A case study on the expansion of power plant from simple cycle to combined cycle

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Abstract

This is a case study of expansion of a power plant from a simple cycle to a combined cycle in Cote d'Ivoire in West Africa. The project is called CIPREL IV Volet B Project. The original plant was composed of 2 units of Gas Turbines (GT) and related equipment. With increasing demands on the electricity in Cote d'Ivoire, the owner of the plant came up with an expansion plan and KEPCO E&C won an EPC project. For the expansion of power plant, a Steam Turbine (ST), two units of Heat Recovery Steam Generators (HRSGs), an Air Cooled Condenser (ACC), and many of other equipment are installed. This paper focuses on civil works among many fields of engineering in the project. In this paper, efforts to overcome environmental and geographical challenges are described. Creative civil design concepts and construction methods of civil works are also described. To address the underground water, the submerged rectangular concrete casing method was applied. Vibration damping springs were installed under the ST foundation instead of pile works. To avoid interference between exist piping line and new civil structure, and to maximize the efficiency, precast concrete product and related construction method were applied. Furthermore, to save transportation costs, steel members were divided into segments and delivered using container.

Keywords: Combined Power Plant, Expansion, Submerged Rectangular Concrete, Vibration Damping Spring, Precast Concrete Product, Segment

1. Introduction

1.1. Project General

The Republic of Cote d'Ivoire, the driving force of West Africa, has resolutely taken up the path to development in a climate of peace. This move will inevitably require investment in infrastructure and electric power, an area where demand is growing at a fast pace (+18% annually). According to this demand increase, the CIPREL IV Volet B Project had been started in the middle of 2013. The plant had been already operated in the simple cycle mode with 2 units of gas turbines and generators. To increase efficiency of power generating capacity without additional fuel, the expansion works from simple cycle to combine cycle had been begun. To this end, one (1) Steam Turbine (ST), two (2) Heat Recovery Steam Generators (HRSGs), one (1) Air Cooled Condenser (ACC), and related equipment were installed.

This is ongoing project and is schedule to be finished in December 2015. This paper is focused on civil works among many fields of engineering in the project. In this paper some of creative civil design concepts and construction works are introduced to overcome obstacles for the successive project.
2. Plan and Construction

As shown on Figures 2 and 3, the master plan was composed with GTG (Gas Turbine Generator) 1 and 2 that are existing. The GTGs generate electricity using fuel gas and emit exhaust gas with heat. This exhaust gas is transferred to HRSG (Heat Recovery Steam Generator) 1 and 2, and steam is generated inside of HRSG 1 and 2. HRSG 1 and 2 are new facilities. The steam is transferred to STG (Steam Turbine Generator) that is inside of STB (Steam Turbine Building) through the steel pipe line on the piperrick. Steam pipe is most important pipe among the entire piping system. STG, STB, Piperrick and Steam pipe line are new facilities. Using steam, STG can generate electricity and this generated electricity is transferred to transformer nearby STB through IPB (Isolate Phase Bus). Used steam is transferred to ACC (Air Cooled Condenser) for cooling and recycling. At ACC, used steam is cooled, condensed and become water. This condensate water is transferred to HRSG again for recycling. The ACC is controlled in the ACC electrical room under the ACC and those are also new facilities. The waste water from each facility is transferred to the water treatment facility. Before waste water is discharged to outside of plant, water is treated fully. The expected total amount of generated electricity is 119MV.
3. Obstacles to Project

During the project, we have faced many kinds of obstacles. In this paper, we describe briefly four main obstacles and how we could address them. First is that the entire process of the project including design, procurement, delivery and construction shall be finished only within 2 years. Second is distance from Korea to Cote d’Ivoire taking more than 20 hours by airplane. Furthermore, communication between the design team in Korea and the construction team in Cote d’Ivoire is difficult due to an 8-hour time difference. Because of the short project duration, sometimes engineering decisions shall be made urgently between design and construction engineer groups with considerable thought. However, these kinds of judgments are hard to make fast due to the time difference. As a result, this may induce waste time of construction. Third is lack of quality infrastructure in Cote d’Ivoire. According to the minimum functional specifications (MFS), we have to produce results with high quality within a limited project budget. We had to use domestic construction equipment (fork lift, back hoe, drilling equipment, etc) and construction materials (steel plate, anchor, etc.) to minimize unnecessary spending according to priority. The transportation costs may exceed the budget, if all equipment and materials are procured outside of Cote d’Ivoire. However, we sometimes cannot use heavy equipment because of limitation on available equipment. So, we must wait until such heavy equipment is available. It is indeed difficult to speed up construction works even after necessary equipment acquired because of poor management conditions. As a result, we shall undergo the project with limited construction techniques. These obstacles are summarized on Table 1. Fourth is natural and social environment limitation. During the raining season (about 2 months), construction cannot be carried out preventing from securing enough time. The construction site is reclaimed land and there exists sea nearby the construction site. So underground water elevation (EL.) is only GL - 2.0m. In addition, the leaked oil from the underground oil pipe line is mixed with the water. So, we shall treat this oily water before draining this oily water out of the site. The spread of Ebola-virus disease in 2014 in the West Africa region also brought impacts on the procurement plan.

Table 1. Obstacles to Project

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<th>First</th>
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<tr>
<td>Short construction period</td>
<td>Distance and time different</td>
<td>Lack of equipment and low quality of material</td>
<td>Natural and social condition</td>
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Figure 4. Site View After Rain Fall

Figure 5. Underground Water After Excavation
4. Efforts

4.1. Vibration damping spring

We applied vibration damping spring between STG and STG foundation. STG is one of the most important and expensive equipment for a power plant. As STG is rotary equipment, stability check under each step of vibration shall be conducted. In consideration of the sensitive characteristic of STG against vibration, STG foundation is usually constructed directly on the bed rock or pile foundation is applied. In this project, after detail structural analysis by civil engineers, we noticed a huge STG foundation will be needed with a deep foundation (pile or casing) due to the bad status of geological condition where soil lay is too thick. It is the reason that we cannot apply point bearing piles even though the soil status (sand) itself is relatively good. Instead of soil improvement and huge foundation, we selected to install vibration spring. By adopting this design concept, cost increase in civil material, construction fee and duration outweighs additional costs increase in the equipment price itself.

![Figure 6. Vibration Damping Spring](image1)

![Figure 7. STG Foundation (sub part) Before Vibration Damping Spring Installation](image2)

4.2. Segments delivery

We divided structural steel members to segements and transported them to the site using container boxes. Usually, one body member (not segment) is better considering convenience of installation and detail steel design since connection details are not needed. In this sense structural steel member is usually fabricated as one body member if fabrication is available and there is no problem on lifting, installation, transportation technique. However, we divided one structural steel member into segments for better transportability from the fabrication factory in Dubai to the construction site, even though no issues on fabrication, transportation technique, lifting and installation were foreseen. In case that some long members cannot be transported using container, they had to be shipped as bulk cargo despite small amount, charging more than the costs of connection detail fabrication works because of long transporation distance..

4.3. Submerged rectangular casing method

Inside of STB, there needs a deep concrete pit (ottom elevation is about GL -7.0m) in order to guarantee the performance of ACC. However, there exists electrical building in the near distance and ground water elevation is GL -2.0m. For water prevention, sheet-pile method is not available with no available sheet pile and related equipment at that time, which in turn we have to select submerged concrete casing method instead of any other water prevention methods. Figure 8 shows the section view of a concrete pit. The Submerged rectangular casing method is applied according to the following procedures;

1st : Construct the 1st wall of a concrete pit on soil
2nd : Bituminous coating for concrete protection and decrease friction between soil and concrete pit
3rd : Submerge
4th : Construct the 1st, 2nd slab and 2nd wall
4.4. Precast concrete product

We applied precast concrete product to the site boundary wall (Length: 420mm, Height: 5.0m) to save costs and to accelerate construction works together since no form work was needed with placing the precast concrete shop in the corner of the site. All precast walls and columns for the site boundary wall were made at site.
5. Conclusion

For expansion works for a combined power plant, new equipment shall be installed while obstacles potentially interrupting constructions works exist. In an effort to tackle such obstacles, creative methods as shown below were introduced and applied to the civil works. As a result the total costs could be saved and construction could be preceded as planned while achieving cost cuts.

(1) Vibration damping spring
(2) Segments delivery for steel member
(3) Submerged concrete casing work
(4) Precast concrete

For the success of project, most important thing is to make a close investigation about site condition, usable infrastructure and culture. Sometimes old technique can be better than latest technique when we consider all things at the same time. So, technical decisions through brainstorming among engineers like described above are very important and essential.

Acknowledgements

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References

[1] American Concrete Institute (2005), Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05), ACI Committee 318, Farmington Hills, Michigan.