the 3D printing construction for the security room may be beneficial if the design is changed to a complex design since it will no longer be a good option to construct using the traditional method which will require skilled labors and special formworks that will all add to the total cost of the project.

Despite the impressive project duration and other aspects, there are few limitations of using 3D printing for constructing the security room and toilet including the following:

- 1) 3D printing construction cannot be utilized for substructures (rafts and foundations) and horizontal elements (beams, slabs and roofs) which means that eventually the traditional construction method will be used to complete the project. Hence, the project duration and cost will be impacted.
- 2) In Dubai, the government regulations and codes of 3D printing for construction is not yet developed by the concerned authorities which means that the process of getting the building permit and necessary approvals to execute the project using 3D printing might be complicated and take longer time.
- 3) Currently, in Dubai, most 3D Vendors are constructing buildings of single floor only due to the absence of 3D printed buildings codes/regulations. This means that it is not possible to consider 3D printing for the entire substation which is a (G+1) building, until the regulation is developed and approved.

6. Future Scope

Aside from the setbacks and limitations mentioned above, the authors still believe that there is room for implementing the 3D printing technology in transmission substations other than the security room and toilet.

For future studies, the authors suggest studying the feasibility of implementing the 3D printing to the boundary wall of the substation. The authors believe that using this technology will allow fast construction of the boundary wall as well as integrating special designs, curves, textures or patterns within the wall with a high quality and impressive finishing.

The applicability of 3D printing for different elements need to be further studied and confirmed since the boundary wall is a continuous and long structure surrounding the entire substation plot and might require to be printed in small segments/sections at the 3D facility or in - situ printing depending on the vendors' recommendations and methodologies.