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Hoang Nguyen

Project Management Electrical Installation of a 50MW Solar Power Plant

Metropolia University of Applied Sciences

Bachelor of Engineering

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For a graduating project in Metropolia UAS, the author of this thesis worked as a project engineer in the management team for electrical installation of a 50MW Solar Power Plant. His goals of the thesis were to gain experience in the solar industry, to apply relevant knowledge and to understand the managerial role.

To accomplish that, first some theoretical review was undertaken, including solar power background which was his University specialization, and project management behaviors. The inherited knowledge made impactful contribution to his application of the complex electrical design. Meanwhile, the later entry of the review proved to be more crucial; as the role of a project management helped improve his awareness of scheduling, leadership, resource manipulation, risk monitoring, quality assurance and auditing.

During the planning phase, the author combined both theoretical enhancements to support his manager building a plan. The project contained installing electrical devices, conductors and safety measures. The plan divided the management team so each member handled one aspect; it also set up human management and construction methods. Due to the dependencies, the team did not achieve a solid schedule; instead they had to be prepared and adaptable to the scenario. The plan also required some documentation for progress reporting and payment.

The execution promised a challenging period for the team. They carried themselves through sensitive human communication and dealt with uncomfortable situations. Although their budget plan made it easier to handle the cost, the quality control demanded the most effort for monitoring the work.

Nevertheless, the project resulted in a success for all related parties; the components were installed correctly and the company received its deserved payment. Regarding the author; although his prior solar power knowledge was hardly applied, he achieved valuable experience and was praised by his inferior for his work monitoring.

Keywords	solar power, electrical, project management, human management, resource manipulation

Contents

Acknowledgement

I would like to have a few words expressing my gratitude to a few people that helped me during the thesis project. From Metropolia UAS, Mr. Kari Salmi, my thesis supervisor, will receive my many thanks for providing me helpful advice and supportive instructions. Also, Mrs. Minna Paananen-Porkka is very patient and informative as she makes constructive comments and useful correction for the language used in my thesis. On the other hand, I would like to show my appreciation to Mr. Ngô Hùng Mạnh for granting me the opportunity to work on the largest project the company has ever handled, and to the supporting team at headquarters' for the procurement process.

Regarding the on-site parties, first I would like to mention my admiration of the shared experience, both about work and life, to my colleague, Mr. Đặng Viết Tưởng and of the advices to the Head of the management team, Mr. Nguyễn Tiến Văn. Also, I send my blessing to both of them for the future they have chosen. For the people outside of Seco-Solar, I would like to show respect to Mr. Đặng Vũ from DTC for his contribution to the project and for the cooperation as our superior. Lastly, I want to thank Mr. Đặng, a technical supervisor from PCZ that we called by his nickname, for the guidance and praise to our work.

Before I finish my acknowledgement, I would like to reflect on myself in this project. Personally, for a graduating student, I believed this would be a good opportunity to uncover first-hand how engineering was conducted; on-site work demanded loads of work, but I expected joy along the journey. From my first thoughts about the job, I assumed there would be much computer work with a considerable amount of data. Therefore, I set my mind on enhancing data sorting skills and construction related programs. As I was going through definition and development of this project, I realized a more important, impactful and career-building requirement that was people skills. This set of skills motivated people to well behave to others, regardless of their status; in the long run, people would acquire solid connections and might exceed in their careers. Such promising achievement could not come readily; it took time, patience, energy and good intention, particularly for a manager.

List of Abbreviations

AC	Alternative Current – a form of electricity used in most household devices.
DC	Direct Current – a form of electricity generated by solar panels.
FD	Financial Department – Seco-Solar’s supporting team from headquarters’ covering procurement and payment processes.
HH	Hoa Hiep Ltd - one of the supporting contractors for PCZ in the project.
LV	Low Voltage - In the text LV cable means one type of cable in the project, conducting current at low voltage.
MV	Medium Voltage – In the text MV cable means one type of cable in the project, conducting current at medium voltage.
PCZ	PCZ Sinenergy - the main contractor for the project Sinenergy Ninh Thuan I Solar Power Plant - 50MWp.
PM	Project Management – a team of Seco-Solar’s technicians and project managers carrying on-site tasks for the project.
PV	Photovoltaics – In the text PV cable means one type of cable in the project, connecting between panels and from panels to combiner boxes.
Seco-Solar	Seco-Solar Trading & Technical Service Ltd – one of the sub-contractors under HH’s supervision.

1 Introduction

Solar energy has become more and more popular in Vietnam. With the high solar intensity of the Southern area and the encouragement from the government policy, there have been over 100 Solar Power Plants under construction between 2018 and 2019, promising to contribute 5TW to the Vietnamese national grid. The author of the thesis was chosen to work as a member of the project management team by the company, Seco-Solar Trading and Technical Service Ltd., involving in the installation of the Sinenergy Ninh Thuan I Solar Power Plant - 50MWp. Therefore, this thesis is on the progress and development of its author during the course of the project, and this chapter will address the goals of the three parties, including the goals of this thesis and those of the solar power plant project and the company installing the plant.

First and foremost, by finishing this thesis document, the author aims to prove the capability to handle technical project work in a managerial department. The objective includes understanding of a management role, application of solar energy knowledge and experience enhancement.

Sinenergy Ninh Thuan I Solar Power Plant - 50MWp was one of the five Solar Power Projects located on the side of Tà Ranh Lake in Phước Hữu District of Ninh Thuận Province. With the total area of 6km^2, the plant would harvest solar energy in order for the owner, A2 Technologies, to gain profits from selling solar energy to the Vietnamese national electricity company (EVN) under electricity form. At the same time, the project transformed an excess desert area to a functional land, thereby creating work opportunities for local people and also upgrading their skills as construction workers for upcoming solar power projects.

Lastly, Seco-Solar Trading and Technical Service Ltd., being referred to as Seco-Solar in the following chapters, would train a team of reliable solar-engineering specialized technicians. The solar power project made it possible to observe how managers operate, to learn how to make better decisions and to view the different aspects of the situation. It was easy to make money on a project, but the ultimate goal must be to develop oneself. “Financial income is not the key to victory, a reliable team of experts can deliver the desired product of any given standards; and that is what I am building today." The owner of Seco-Solar Ltd. – Mr. Ngo Hung Manh

2 Project background – Companies and related parties

This chapter is a basic introduction to the project and its participants. It explains the location and provides a brief description of the project; the companies involved and their related scopes are also mentioned, along with the expectation, scope and requirements from the author.

2.1.1 Location

Located on the southern part of Vietnam, Ninh Thuan Province captures the most solar radiation in the whole country. Hence, the desertification process is enhanced and a majority of soil is covered in sand, so hardly any flora farming can be done. However, solar farming has increased in this area since 2010; and it helps the Province immensely. The local people work and familiarize themselves with the solar power technology, they have become trusted workers with high quality and solar centered knowledge.

On the other hand, a vast number of contractors, subcontractors and engineering companies have come to survey the land for construction of solar power plants. Hence, the travel service has grown; and the Province once lacking inhabitants is now becoming populated.

About 10 kilometers from the national highway, the Phước Hữu district has drawn the solar investors' attention, inserting 5 Solar 50MW Power Plants in one district. Being next to Tà Ranh Lake and Mountain, the Sinenergy Ninh Thuan I solar power plant - 50MWp promised its contribution to solving the energy crisis in Vietnam lately.

With the inclination of 15 to 25%, the landscape makes it hard to design a solar plant or to complete precise measurements. The soil layers are also problematic as under the sand layer there are a thin clay layer and a dense rock layer thus any foundation installing activities come after drilling and occasionally rock explosion. Furthermore, the vexatious soil components make it impossible for natural water runoff after a rainy day.

Those landscape issues did not stop A2 Technologies on an attempt to exploit the wasteful deserted area and engage in a long term profitable solar power project.

2.1.2 Description

Being a part of the Asia Precision Public Company Ltd [1], A2 Technologies Company Ltd has its credentials on energy related businesses over the South East Asia. Their main activities involve distributing constructional materials and tools for power plants and provide engineering services. In addition, their work extends to water services with water treatment and related services.

In Phước Hữu district, A2 Technologies tended to build a Solar Power Plant with a capacity of 50MWp on a rectangular shaped area with the dimensions of 6km length and 1km width. Figure 1 describes the geographic features of the Power Plant, including the local landscape, the entrance path, the coordinates and the plant location. As can be seen, the plant stood on the lakeside of Lake Tà Ranh, having its entrance in the south west area. From the south east area, the dashed line indicates the high-voltage gridline from this power plant, connected to other power plants and integrated to the national grid.

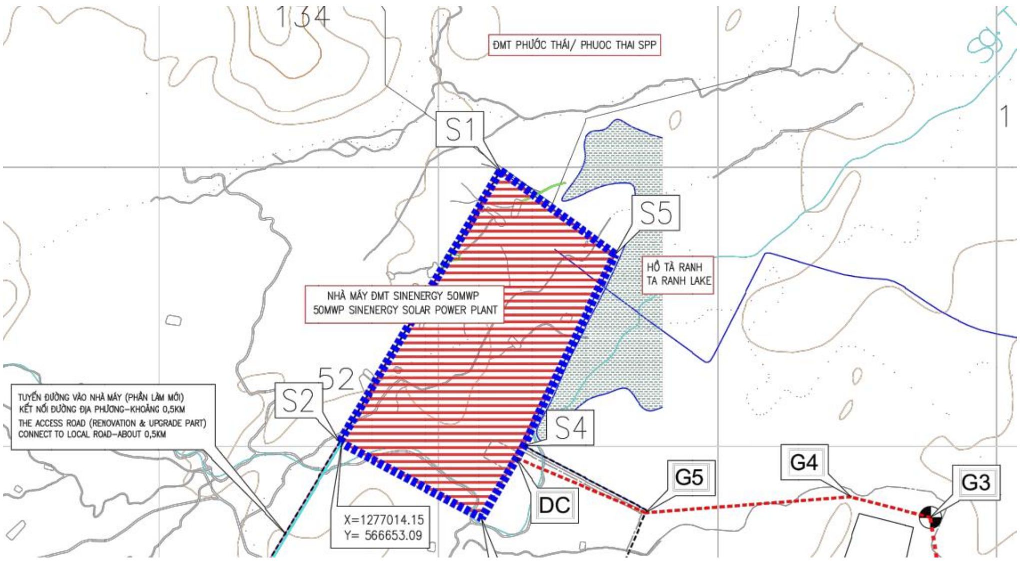


Figure 1. Location of the Power Plant. Reprinted from A2 Technologies [2]

Note: Appendix 1 shows more pictures of the Power Plant condition in reality.

The project is called Sinenergy Ninh Thuan I solar power plant - 50MWp, with the aim of harvesting the solar energy for selling to Vietnam's National Electrical Company. The main contractor is Sinenergy from China; they provided the design drawings and the main list of materials.

The overall system of the power plant consists of over 151,000 solar panels transmitting DC electricity to combiner boxes, which gather the power and transmit it to the inverters. Then, the inverters shift it to AC form, increase the voltage and transmit the electricity to the main control house, which has a main inverter and a main transformer. Finally, from the main control house, the electrical flow is raised to 110kV in order to join the main national grid line.

2.1.3 Organization hierarchy

As mentioned in figure 2, A2 Technologies Company was the owner of the constructing power plant. Along their side was the main contractor Sinenergy PCZ, who provided materials and consultancy; they also monitored the work of the contractors, including 319 Construction and Hoa Hiep companies. 319 Construction handled the installation of PV panels, while Hoa Hiep was responsible for electrical installation and building the control house. Under supervision of Hoa Hiep are 7 sub-contractors, with Seco-Solar being one of which; Hoa Hiep authorized Seco-Solar to be in charge of cable laying and connection, grounding system installation and device installation.

Note: The companies mentioned in this chapter will from now on be referred to by using abbreviations of their names; the owner will be A2, the main contractor is PCZ and Hoa Hiep will be HH.

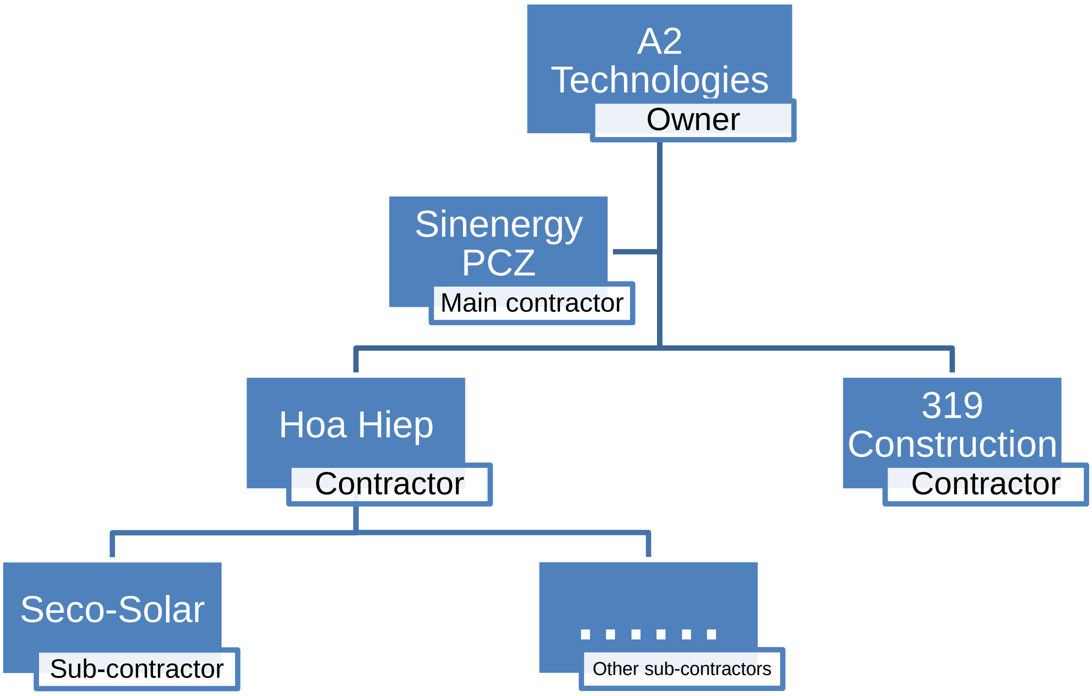


Figure 2. Project organizational hierarchy

According to the contract, the scope of Seco-Solar consisted of, but was not limited to, the following tasks:

1. Installing the horizontal grounding system
2. Attaching the vertical electrodes to the horizontal grounding system
3. Installing the grounding steel of PV mounting structures
4. Installing the grounding wire in cable trenches
5. Inserting the inverters to the prepared foundation
6. Assembling the combiner box supports and installing them with the combiner boxes
7. Pulling and laying cables
8. Connecting cables to the responsive devices

In the process, if any additional tasks occurred, Seco-Solar would receive additional payment for completing them. In addition, for ease of communication, Seco-Solar would prepare an inspection with the main contractor PCZ and if the inspection resulted in approval, it would be used in the payment document with HH. Similarly, Seco-Solar may directly ask for materials supply from PCZ, receive materials and return them. HH would not have to be present in those situations; instead they monitored the actions via daily reports and provide payment or penalty based on approval of PCZ.

From the hierarchy, it seemed that PCZ was a consultant and HH just distributed and organized the workflow between its sub-contractors; in fact, they had more impact on the work, although it would be carried out by Seco-Solar and the reciprocal parties. Firstly, the plan of the company the author worked for must be approved by both HH and PCZ before being deployed; this is a usual procedure in any construction project. Next, the equipment and management personnel had to either have a certificate or pass tests to prevent unnecessary breakdowns. Finally, a complex agreement between the parties indicated that both HH and PCZ supplied materials for the Power Plant; which caused a large number of problems involving the timing of delivery and correspondent types of materials.

Table 1. Supply breakdown example

Task description (Seco-Solar)	**Materials**	**Equipment & Resources**
Inverter installation Installing inverter to its foundation and attaching by electrical welding	PCZ: inverters HH: Metal plates, welding rods, rust-proof paint	Lifting crane Civil workers Electrical generator, welding machine and paint brushes

According to the agreement, PCZ would purchase and deliver heavy devices and conductors, while HH was responsible for light and consumable materials. Table 1 brings about an example about a process breakdown to its materials, equipment and resources. To install an inverter, first HH would have had to prepare a foundation including metal plates; then Seco-Solar inserted PCZ’s inverter on to the foundation and fixed it by electrical welding on the plates. Finally, since the plates could be damaged by welding, rust-proof paint had to be applied for further protection. The table suggests that PCZ would only supply inverters and their accessories like ventilation and grounding media; the rest of materials and consumables were provided by HH. Seco-Solar was responsible only for arranging a lifting crane, some workers and suitable equipment. PCZ and HH would not prepare equipment and resources; similarly, Seco-Solar was strictly forbidden to contribute their own materials for the project; a doubtful ventilation part would be investigated and an agreement fine would be credited to the responsible parties.

2.1.4 Seco-Solar

About the Project Department, Seco-Solar had sent a group of 3 engineers and a skilled worker to handle the management, along with a supporting team at their disposal. Figure 3 marks the participant members of Seco-Solar in the Sinenergy I Project, including even the CEO of the company for processing general requests such as increasing members or procurement approval and giving advice for situational responses.

The project involved 2 Departments from Seco-Solar, the Project Management (PM) working directly and representing the company at site and the Financial Department (FD) providing support and producing financial reports from the headquarters' in Hanoi. The FD was rather busy as they supported more projects of the company; the Head Accountant, Mrs. Phuong Nguyen processing financial documents and monitoring the financial status of the project via a method called Financial Circle, which will be analyzed in Chapter 5.

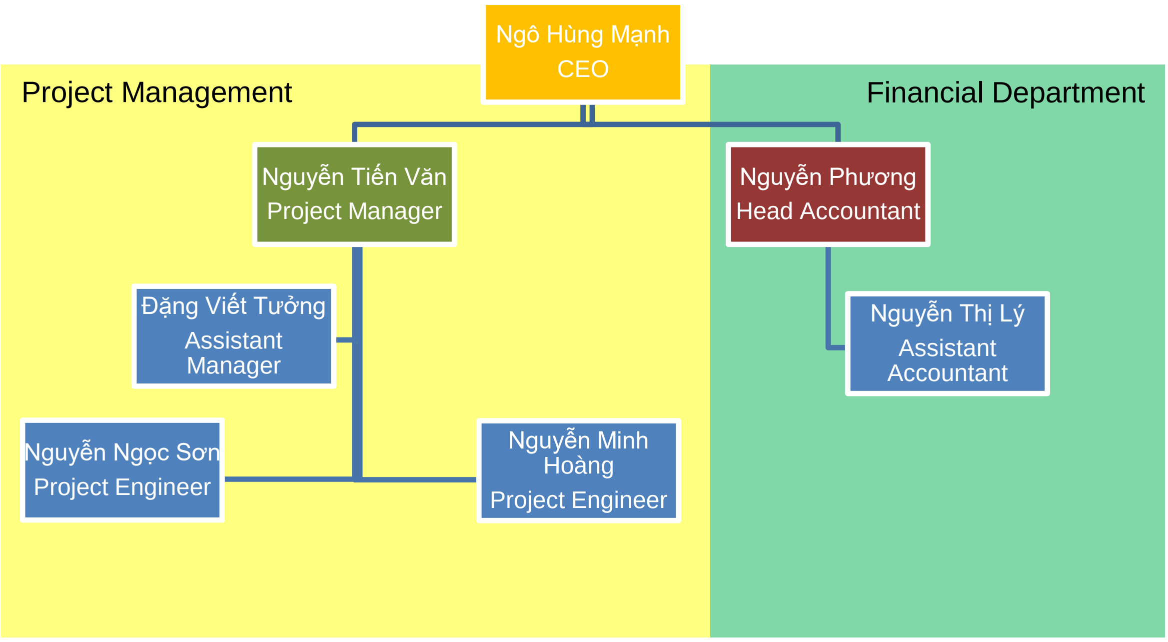


Figure 3. Seco-Solar's Project Organization Hierarchy

The on-site team covered the project management work; consisting of 4 members including the thesis author

1. Mr. Nguyễn Tiến Văn functioned as the project manager, the leader of the group, and possessed the highest authority in the department. His duties con-

tained making plans and schedule, dividing the work between the labors, controlling the material flow and keeping track of the auditing document.

2. Mr. Đặng Viết Tưởng was an experienced construction manager and assisted the project manager in making plans and schedule, controlling the material flow as well as consulting constructional behavior.
3. Mr. Nguyễn Ngọc Sơn was a skilled worker recruited for this project to provide technical advice and monitored the work on site. He also took responsibilities for safety awareness and precautions at the workplace.
4. Mr. Nguyễn Minh Hoàng, the author of the thesis, provided engineering insights, contributed to monitoring both the work and the material flow, and conducted inspections with PCZ.

With the personal background clear, the team was set to assemble on March 8, 2019 in Ninh Thuận Province, discovering the construction site in reality.

3 Theoretical Background

In this chapter, literature acknowledgement had been prepared before the project actually started is presented. For better understanding, the review was distinctively dispersed into Solar Power recognition and Project Management enhancement.

3.1 Solar Power System

Environmental engineering studies in Metropolia UAS have enabled the author of this thesis to engage in a large-scaled Solar Power Project. The acquired vast knowledge about renewable energy improved the understanding of the design as well as the operation of the power plant. This section explores the solar-related portions of the studies which enhanced such confidence and readiness.

3.1.1 Solar Power System in general

Solar power technology is rapidly increasing its popularity in South Asian countries. The use of conventional fuel sources is considered harmful for the environment and is being replaced by clean renewable sources, such as sunlight. In the early 1950s, one of the scientists in Bell Laboratory, in search of improvement for a communication system, found that Silicon was sensitive to light, and could generate an immense amount of voltage if treated with impurities. This discovery paved the way for photovoltaic research to flourish and achieve the attention it has today. Silicon, the second most abundant element on Earth, has the potential to change the future of energy harvesting. The PV cells produced from silicone, extracted from a ton of sand, could possibly generate as much electricity in a lifetime as burning 500,000 tons of coal. [3]

The main components of a solar power system consist of photovoltaic cells, inverters and loads or storages. Photovoltaic cells, the electricity generator, capture sunlight and convert it into direct current form of electricity. Module or panel is the most common device to arrange a set of PV cells into, the goal is to put the cells in series to receive constant currents and fluctuating voltages from them. An array is a series of modules or panels connected together and to the inverter. On large scale systems, there is a combining device to collect all separated input from solar arrays and output just one electricity line to the inverter; and a separated electrical protection device apart from the grounding system. Since the PV cells produce direct current and most of the loads use alternative current, an inverter must be installed to change the frequency of electricity and, thus, convert DC into AC form.

There are 2 kinds of loads, DC loads and AC loads [3]; they respectively consume direct current and alternative current. The DC loads are most commonly found in air-conditioner, road lights, and water pumps, while the AC loads are household devices such as computers, fans, lamps and TV, and the national electricity grid. In a solar system, electrical storage is an optional device; it can be a chemical battery, a heated oil tank or an uphill reservoir.

Depending on the purpose of use, there are 4 types of PV systems. A grid-tied system connects and depends on the electricity grid; it both generates electricity and collects electricity from the grid. It consists of modules, inverter, utility meter and a connection to the transmission line. The aim is to make the electricity flow interchangeable, when it is working, any excess energy is transported into the grid, and if the demand of energy is higher than the supply, electricity from the grid is transferred back into the system. This is the most commonly used system in Asia due to the low cost, and Sinenergy decided to apply the grid-tied system in the 50MW Power Plant, the detail of which will be covered in the next section. By using the system, the owner can sell the excess energy according to the utility meter during the daytime, which significantly reduces the cost of electricity. On the other hand, the system is reliable on the grid; when the grid stops working, the system automatically shuts down to eliminate any flow to the grid and ensure the safety of the grid maintenance.

An off-grid system works like a stand-alone electrical system, including batteries to store power, not connecting to the grid and optionally wiring to a second generator. During the daytime, the PV cells produce electricity, the abundant part of which flows to the batteries for storage. When there is no sunlight, the inverter drains power back from the batteries, and the backup generator is launched either when the demand is higher than the battery capacity, or if the batteries need charging. The purpose is to separate the power system from the grid in areas that hardly have much grid connectivity. Being so independent, the off-grid system allows a consistent electricity flow at a price of high initial cost of the batteries.

A hybrid system is a combination of grid-tied and off-grid system, consisting of PV cells, inverter, charge controller, battery, utility meter, a grid connection and, optionally, a second generator. The principle does not differ much from the two previous systems, the cells and the second generator produces energy for use, and the charge controller manages whether the abundant energy goes on-grid, or is charged into the batteries. At an enormous cost of materials and devices, the hybrid system provides an uninterrupted electricity supply and the income from selling electricity. Lastly, an integrated system is a set of all components, with solar cells, batteries and DC loads in one device. The main reason for this system is to maintain independent power supply while minimizing the use of disposable batteries. This system is widely applied in traffic lights, chargeable batteries, flashlights, clocks, and sometimes, in heaters and air-conditioners.

3.1.2 Technical Design of the project

According to chapter 2, the scope of Seco-Solar Ltd was vastly limited, it only covered the electrical installation; so the instructions and manuals were solely enough and technical knowledge was not highly demanded. However, the work was divided into tasks and each individual task still required literature research and understanding of how each component of the system could function.

This part of the chapter will explain the electrical system according to the scope of the company as the components, designs, procedures, and operations remained strictly classified from unrelated parties, including the author of this thesis.

As mentioned, Sinenergy deployed a grid-tied system Power Plant to sell electricity to the Vietnamese national Electricity Company (EVN). The system had a set of solar panels to collect energy, combiner boxes as a medium to gather the collected energy and to detect any defects, inverters to convert the electricity into AC form and a transformer to raise the potential for transmission. The Plant had a size of 50MW and connected directly to the national grid and the owner got the profits out of sold electricity.

Firstly, the 60ha area Power Plant had the connection from the national grid from an 110kV substation which collected solar energy from 17 zones of similar structure and roughly the same power. Each of the zones had almost 10,000 PV panel, grouped in 297 or 298 strings of 30 panels, absorbing solar energy and transmitting to 16 combiner boxes, where any defect from a panel was reported directly to the control house. From the combiner boxes, the collected solar power travelled to the container-type inverter as ideally 1,140V electricity in DC form. The container-type inverter collectively gathered the energy into its two 1500V inverters, thereby converting the electricity into AC form. Another important component in the container was the 2500kVA transformer; this device raised the potential of the 1,140V current up to 22kV, minimizing the transmission loss. Also, an auxiliary transformer and a Ring Main Unit (RMU) were installed for safety purpose.

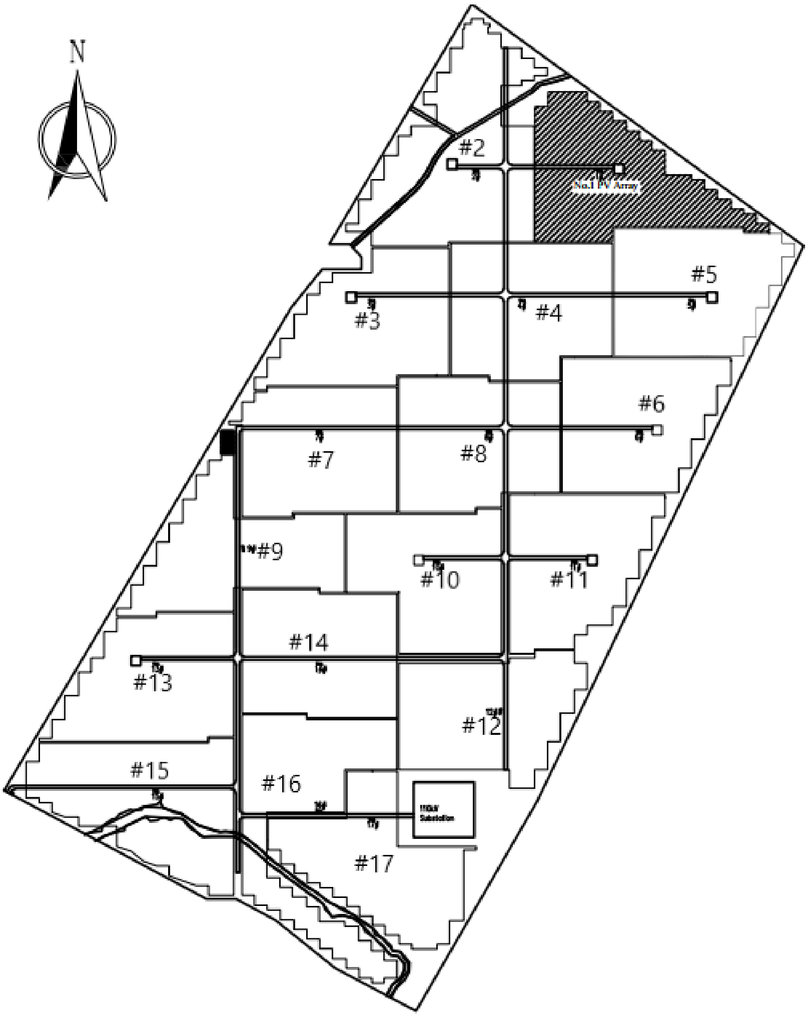


Figure 4. Power Plant layout map (cross-line at zone 1). Modified from Zhongnan Engineering [4]

Figure 4 has the layout observed from Zone 1 of the Power Plant, with 17 zones marked from #1, #2 to #17, indicating the position of each zone. The picture also shows the road between each zone and the control house located next to Zone 12, 16 and 17.

The container-type inverters were then connected in a series of 2 or 3, resulting in 8 collector circuits arriving at the main substation. Considered as the heart of the Power Plant, the main 110kV substation consisted of a control room, the main transformer, a cooling system, and auxiliary components. The control room had a system of 22kV switchgear compiling energy from 8 collector circuits and feed it into the main transformer, which increased the voltage from 22kV to 110kV to match the specification of the national gridline. The generated electricity finally reached the electrical meter and entered the transmission line of the national grid, whereas the excess energy was transferred to an auxiliary transformer for protective grounding. To prevent the substation from overheating during high voltage operation, a cooling system was installed, providing water and oil when necessary.

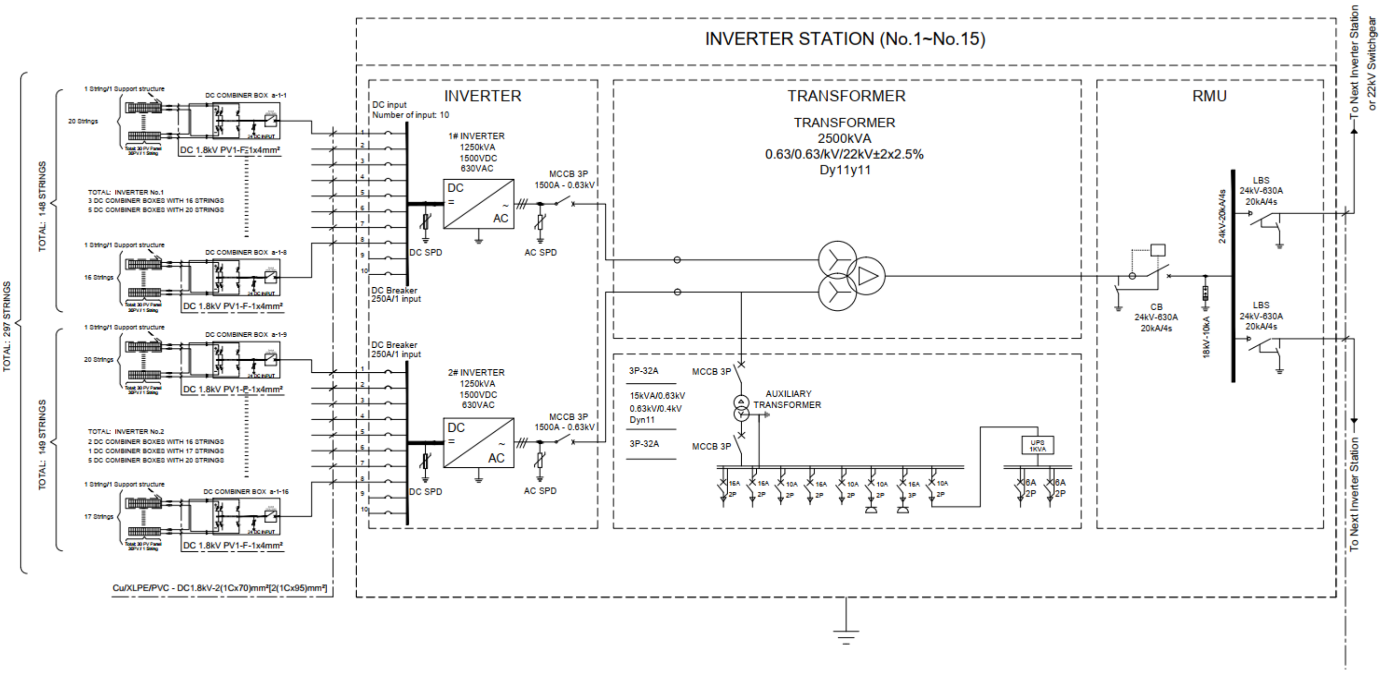


Figure 5. Component Electrical System (Inverter Station). Reprinted from Zhongnan Engineering [5]

Figure 5 illustrates the electrical system up to the inverter station, with the focus on the components inside the container-type inverter. Since the main substation was out of Seco-Solar’s project scope, the design and description of it were not provided.

The medium of electrical transmission was distinguished by the two ends where it was connected; by this way, there were 3 types of cables. The PV cable handled the energy from solar panels and directed it to the combiner boxes. The DC cable connected the combiner boxes to its equivalent inverter station. The AC cable, or sometimes MV cable, carried AC power in medium voltage (MV) from inverter stations to the substation in the control house.

As common electrical projects would require, the transmission medium within the Power Plant area at medium or low voltage must be underground, and going through protective pipes when crossing the roads. Digging the cable trenches, however unorganized an arrangement might get, belonged to the construction company; therefore any electrical installation had to start after the digging completed. This would have a major impact on the procedure of Seco-Solar Ltd, and will be thoroughly analysed in the following chapters.

Like a standard power plant, a carefully designed grounding system was applied. The average electrical resistance of a major power plant was 0.5 ohms, and all electrical media and devices must be safely grounded. For an easier to install and to measure, the design implied a buried steel system spreading across the site as the main grounding system, with medium and device grounding connected to it. Since earth has zero potential, in case of a potential burst such as lightning, electricity finds the shortest path to the ground, regardless of any obstacle. Hence, this grounding design directed it to the ground first, before distributing among the underground area, minimizing the damage to electrical media and devices.

The technical design in this section is theoretical; it is recommended to visit Chapter 6 and the first Appendix for some pictures of the Power Plant, including its location and construction condition.

3.2 Project Management

As can be seen from the previous section, the technical requirements and engineer understanding for this particular project were inconsequential; therefore, the main focus of the thesis is about managing a project from an engineering standpoint. Hence, this section should be the main focus of the chapter.

Project management has gained its popularity since the later periods of the 20th century, playing a key role in gaining success in running a project. The optimal measure from a project manager is to balance between the project specialization skills, in this case, electrical installation in a solar power system, and resource management. While the previous sections describe clearly the demand for the project specialization skills, the latter part of the balanced scale will be reviewed in this section.

3.2.1 Introduction and Definition

To understand the work and requirements of a project manager, the definition of a project must first be reviewed. A project delivers particular products or services, requires a temporary contribution and contains some aspects of uniqueness. Jack R. Maredith and Samuel J. Mantel, JR. [6 p. 9] categorised a project as a one-time activity and separated project from daily tasks. Whereas, Harvey Maylor [7 p. 5] claimed that project had to be unique regarding time, place, resource and the team carrying it. A project manager is the one that monitor the project, making the plan, gathering resources, controlling the outcome and responding to the customers. As project management is “the best way to accomplish certain goals” [6 p. 22], there are reported benefits of being a project manager. Such benefits include better control and organization of work, a stronger relation with the clients, efficient use of time and resources, sharper approach to problem solving and higher worker morale. [6 pp. 11-12]

3.2.2 Leadership

The role of a project manager should never be telling people what to do and expecting the procedure to follow as planned. Instead, a successful project manager is also a good leader, who understands his employees and influences their action via personality. And the best way of influencing is motivation; which enhances pride and confidence allowing people to perform better.

> “The individual will need to gain satisfaction from the tasks they are assigned, as work generally occupies a significant part of their lives (call this a “social duty”). By providing for the needs of an individual, their performance can be made less uncertain and, to a degree, managed for benefit to both the individual and the organisation.” [7 p. 274]

The book Project Management, written by Harvey Maylor, describes the work motivation by a set of theories, described in figure 6 [7 p. 275]. In those major theories, scientific management holds the four principles for motivation of repetitive work. Firstly, the work must be carefully studied in order to be divided for maximum efficiency. Secondly, the workers should match the work in a certain way; carrying a heavy load requires a more muscular person than driving a truck in shipping industry. Thirdly, the workers must receive proper training since it is reasonable to spend some time and effort to teach them how it is done, hence ensuring the delivery of a desired product. Fourthly, everyone deserves some appreciation; so the manager needs to create the feel of rewarding for the employees when the result is delivered.

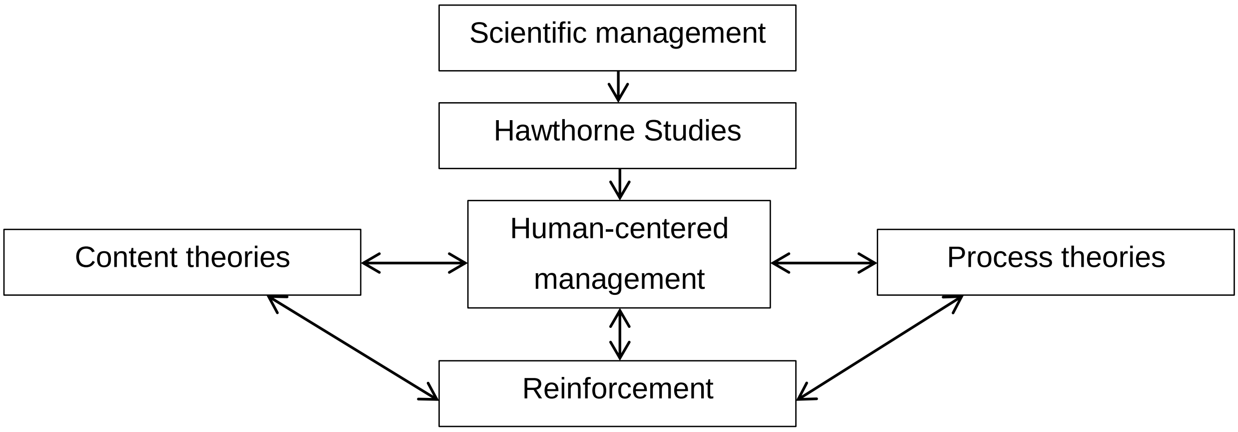


Figure 6. Main theories of work motivation. Reprinted from Harvey [7 p. 275]

The Hawthorne Studies is initially indicated as the assessment of physical condition impacting on the motivation of the workers. A group of production labours showed a rise in their productivity when the lighting condition in their factory improved. The conclusion then was that the improved lighting led to higher motivation and was proven premature. When the lighting condition was restored, the productivity still grew; this surprising experiment resulted in the ultimate discovery of the cause for motivation. It was in fact attention that caused the labours to have motivation thus increasing their productivity. “There is a clear implication for practical application here which many excellent project managers reinforce, that paying attention to groups improves the likelihood of good performance.” [7 p. 275]

The modern theory of human centred management consists of 3 elements: process theories, content theories and reinforcement. The process theories suggest that individuals can choose how much effort they put in a project; this amount is dependent on their view of how desirable outcome they may achieve. The first level of outcomes relates to intrinsic performance, from the satisfaction of doing a fine job to the cheerfulness of developing their skills. The second level relies to a more external reward; such as compliments from a colleague or a promotion.

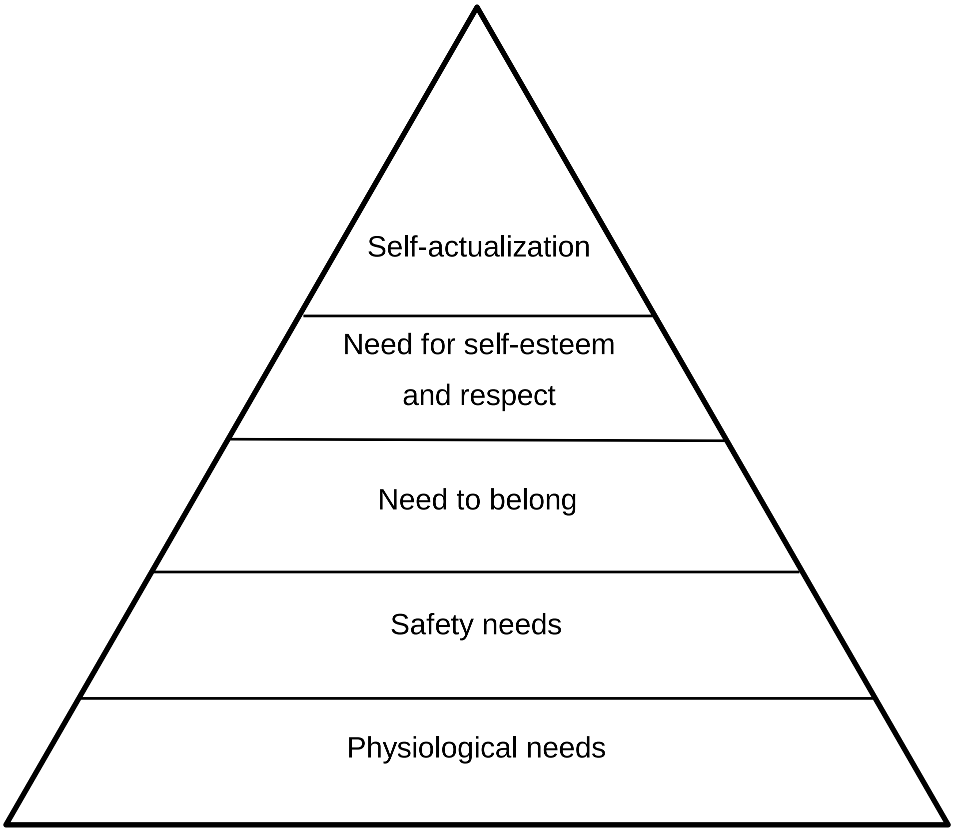


Figure 7.Maslow’s hierarchy of needs. Reprinted from Harvey [7 p. 276]

Figure 7 showed the pyramid of unfullfilled needs that help get motivated. The theories suggest building a situation where an individual works to meet the needs and that act of pursuing creates motivation. [7 p. 276] In addition, the needs are categorized in a pyramid indicating that one must achieve the lower parts before considering the higher ones. At the lowest storey, the physiological needs represent the basis of living, such as food or shelter. The next entry is the safety needs, when an individual is able to provide for the family, he starts looking for security. At higher ranking, the need to belong provides an identity to a person, as the human nature is to seek recognization in another person or a group of people. The need for self-esteem and respect comes when a person knows what he is capable of and therefore raising the standards. Self-actualization is the highest achievement according to the theories, it holds the goal for an individual to be as good as possible; an chasing (not meeting) this goal is the most joyful and satisfactory journey in a lifetime.

The theories behind reinforcement is rather straight forward; it implies that good behaviors should be rewarded and encouraged, hence individuals are motivated to repeat trying to achieve more good behaviors so as to get satisfaction from the reward and encouragement. Also, the theories give five advices on how to reinforce and how to let the target individuals feel reinforced. The first advice requires the manager to give praise to a specific achievement; general praises like “Good job” usually means perfunctoriness rather than sincere appreciation. The following advice suggests making compliments as soon as the achievement happens; this enables the individual to create a link between a good performance and the praise for it. Dividing the tasks into achievable milestones so the worker is able to accomplish is described in the third advice, since it is more convenient for the worker and it shows care and guidance from the manager. The forth advice reminds the value of the intangible; as Maylor endorsed “Praise may be more of a motivation to future performance than pay or status” [7 p. 276]. Finally, the manager should make encouragements as unpredictably as possible as an unexpected congratulation triggers rewarding motivation.

3.2.3 Time Management

Time management plays an essential role in project management, as a failure in scheduling causes tremendous loss of resources. To avoid the project tasks from getting out of control, it is recommended to build a prior estimation exclusively for the schedule, neglecting other resources. The exclusive estimation is then analysed to achieve precautions of unexpected events; finally, it is compared to other resource plans and budget and is adjusted feasibly. Estimating the time for the whole project is a close to impossible task in any project; hence, it is preferred to conduct a deconstruction plan before starting to schedule. Harvey Maylor (2010) [7 pp. 132-135] suggested 3 types of work deconstruction, which were activity breakdown, functional breakdown and physical grouping.

This thesis, adopting the mentioned classification, will present its own definitions, relating to the Solar Power Plant that the author was involved in. The activity breakdown is the deconstruction based on tasks and achievements. The functional breakdown divides a project into independent activities. Whereas, the physical grouping gathers the relating work on each physical unit, with a single entry showing milestones or activities for one physical object. Table 2 demonstrates the deconstruction of Seco-Solar’s work in those 3 methods; they are examples and, in fact, the work has to be further deconstructed into easier-to-manage tasks, but the table should illustrate a clear idea of those breakdown methods.

Table 2. Work deconstruction of Seco-Solar

	Activity breakdown	Functional breakdown	Physical grouping
Electrical Installation	**Planning**	**Finance**	**Device**
	Cost, time and resources	Demand and usage	Inverters, combiner boxes
	Execution	**Work monitoring**	**Conductors**
	Monitoring and adjustment	Time and resources	PV, DC and MV cables
	Inspection	**Contact with stakeholders**	**Safety**
	Quality check	Inferior and superior	Grounding medium

After work deconstruction, it is necessary to create link between the smaller tasks. There are 4 different ways to link 2 tasks A and B together, depending on their start and finish; and they are listed below. [7 pp. 136-138]

- **Finish-to-start**: This means linking the end of task A to the start of task B. Task B can only begin after task A ends; the amount of time to complete both tasks equals the total amount of time to complete each task.
- **Start-to-finish**: This is strictly the opposite of the previous method, where task B can only finish after task A starts. The amount of time to complete both tasks equals the total amount of time to complete each task.
- **Start-to-start**: This method links the starts of task A and B; meaning that they are parallel processes. The amount of time to complete both tasks equals the longer amount of time to complete either task.
- **Finish-to-finish**: This results in 2 tasks ending together, regardless of their starts. The amount of time to complete both tasks equals the longer amount of time to complete either task.

The prior time estimation is completed when the linkages between deconstructed tasks are created. Then, the scheduling process takes place, with costs, human and other resources being under consideration. The more thoughtful the final schedule is, the easier the monitoring process becomes. To achieve such final schedule, a project manager must try putting all resources into the prior estimation; decide its feasibility, fail and retry. There is not a short-cut for this process, because time and resources are unlikely to match. For instance, Tuesday is the perfect time to start installing the inverter stations because the welding worker is free. However, the inverter containers are scheduled to arrive on Thursday; hence, the welding worker needs to carry other tasks or he receives 2 paid days off. [7 pp. 142-143]

In the scheduling process, it is necessary to fail and retry during the few initial iterations; because each failure uncovers a misfortune or a mistake in calculation that may be hidden in the prior estimation. Such misfortune is prevented by risk management and explained in the following section.

3.2.4 Risks Management

Risks management is basically a process of seeking potential risks, recognizing their impact and come up with solutions. Good risk identification allows proactivity when the risk eventually occurs; plus it boosts confidence in execution phase. Meanwhile, failure to recognize the risk effects may result in a waste of materials, budget and time. Risks assessment should be carried out several times in a project in order to re-establish the identified risks and search for new ones. More assessments enable project managers to expect the risk and counter it rather than dealing with its aftermath. Michael Stanleigh (2011), the CEO of Business Improvement Architects, presents the rules of thumb for risk management: [8]

- Locate the risks as early in the project as possible: The earlier the risk search, the earlier the solution arrival.
- Pay attention to risk communication: The communication is important, whether it's the risk notification from team members or the precaution from other stakeholders.
- Look out for opportunities also: A risk may accompany with an opportunity so be positive.
- Prioritize: Some risks may have higher impact or urgency, it is advised to rank them then analyse the higher entry first.
- Source and outcome: To have a deeper understanding, the manager should be able to identify the root causes before working on controlling the aftermath.
- Risk response: Normally, there are 3 distinct solutions involving how to prevent the risk from happening, what to adjust if the risk happens, and how to be in favour of opportunities. Planning for all 3 is optional, but it increases the proactivity so it's better to have more responses to a risk.
- Preventative measures: It usually is easier to prevent risks than to deal with the outcome. Therefore, simple tactics can be introduced to prevent accidents and thereby eliminates improvising.
- Backup plan: Also to minimize improvising, a secondary plan should be ready in case of an incident.
- Risk register: It's important to document the risks and responses so as not to forget them. There are some methods of structuring the document, including risk log, so it can be checked readily by all stakeholders.

- Do it on a daily basis: The project manager shall read the risk documents along with other daily tasks to keep track of the current situation and find a suitable response if necessary.

3.2.5 Material Flow

One of the problems with the material flow is its inconsistency. When the consumption fluctuates, the amounts of work and of labours fluctuate as a result. If the materials are running short, there will be hardly work and the number of workers needs reducing. Without work and payment the local people would shift to another project immediately; and the company cannot afford to pay for their days off just to keep them with the project. Therefore, maintaining a continuation of work for them is a must, after an exhausting instalment of local workers.

Project Management – a managerial approach [6 p. 457] by Jack R. Meredith and Samuel J. Mantel Jr. demonstrates an effective method of dealing with inconsistent material usage. The presented resource levelling method implies that a levelled material usage demands less monitoring from the project manager and helps avoid troubles when materials delivery comes late. It was true that telling the storage keeper to distribute the same amount of steel pieces everyday makes it easier for keeping track of the steel flow.

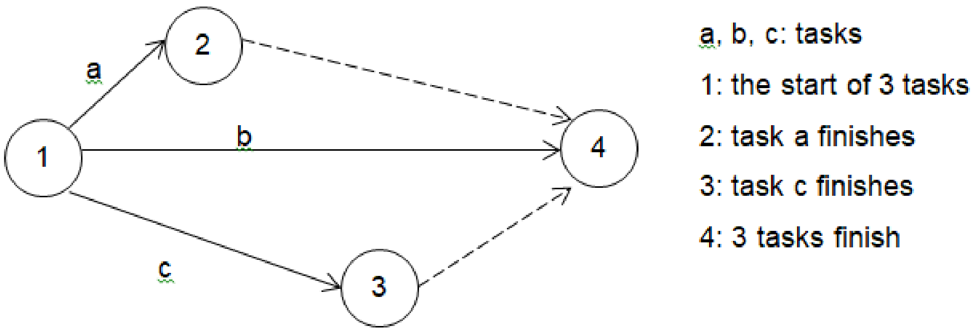


Figure 8. Example schedule, Reprinted from Meredith and Mantel Jr. [6 p. 459]

Let’s take an example from figure 8. There are 3 independent tasks a, b and c to be completed between anchored events 1 and 4. Task a takes 2 days, task b takes 6 days and task c takes 3 days, assuming the material is steel pieces for all 3 tasks. Event 2 and 3 are when task a and c finishes respectively; therefore, they can be adjustable.

The dashed arrows indicate the results of those events being applied to event 4 without any task within. [6 p. 459]

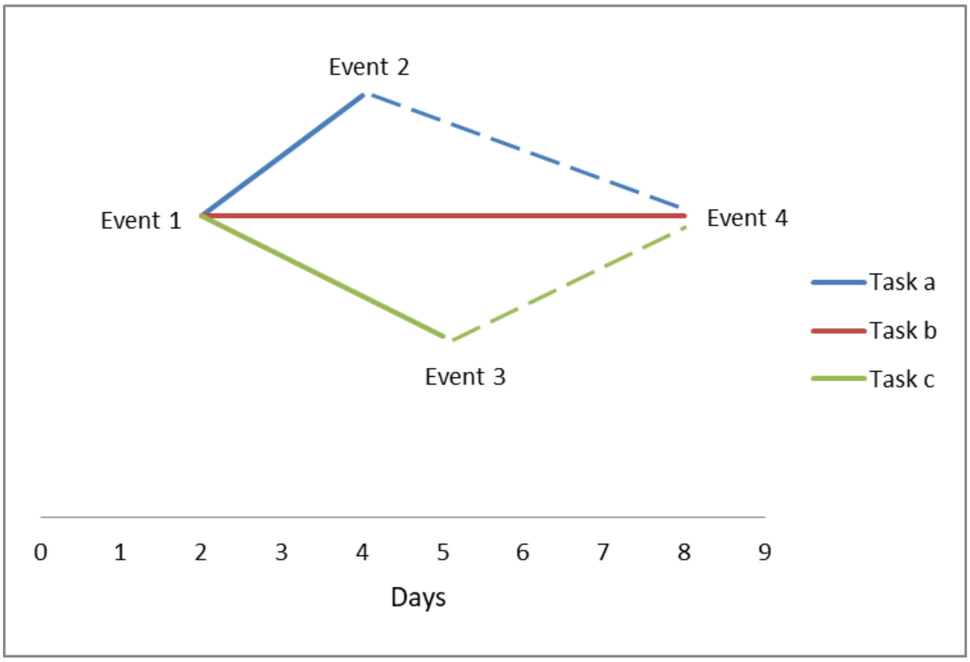
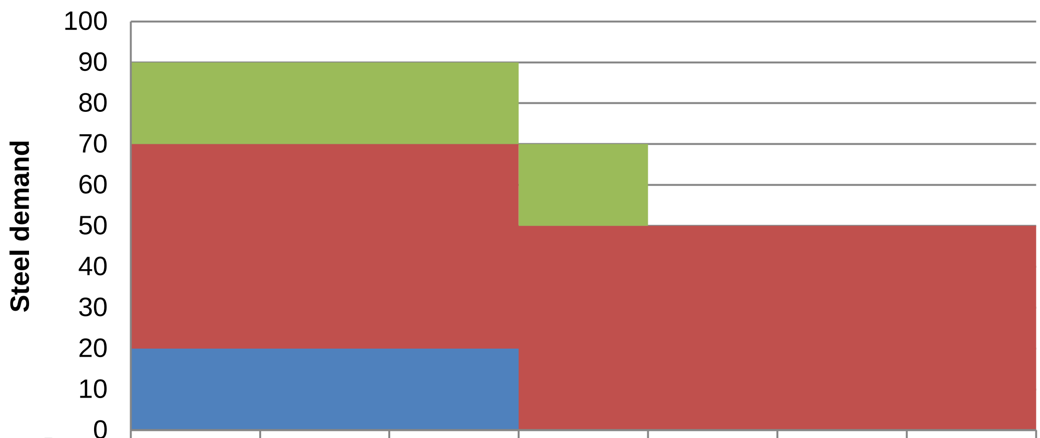


Figure 9. Possible arrangement. Data gathered from Meredith and Mantel Jr. [6 p. 459]



Day	2	3	4	5	6	7	8
Task c	20	20	20	20	0	0	0
Task b	50	50	50	50	50	50	50
Task a	20	20	20	0	0	0	0

Figure 10. Material demand. Modified from Meredith and Mantel Jr. [6 p. 459]

A beginner mistake is to launch the three tasks concurrently as illustrated in figure 9 and 10, where the material usage drops from a total of 90 units on day 2 to 50 units on day 8. This material reduction causes the problem mentioned in the beginning of the section, leading to labour scarcity after event 4. [6 p. 460]

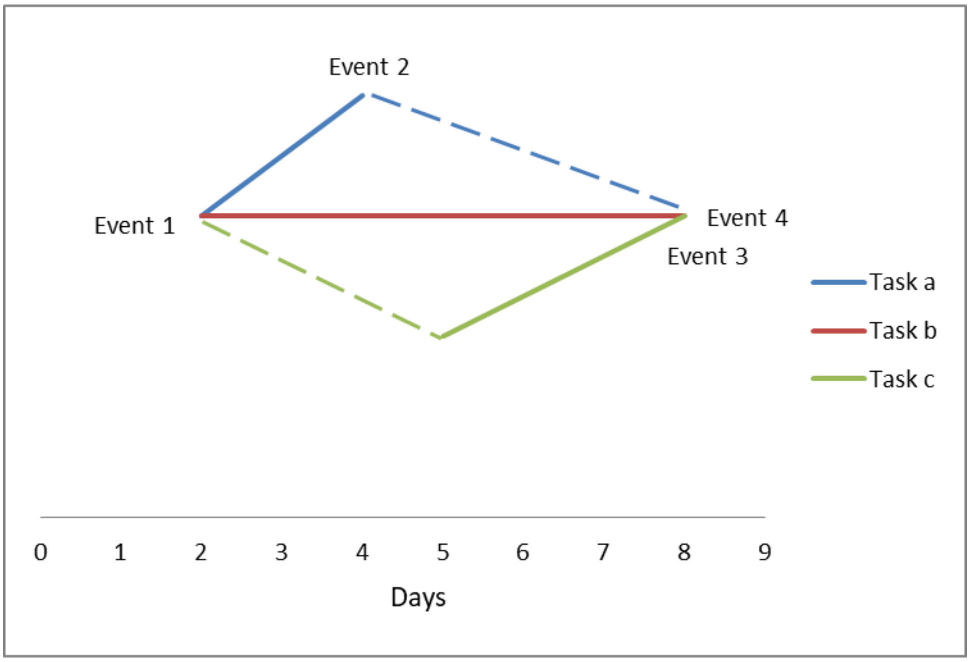
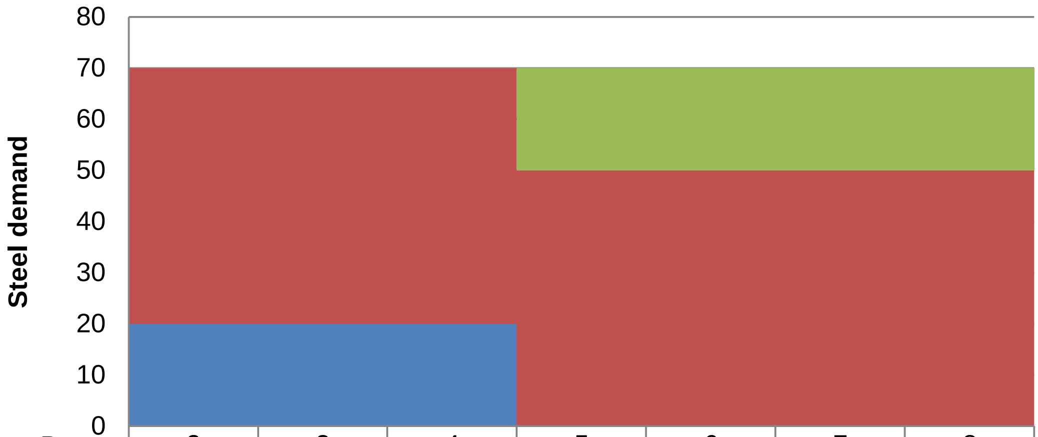


Figure 11. Example schedule (after resource levelling).

Data gathered from Meredith and Mantel Jr. [6 p. 459]



Day	2	3	4	5	6	7	8
Task c	0	0	0	20	20	20	20
Task b	50	50	50	50	50	50	50
Task a	20	20	20	0	0	0	0

Figure 12. Material demand (after resource levelling).

Modified from Meredith and Mantel Jr. [6 p. 459]

A preferred setup would be to move task c till after task a is finished, as the graphs in figure 11 and 12 imply, making the steel demand stay at 70 units total. Not only is the materials stabilized, but the workers from task a can start performing task c on day 5. Hence the levelling technique helps ease the material monitoring and keep the labours occupied. [6 p. 460]

3.2.6 Quality Control [9]

After a construction process, there is always an inspection process involving the managers assessing the products before delivering to the customers. The inspection process relates heavily on these 3 terms in project management; although they are beyond the requirements for the author, it is worth recognizing them for future development and career flexibility.

Quality Assurance (QA) means the process of which the manufacture or service delivery can be monitored by the supervising engineer to reach the design quality. Any change or undo is conducted during the construction process in this particular project, and can possibly alter the design to meet reality.

Quality Control (QC) comes after the product or service has been completed and could be double checked or modified by the inspection engineer. He will tell where to improve the result and usually avoids major change in the initial design; after his work, the product or service can be delivered to the customers.

Quantity Survey (QS) checks the amount of materials, costs and efficiency to determine the performance of the construction process. This is the final procedure of the 3, concludes the delivery and decides the success of the project.

3.2.7 Auditing and Evaluation

Each project is an experiment; the performance should be measured for future projects to learn from the experience. Such measurement is called project auditing; the word "audit" often misleads to financial concept, but the term "project audit" means a detailed judgement over a project's fulfilment , it sometimes involves budget and profits but is not a financial based operation. Jennifer Bridges (2018) defined the project audit as "an independent assessment that determines the project performance and the maturity of the project management process". [19]

The audit discloses any issues or challenge, reviews management effort, opens up potential opportunities as well as comforting any misfortune. Usually, it requires an auditing team to receive and analyse project documents, organize a meeting with the management members and have access to the financial state of the organization. The challenge for the management team is that the auditing team often is not close attached to the project; in some construction projects, they may not even come to the site. Therefore, it takes time for them to get acquainted with the technical specifications; so it is up to the project members to keep them interested but not overwhelmed with the project. On the other hand, pausing the project to engage on an audit report causes distractions and the audit result may even bring up disco-ordination between the members. It is advised that the auditing members use constructive language and keep the personal information confidential in the report; whereas the management group should be open-minded and instructive towards them. Ultimately, this is a complex collaboration that requires mutual respect and understanding between two departments.

Regardless of classification, each project has a consistent auditing process. Whether made by a professional auditing team or assigned to some members of the management group, the audit structure comprises of these steps: [19]

- Preparation: Rule out the scope and success criteria for the project audit; determine the appropriate time to conduct the procedure.
- Research: Be familiar with the project goals, methods and technical requirements; go through the project documents about scope, budget, resource, risks and schedule; diagnose some of the challenges and prepare questions for the meeting.
- Meeting: Listen to other members; understand their goals, methods and difficulties; have a grip on the current situation and update the progress.
- Analysis: Based on the collected information, conclude the performance of the project team until that point.
- Result presentation: Pitch about the analysis, acknowledge the strength and recognize the challenge; help develop a solution to the challenge and look for opportunities.
- Finalization: Document an audit report on the result; include a recommendation list for the audited process in the coming projects. Repeat the process for the next project audit.

The project audit can be done in any period of a project, but its impact will differ (in figure 13). At the initial state of a project, the audit usually identifies the potential risks and possible solutions to given risks; thereby keeping the project moving forward. On the other hand, the termination phase often requires a project audit to collect data about resources, expenditure and quality to either serve as payment documents for the customers or fill in the achievement list on the company's profile.

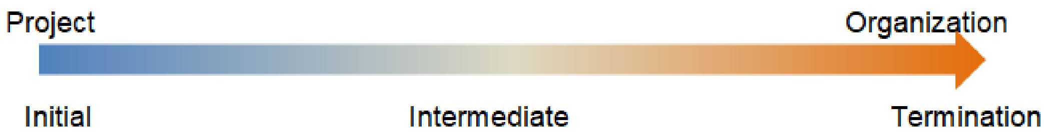


Figure 13. Impact of the project audit along the project timeline

If the project audit is the bow, the project evaluation is considered an arrow pointing a project to its target. A project evaluation, identified by Jack R. Meredith and Samuel J. Mantel Jr. (2003), is where a project's attributes are carefully graded to determine its successiveness. Such attributes contain how effective the resources are consumed, or project's efficiency. Particularly, it is how wisely the management team control the materials, time and budget required in electrical installation. In addition, a direct attribute would be the business success of the project, measured by how much the company financially benefits from it. [6 p. 611]

The authors also mention customer impact as the most complicated factor, where success equals satisfaction of the end users. It is immensely difficult to assess whether the project's owner is pleased or disappointed with the power plant, given that the communication is either via a distant email or a meeting with representatives. Therefore, the rule of thumb is to first meet the design requirements then modify as the owner's demand. The last attribute of the evaluation is the future potential, ranging from the possibility of taking a similar project to developing a new method of design and operation. [6 pp. 611-615]

The primary purpose of the evaluation is to leave a set of recommendations for future projects to achieve success and avoid mistakes. On the surface, these recommendations help achieve the direct goals that are set when the company or organization launch a project. Those direct goals include getting large profits, improving collaboration, identifying risks and locating opportunities. But these are just a tip of the iceberg; the evaluation also paves ways to accomplish collateral goals. These goals are equally important but hardly ever mentioned; they concern human interactions and hidden advantages that require logical deduction to be pointed out. Some examples of collateral goals are

- Improve the working environment
- Widen the approaches towards a project
- Recognize risks and improvements

- Identify the way which a project can influence the growth of each team member

Theses collateral goals improve decision making and managerial behaviours. They assist on raising the team’s performance, acknowledging the risks and providing equally opportunities to excel on a project thus create a professional situation where everyone happily cooperates. Such impactful goals are, yet, not readily recognized as hardly an organization may notice or evaluate how they are reaching these aims. Normally, an executive want to encourage his employees to be active and initiative; however, he usually refuses to set it as an attribute to a successful project. [6 pp. 612-615]

4 Planning

The first stage is the most critical procedure of the project: Planning. This is the project foundation that makes way to develop and monitor the process; failure in properly planning leads to a massive loss in budget, time and credibility. Regardless of classifications, a project manager must have a plan of action till at least the termination phase of the project, or watch his work crumbles and his team falls apart. The goal of the planning process is to grab control over the situation and eliminate surprises; not every part of work demands detailed preparation, but a thorough acknowledgement enlarges confidence and keeps one in the driver seat.

After understanding the scope, timing and condition of the project, the preparation began. The team set out the structure of the project, divided it into milestones and assigned corresponding personnel for each tasks. With that said, this chapter will describe a general plan, including conceptions, ideas and mindsets for leadership for the project.

4.1 Construction method

The project was divided into tasks small enough to be deployed by a fixed number of workers. Also, since the design and manual had been provided, the plan was created accordingly, including grounding connection, inverter installation, combiner box installation and cable laying and connection.

With the description and instruction given, it seemed rather trivial to come up with a method of operation. However, a complete plan must cover as many risks and unexpected events as possible; in this case, a plan should be a modified version of the instruction, varying the construction method instead of restricting it.

4.1.1 Grounding connection

The main grounding system consisted of a border grounding grid and branch grounding grid. According to the design, the border grounding grid ran directly beneath the border fence system of the Plant; the branch grounding grid was located on both sides of the road. Each grid consisted of horizontal grounding flat steel and vertical grounding copper bars. Outside of the main grounding system, there was grounding of PV mounting structure which this sub-section will mention because it used the same material as the main system.

Figure 14. Main grounding grid. Reprinted from Zhongnan Engineering [10]

Figure 14 illustrates the main grounding system from Zone 12 to Zone 17 from the design drawings. The borderline fence was illustrated by the solid line covering the whole area and represented the perimeter of the Power Plant. In the main grounding system, the horizontal conductor was denoted by dashed lines that covered the borderline of the plant and its electrical devices, and both sides of each internal road. Connected to the horizontal conductor were the vertical electrodes, the position of which was illustrated by the dots.

Towards the south-end of the plant, there was a small river to prevent flooding of the solar farm by gathering the raining water and directing it to a nearby lake. Therefore, the panels were positioned on both sides of the river, and hence, the grounding grid appeared on both sides of the river. Also, the grounding system surrounded all electrical components of the Plant, such as inverter stations and the main substation, for the purpose of connecting all component grounding to the main system in the shortest way possible. Lastly, lightning poles were installed next to each inverter stations and in the main control house to attract lightning away from those sensible electrical devices. They were a substantial part of the grounding grid, as each pole contained a lightning rod installed 6 meter above the ground level to ensure it would catch lightning. To protect the electrical device from a burst of potential, they were directly connected to the nearest point of the main grid to spread the energy directly to the ground at as large area as possible.

The installment of the grounding system was divided into flat steel installation and grounding electrode connection. Since the procedures were heavily dependent on the material supply from the main contractor, a plan deciding how long a milestone was completed after receiving enough materials was deployed. In addition, the flat steel installation covered the grounding of PV structures due to the use of the same material. The structure grounding were simply pointing a flat steel deep to the ground, and to save materials, the designers gathered the grounding flat steel of 2 mounting structures and ended up with 1 steel piece for 2 strings.

Flat steel installation

This process extended to connecting steel for mounting structures and installing the main grounding system. Figure 15 illustrates the grounding connection between PV mounting supports; the design required the steel to be connected by bolts and buried at least 30cm but did not restrict the shape of the connecting steel. Also, the dimensions of the steel should be suitable for the practical gap among the mounting supports differing in reality. It was noted that bending a 50mm x 5mm flat steel piece was a tough challenge, so the contractor agreed to add obtuse angles and modify the piece into a trapezoidal shape.

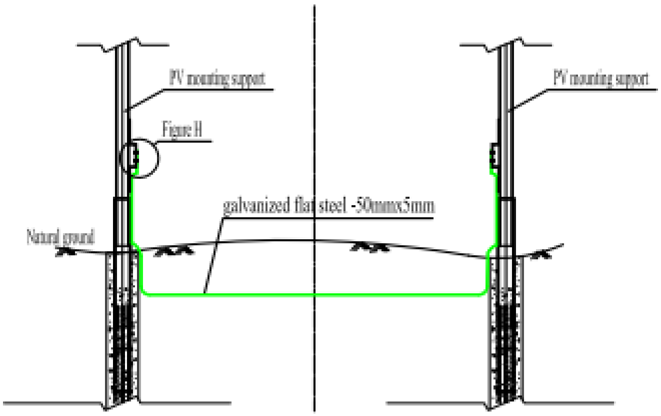


Figure 15. Grounding flat steel between mounting structures

Reprinted from Zhongnan Engineering [11]

This procedure was mostly independent from the trench work so the labors could dig out a small channel from the soil along with forming the flat piece into shape first, then connect the piece to both structures and bury the channel. Hence, the procedure prioritized the independent connection; whereas some of the grounding steel between strings intersected a cable trench and had to be connected after cable work. There were 2 scenarios, either internal trenches or external trenches; internal trenches were trenches that went between 2 mounting structures whereas external trenches lied between a mounting structure and a road. The steel crossing internal trenches structured similarly as figure 15 and figure 16 help visualizing the path of such grounding steel meeting a road, with one end attached to the main grounding grid.

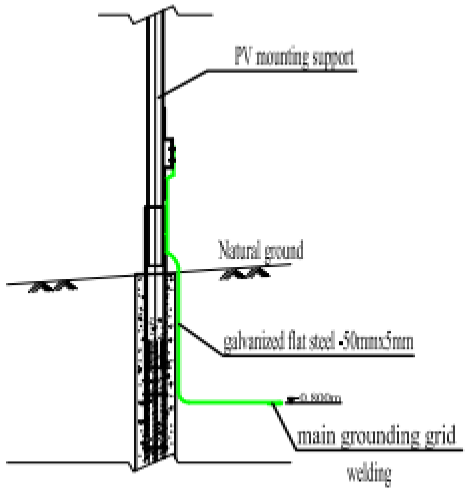


Figure 16. Grounding flat steel between mounting structures and main grid.

Reprinted from Zhongnan Engineering [11]

To sum up, the process boiled down to these chronically progressive milestones.

1. The workers dug the small channels for the flat steel.
2. The engineers measured the practical distance between the adjacent mounting structures, then achieved the dimensions for the steel piece shape.
3. After the steel material arrived, the workers cut formed into shape, prioritized the steel connection between 2 mounting structures.
4. After the bolt material arrived, the workers attached the steel pieces to the 2 adjacent mounting structures.
5. The project manager and engineer did inspection with the contractor and made adjustment where necessary.
6. Upon approval from inspection, the workers might cover the steel pieces and fill the channels with sand.
7. (A big gap of postpone occurred before the next step to wait for the completion of the work under cable trenches)
8. The crew continued from step 4 to 6 for the flat steel intersecting trenches.

At the same time as the flat steel connection process, the crew launched the flat steel laying in grounding trenches to install the main grounding grid. The procedure was rather straightforward, the workers, following the design, placed the flat steel materials in the grounding trenches and connected the pieces by electrical welding. However, the welding machine required an electrical generator; and carrying both to weld several points around the site was time consuming. Yet, connecting the steel before placing it into the trench solved the issue, but raised the concern of the workers' inability to carry the connected steel since the way to the trenches was so narrow that the vehicles could hardly approach. Ultimately, the plan should balance between carrying the steel pieces and transporting the welding machine and generator as follow.

9 The workers connected the flat steel to get several 20-to-30-meter pieces, 3 workers should be able to carry a piece.
10 The truck transported the connected steel pieces near the trenches; the workers unloaded and carried them down the trenches.
11 The welding worker connected the pieces together under the trenches. The border grid was completed first, then the branch grid, finally the intersection of the border and the branch grid.
12 He then connected the grounding steel of PV structures to the main grounding system i.e the pieces under the trenches.
13 The contractor did the inspection and the workers filled the trenches upon approval.

Grounding electrode connection

The vertical grounding electrodes were 2.5-meter copper bars; they needed stomping into the ground and connected to the flat steel in the grounding trenches by thermal welding. Figure 17 dictated the depth which the bars were inserted and the connection type of electrodes and flat steel.

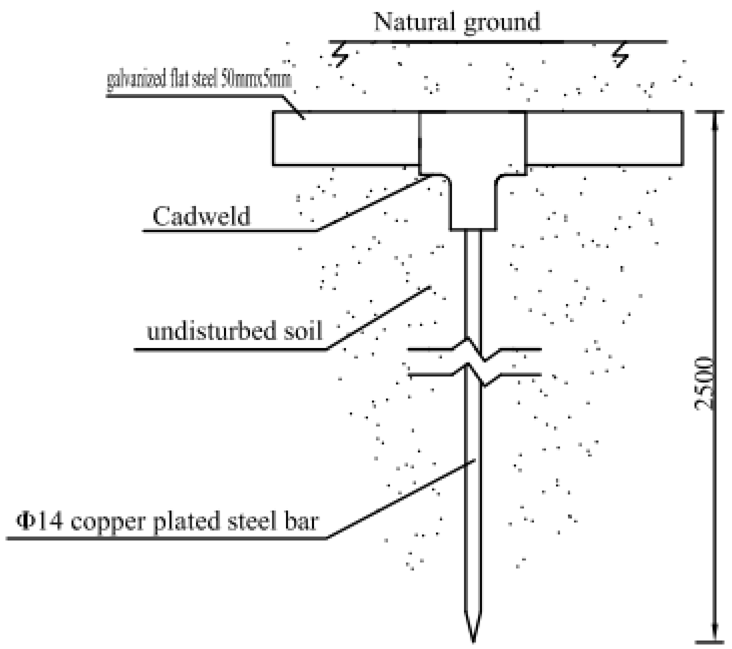


Figure 17. Connection between horizontal steel and vertical bars.

Reprinted from Zhongnan Engineering [11]

The procedure was uncomplicated; the workers just hammered the bars under the grounding trenches, and then connected them to the flat steel by cad weld. Finally, they buried both after inspection by the contractor.

4.1.2 Inverter Station Installation

This should be the heaviest work, but require the least effort into planning. The base of the inverter was prepared by the construction company, with designed 8 metal plates for the inverter. Seco-Solar Ltd. was required to install the container-type inverters on the bases, with the metal plates of which attached to the metal connection pieces of the inverters.

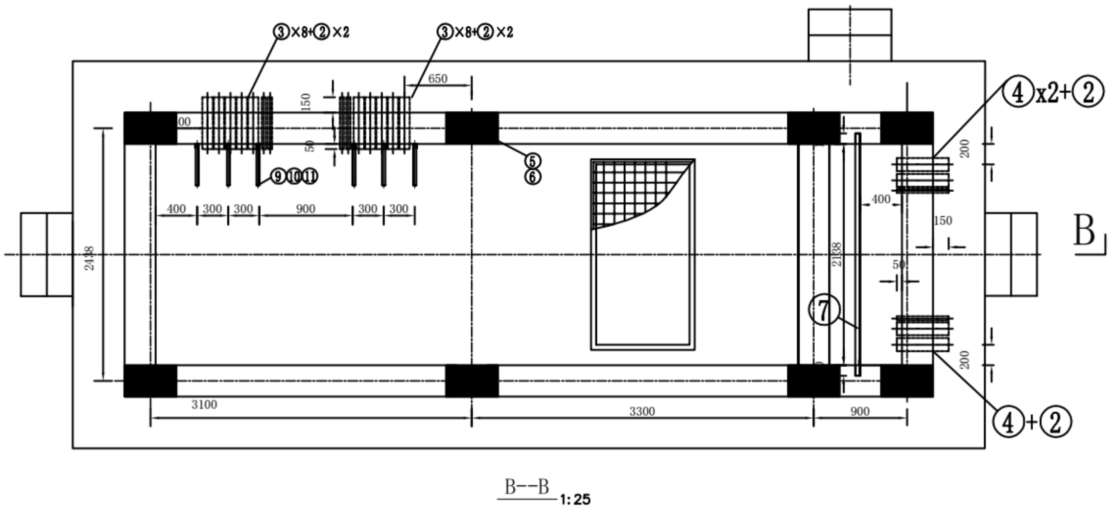


Figure 18. Foundation of Inverter Stations. Reprinted from Zhongnan Engineering [12]

Figure 18 showed the top view of the inverter base, with the metal plates in thick black. The procedure included hoisting the container-type inverter by a crane and slowly lowering while adjusting it to fit the plate on the base. Once the inverter was on top of the base, a worker attached the plates with the inverter metal pieces by electrical welding; then the process was repeated with 16 other inverter stations.

4.1.3 Combiner Box Installation

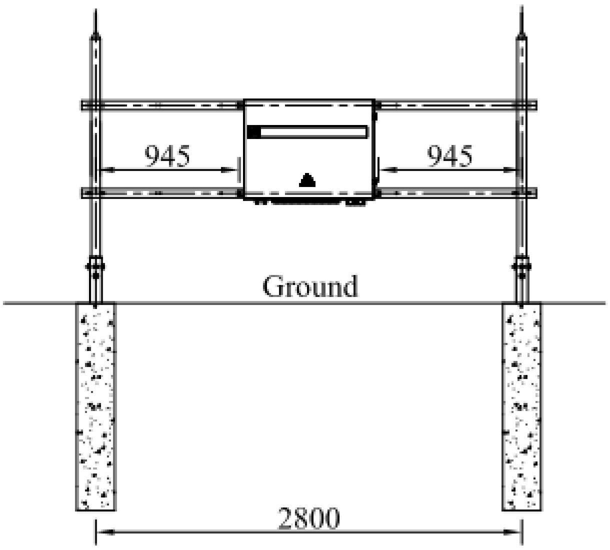


Figure 19. Combiner box bracket. Reprinted from Zhongnan Engineering [20]

As agreed with the contractor, Seco-Solar was responsible for installing the combiner boxes alongside its support structure. The combiner box rested on two brackets that were connected to the structure of the PV modules. The construction company had installed the vertical steel structure; it was up to Seco-Solar to install the horizontal brackets, the combiner box, and the cable support. Based on figure 19 and figure 20 [13] taken from the design, it was necessary to first attach the two provided 6-meter C90-steel pieces to make the bracket, then install the combiner boxes and grounding wire properly.

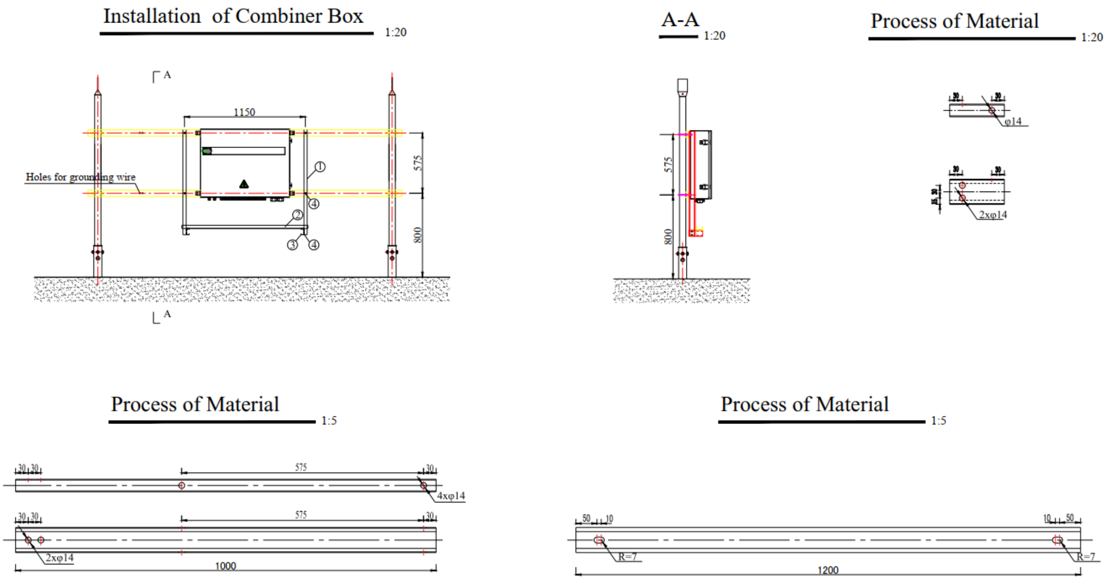


Figure 20. Cable support for combiner box. Reprinted from Zhongnan Engineering [13]

To secure the wires going in and out of the combiner box, a U-shape support structure needed attaching to the brackets. For this particular part, the contractor supplied with 10-meter C90 steel pieces and required preparation of the materials in own work yard before assembling on the brackets.

4.1.4 Cable Installation

Section 3.2.2 Technical Design of the project indicated that there were 3 types of cables to be installed. PV cables connected between a series of PV modules and from modules to combiner boxes. DC cables transported energy from combiner boxes to inverter stations and AC, or MV, cables carried electricity from inverter stations to the control houses. In addition, grounding wire was inserted to the cable trench in the form of D14 steel wire.

The contractor provided a cable list containing the design measurements of the cables and expected Seco-Solar Ltd. to follow the list and notify any found discrepancy. It was allowed to reasonably change the cable lengths to suit the site condition when pulling cables. Also, there were protective pipes for some cables, and they will be noted in table 3.

Table 3. Cable path and protection

Cables	On PV structures	Depth in trench (from lowest)	Protective pipe in trench	Protective pipe crossing roads
PV	Yes	4	Spiral rib HDPE pipe	D40
DC	No	3	No	D100
AC/MV	No	2	No	D125
D14	No	1	No	No

The cable laying process required vast effort to control, as there were over 25km of cables, excluding grounding wire, in each zone; a systematic set of coding was designed for easier documenting. Chapter 3 indicated that there were 8 collector circuits to the control house, and those circuits were denoted by letters from “a” to “h”. Each circuit gathered the power from 2 zones, with the exception of circuit “h” gathering from 3 zones. Each zone had 1 inverter station and that station was labeled by its zone. An inverter station collected energy from 16 combiner boxes, each of which congregated up to 21 strings of 30 modules. The coding ensured the uniqueness of either a string or a device by including its collector device as detailed as possible.

For example, figure 21 [14] demonstrated the cable path in a small area of Zone 3. It contained blocks and lines for indication of component and cable respectively. There was a block with an ellipse inside labeled b-3-4-16 at the top left corner. The label meant that this block represented a component from circuit “b”, inverter station No.3, combiner box No.4 and string No.16; so the component was a string of 30 modules. Similarly, a block labeled b-3-4 at the top middle of the picture illustrated the 4th combiner box in inverter station No.3 of the circuit “b”. The rectangular shape device with label No.3 was the inverter station of the zone.

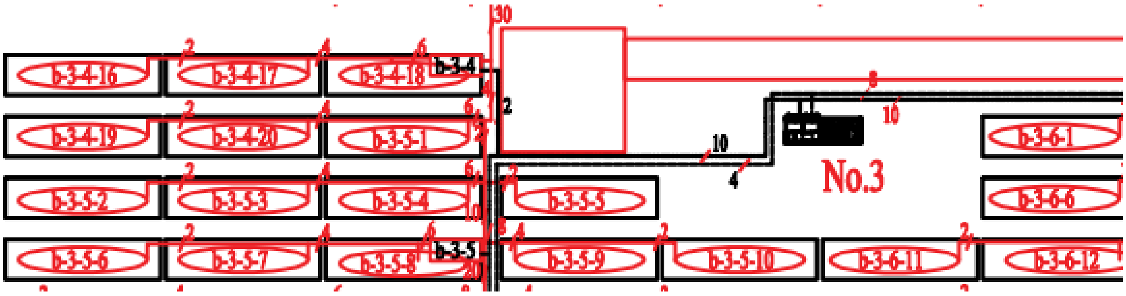


Figure 21. Zonal electrical path. Reprinted from Zhongnan Engineering [14]

Also in the picture, there is a line coming out of the block b-3-4-16 with number 2 on it when it reached block b-3-4-17. The line continued pass block b-3-4-17 with number 4 and block b-3-4-18 with number 6 before ending up in box b-3-4. That line represented the PV cable path coming out of the 16th string going pass the 17th and 18th string to meet combiner box b-3-4. The number indicated the amount of cables going by the path; initially the path joined 2 PV cables output from the 16th string, then it picked up 2 PV cables each from the 17th and 18th strings summing up 6 cables going into the combiner box. This labeling technique also applied to DC and AC cables, which will be mentioned in the Section Cable Pulling and Laying in trenches.

According to the design, the amount of cables on PV structures accounted for more than in the trenches. Hence, the work can be divided evenly into installment on structures and in trenches and be done at the same time.

Cable Pulling and Laying on PV structures

From table 3, only PV cables went on the support structures, and there were 2 types of PV cables, the module cable and the string cable. The module cables were attached to the solar panels and used to connect them in series to form a PV string. The string cables directed the electricity from a string to a combiner box, and were shown in the previous example with figure 21. Internally for a string, the 30 modules' PV cables were interconnected in series, sparing a positive and a negative terminal for connection with the string cable. The connected module cables and the string cable were both held on the C-shape horizontal beam of the mounting structure, and secured by cable ties. For the protection of string cable, HDPE spiral rib pipe was applied on the gap between the strings.

Cable Pulling and Laying in cable trenches

The contractor had prepared the detailed layout of the cable trenches, in figure 22, and the plan was to install from the bottom up, with D14 wire first. The layout also enclosed the optical cable, protective bricks and warning tape installation; however those were out of Seco-Solar Ltd. work scope.

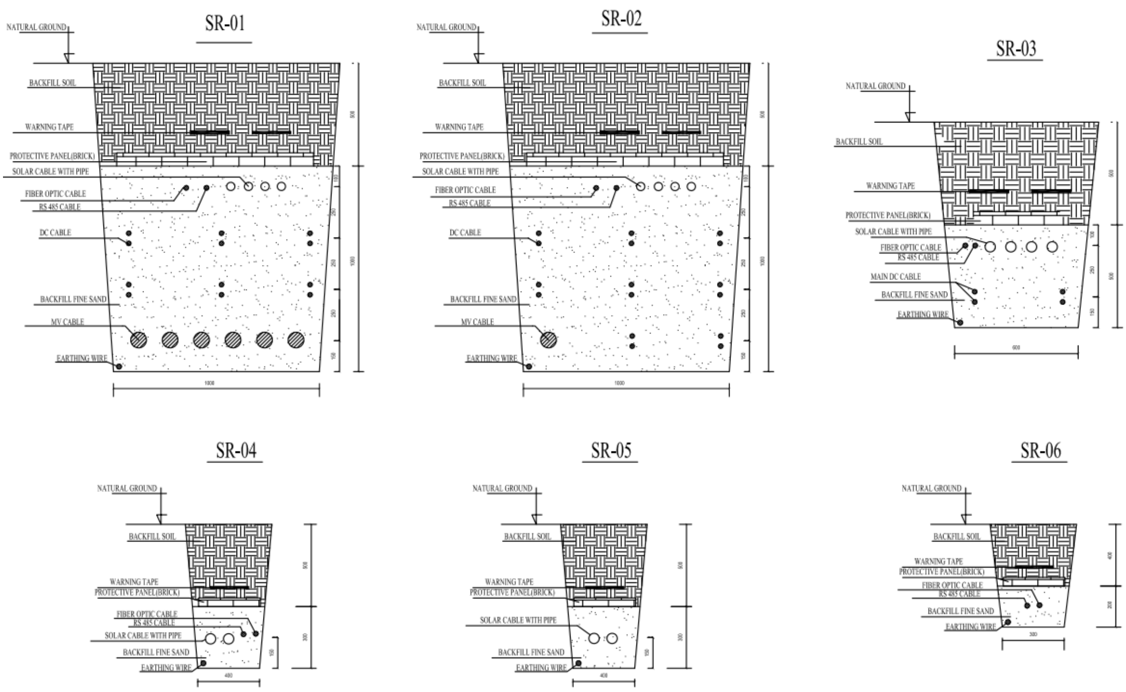


Figure 22. Cable layout in trenches. Reprinted from Zhongnan Engineering [15]

Accounting methods and requirements for pulling and laying cables on structures and in trenches, a chronological plan was deployed including some main tasks as listed below

1. Attaching HDPE spiral rib pipes on the beams.
2. Inserting PV cables on the beams, labeling and recording the length.
3. Laying D14 grounding wire in the trenches. Backfilling.
4. Laying AC cables in the trenches. Backfilling and recording the length.
5. Laying DC cables in the trenches. Backfilling and recording the length.
6. Laying HDPE spiral rib pipes in the trenches.
7. Inserting PV cables in the HDPE pipes in the trenches. Backfilling and recording the length.
8. Connecting PV, DC and AC cables in the trenches.

9 Connecting PV cables on the beams and securing them with cable ties.

It was important and pre-cautious to note that the connection to the electrical generator, the PV modules, had to be done last to prevent electrical potential jumps since the modules already generated power before connection.

4.2 Schedule

On a large-scaled project with many dependencies, the team members agreed to structure the plan based on deliverables rather than procedure. It was more rational to present how long it took to achieve a milestone on paper than to report what needed to be done in 3 days. This was the main difference between a time-based plan and an objective-based plan. It was earlier pointed out that the project depended heavily on other parties' behaviors, ranging from the contractor's supply of materials, to the schedule of the construction company digging the trench. Therefore, a time-based plan would fail readily since there were hardly chances to control the material supply from the contractor, or the schedule of another party. Finally, a decision was made to create a plan saying how long a milestone could be achieved provided that the materials and the construction site were sufficient to launch.

Table 4. Expected schedule

Tasks / Milestones	Starting date	Expected completion	Deviation	Number of workers
Grounding system	04/03/2019	55 days	15 days	20 (with a truck)
Combiner box Installation	04/20/2019	34 days	2 days	4
Inverter installation	05/09/2019	3 days	0.5 days	3 (with a crane)
Cable trench	04/03/2019	70 days	10 days	40 (with a crane)
Grounding of PV structures	04/10/2019	40 days	5 days	35 (with a truck)
Cable on beams	05/02/2019	51 days	5 days	20

Table 4 summarized the expected time for the given tasks. A sufficient amount of materials was expected to arrive before the starting date; otherwise the starting date could be changed due to the arrival variation, but other values remained unchanged. The expected completion time and its deviation were estimated based on the experience of the worker and the construction progress of other parties. Finally, the number of workers was a rounded average of the expected numbers of available workers by week.

4.3 Human resource

In this particular project, the human resource activity was divided into two main parts: Recruitment and Management. Recruitment, as it is, means that the management team searched for a source of labours that could deliver the work under supervision, and paid them to do it. The author of this thesis was not responsible for recruiting; rather he took part in managing the recruited labours. The management process included supervising, acknowledging the problems, and solving them as quickly as possible. This subsection will mention how the team planned to manage and the initial risks of management.

Although not involving in the recruitment process, the company had an initiatory tendency to recruit local people as they were familiar with a solar power project. With that in mind, the team set to discover the local area and learned the local culture. From the research, there were some benefits and some issue to be discussed among the management members.

Firstly, Ninh Thuan has over 100 projects associated with solar power; therefore, the local people got well acquainted with the technical demand as they worked in those projects. They readily acknowledged the structure of this project and they knew which and where to acquire equivalent equipment at a local distance. Secondly, most local people belonged to the Chăm ethnic group in Vietnam, and the ethnic culture dictated the men to stay at home while the women could have a steady income to feed the family. Due to this nature, the local area had a reversed family role where the local men should only work during crop seasons; this left them in boredom of having hardly any work and, hence, they committed vastly their time and energy into a potential work under reasonable terms.

The greater the opportunity seems to be; the greater the threat might arrive. At an early stage of the project, identification of the highest risk and estimation of its potential outcome needed analysing. Recruiting local people in such a large-scale Power Plant resulted in their overwhelming power on the management team. Since there were over

100 projects in the area, the labour members could jump to another project with ease whenever an inconvenient situation occurred. Not only might it prolong the procedure, but it also could take a while to find a replacement because most local men were working on a project at the time.

To prepare for the issue, the most crucial acknowledgement was that discordance is inevitable; one is unable to stop the outbreak of a fight, but can contain the outcome of the situation. Now this brought about the people's different perspective when an uncomfortable condition appeared, such as confusion of the technical method, delay of the pay check or inconsistent workload. Meri Williams mentioned in his book "The principles of project management" [16] that this was among the people problems that needed solving via good communication.

> When something goes wrong, look for people problems first. The role of the project manager is to make sure that the different parties' viewpoints are heard, and that everyone agrees to respect the course of action chosen, even if, as individuals, they would have made a different decision. (The Principles of Project Management – Meri Williams) [16 p.24]

When a disagreement happened, "because it was bound to happen", a good approach was to first address the related person, then to use means of communication to reach a concurrence. For a manifest understanding, Mr.Williams suggested 3 different features of a good communication process. [16 pp.30-33] Firstly, a manager needed to find a suitable form to communicate with the disagreeing members. Such form ranged from a one-to-one interaction to a group presentation, if there were many people with different perspectives to the situation. For example, a change in schedule required an official announcement and a technical problem suggested a mini-presentation limited to the wondering members.

Communication method indicated what means or how to communicate with people; and disparate method was most effective with its supported form. An email should correlate excellently with the one-to-one or one-to-many interactions, but grant negative effects with many-to-many conversations. Moreover, the method needed to be suitable for each person according to his preference. Some people considered email as a simple notification and it did not require an immediate response, whereas a phone call represented an on-coming necessity and deserved more attention. Hence, a strategy popped up saying the more important the message was; the more methods it demanded to ensure delivery. [16 pp.30-33]

In addition, the content played a crucial role in good communication. The key ingredient was to get straight to the point to avoid confusion as a speech was a most likely means of informing. The answer to whether the project was on schedule had to be either "yes" or "no" before getting into details. Or a request statement for technical change should be brought up before reasons of its change. Although there might be prospective risks, these preparations helped handle most of the people problem with the labours; and in the long run, they secured a smooth working process.

4.4 Documentation

This section described the documenting plan of the management team without a secretary or an accountant. The lack of equivalent knowledge, time and tools prevent us from making detail document derived from careful calculation. All control methods and estimations were operated on MS Excel and there was hardly a complex formula applied.

Material flow

As in the contract, the materials would be provided by the main contractor PCZ and the sub-contractor HH. For ease of monitoring the material flow, two managing members carried out the flows respectively by creating separate but harmoniously formatted Excel calculation lists which then were combined by the leader to get a complete overview of the flow. The author of the thesis was chosen to take care of the flow from PCZ the main contractor, using the provided material management template. Firstly, a material map was created to acknowledge the patterns and to allocate the materials upon necessity. The result is illustrated in figure 23, completing the circle of material handling. Originally, the contractor distributed evenly the materials to all of its sub-contractors including Seco-Solar Ltd which provided them to the workers. After the work was done, excessive materials would be returned to Seco-Solar Ltd and from that either to the contractor for storage or to the other sub-contractors to continue their portion of the project. The similar role applied to all sub-contractors: after finishing their work, they must conclude the material usage and transfer the remaining to either the contractor or other sub-contractors.

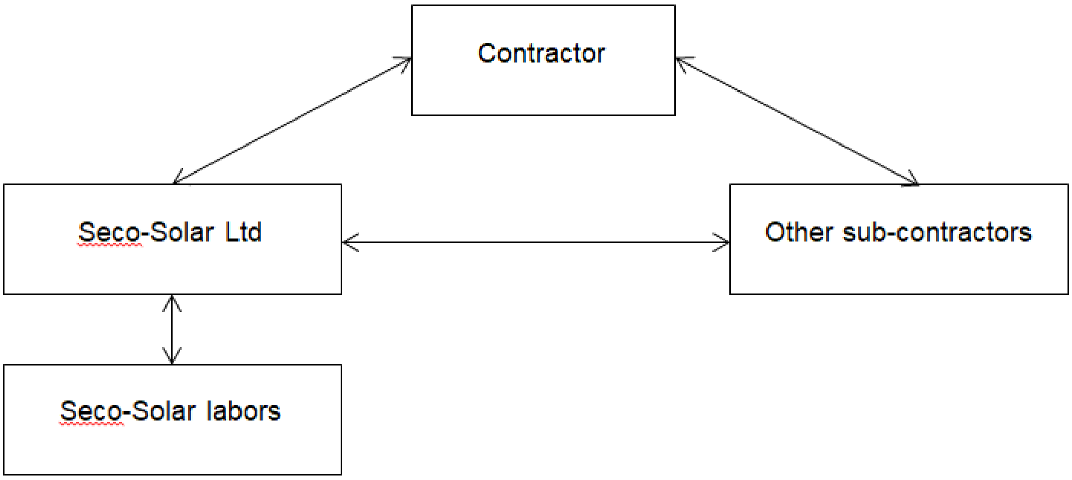


Figure 23. Material map in the project (PCZ side)

From the material map, it was compulsory to create an internal material flow sheet and was advantageous to keep track of the contractor's material distribution. The later task might be free formed but it should include at least which material, when and how much was given to which sub-contractors. On the other hand, the compulsory material flow had to follow strictly the format since it complemented to the HH flow done by another member and they synchronized to reach the overall material management file.

Table 5. PCZ material flow monitoring

Excel sheets	Progress	Import	Usage	Export
Description	Calculation of total usage	Lists of material directions documented by dates		
Important features	Total U Total (I – E)	Date Amount I From who	Date Amount U By whom of the labors	Date Amount E To who

The material flow was supervised by an Excel file with detail in table 5 with the linked values in blue. The file consisted of 3 lists and 1 calculation sheets; the lists were simply a material diary in which the receiving and providing of material by Seco-Solar were documented. Noticeable information in those lists was date, amount and appointee; otherwise there was not any calculation.

In the Progress sheet, the values for material quantity were referenced from the 3 lists and applied to a formula

$$Total\ usage\ U = Total\ import\ I - Total\ export\ E \tag{1}$$

The total usage was computed both by taking the sum from the Usage sheet and by formula (1). The first method along with the Usage sheet served in the payment to the labors whereas the second method functioned similarly to the contractor. Moreover, that the two methods shared equal results marked a complete circle of materials. For instance, Seco-Solar was given 50 units of material A for process X; they completed the process using 20 units and another sub-contractor had taken 20 units. In documenting, Seco-Solar had imported 50 units, used 20 units and exported 20 units; hence, the result from method 1 was 20 units and that from method 2 was 50 – 20 = 30 units. There should be an imbalance, resulting in Seco-Solar returning the remaining 10 units to the main contractor.

Cost estimation

Based on the contract, Seco-Solar Ltd. was not responsible for material provision; hence, the cost estimation uncomplicatedly enclosed the cost of working means and the living support for the management team. The cost of working means related to the cost of all types of labors, vehicles and tools detailed from the schedule plan which was summarized in table 4 of section 4.2 Schedule. Hence, the formula for such cost was inferred

$$Working\ means = Labor \times 20\% + Tools \times 30\% + Vehicles \tag{2}$$

Formula (2) suggests the working means cost equaled the sum of labor, tool and vehicle expenditure. To cover uncertainty, labor and tool expenditure should be more than the planned values; their objective uncertainty indexes accounted for 20% and 30%

respectively. On the other hand, vehicle expenditure was fixed since it was recommended to make a contract and rent a vehicle for the whole month.

According to the grant policy for business trip of Seco-Solar Ltd, its employees will be remunerated with the basic living cost, transportation fees and distant office fund. The basic living cost covered house rent with 3 meals per day; transportation fees consisted of travel expense both between site and office and from office to home. The distant office fund comprised of the cost to set up an office in the accommodation and to work at the office. They are all applied in formula (3).

$$Living = House \times 10\% + Transportation \times 40\% + Office \quad (3)$$

The housing cost had 10% uncertainty index to provide for the water spend that was not in the rent. The transportation fees meant the cost to purchase and maintain motors bike for traveling to and forth work and the cost of employees' occasionally traveling back to their hometown, with a considerable 40% uncertainty. Finally, the fund for setting an office was simply the fixed equipment and device expenses as the electrical cost was included in the house rent.

$$Project\ estimation = (Working\ means + Living) \times 25\% \quad (4)$$

Summing up, formula (4) indicated the cost estimation for the project being the total of the two costs in (2) and (3) multiplied by the uncertainty index of 25%. One might argue the uncertainty indexes in all formula (2), (3), and (4) being unreasonably high. However, the deployed strategy for budget handling required the estimation being higher than the actual cost; and the uncertain expenses being remotely above their expected values. The method was internally named financial circle and will be analyzed in Chapter 5.

5 Execution

The planning process was completed; it was time to put strategies and preparations into action. However, recapping and reflecting all of the theory and plan from Chapter 3 and 4 seemed unnecessary; hence few of the plan attributes will be mentioned and discussed.

5.1 Budget handling

Section 4.4 Documentation described the project cost estimation; this section will mention how Seco-Solar Ltd handled the cost with the method of financial circle. This method implied that the cost was estimated monthly, the overall estimation accounted for the maximum of the monthly estimation; and the financial supply of the following month yielded for the actual cost of the previous month. Hence, a circle of cost and supply showed up, guaranteeing the precise of the budget flow and preventing overspending.

Table 6. The financial circle method for budget handling

	Launching	March	April	May	Termination
Supply	Estimation (E)	0	C3	C4	C5 – E
Cost	0	C3	C4	C5	0
Supply - Cost	E	0 – C3	C3 – C4	C4 – C5	C5 – E
Accumulation	E	E – C3	E – C4	E – C5	0

For the security of the company’s information, exact values for budgeting and spending are kept classified. Instead, those values will be denoted by letters in table 6. Initially, the highest monthly estimation E would be supplied for the first month. The actual cost was recorded monthly, and the supply for the following months was the costs of the previous ones. In addition, the accumulation values of the supply-cost difference decided the final supply or indemnification. Ultimately, the method cemented the highest expense to the highest estimation, thus balancing between preventing excessive spending and preparing for unexpected scenarios.

For instance, the management team had been given E and had spent C3 in March before the supply in April delivered C3 to the project. Therefore, in April, the maximum spending should not exceed the original supply E, and the process repeated in May. Finally, the project termination underwent the team submitting the expenditure documents, receiving or reimbursing the remaining supply-cost difference.

It was mentioned in Chapter 4 that the estimation had to be much higher than the actual cost; in fact this was difficult to achieve when planning. On paper, it was the primary approach to have the estimation-cost difference high to avoid unexpected circumstances such as schedule delay due to bad weather or labour lack during crop season. Thus the solution would be raising the estimation for higher supply and reach financial confidence. However, the Financial Department of the company would demand not to overreach the project situation and want to narrow down the budget to prevent the project money to be spent elsewhere.

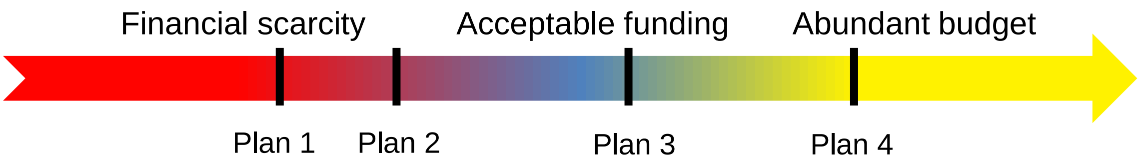


Figure 24. The gap between Maximum Estimation and Maximum Cost

There were a few discussions between the Project Management team and the Financial Department to determine the satisfactory supply amount. The PM team presented a list of reasonable suggestions and the FD provided an acceptable funding interval given the financial state of the company. As a result, the amount corresponding to plan 3 in figure 24 was chosen to launch. The amount satisfied the need of financial confidence as well as preventing the project from going into overspending. Although hardly any number was mentioned, this section has explained the strategy and concluded the budget calculation in the project.

5.2 People handling

This section is distinct from the whole thesis, because it aims at a more sensitive aspect of project management that could limitedly be prepared through experience. Human resource is much different than time or materials. Managing such resource requires not only understanding and mutual respect, but also adaptation since handling people problems is a learn-from process. This term means that the skill cannot be planned; it might only be prepared during execution, when those people problems are in fact encountered, the young project manager must pay attention to how senior managers deal with them and learn how to untangle similar situations.

5.2.1 Towards the inferior

Among the biggest human problems, labours' leaving for other projects was mentioned in Section 4.3 Human resource. The reason for leaving was, for example, a delay in pay check, which was not controllable by on-site management team. Also, in the workers' shoes, the target was the agreed income, neglecting company policies or financial complications; so it had been redundant to explain the financial situation for them. Predicting the delay and the local people's behaviour, the Head of Project Management team, Mr. Van had made a pre-emptive move. The goal was to maintain the labour team without rushing the transactions from the financial team; and this seemingly impossible task was solved by giving all members some paid days off from work before the pay check period.

Initially, the strategy succeeded because the workers deserved some rest after intense performance. Also, the paid days off relieved the tension among people when the financial delay was finally announced. In the long run, the workers stayed as they believed in the company's fair treatment; thus the solution won their trust and kept a unite team. The drawbacks were delay in progress and that some workers left due to urge of payment; however, with the labour crew being the heart of the project, the solution was considered a fortunate success.

5.2.2 Towards the superior

Keeping a good contact with the contractor was also a challenging task. It occurred regularly that the contractor demanded more than in agreement from its subordinate companies; and they often complied to please the one paying them. This section would not argue with such behaviour, rather it agreed only to an extent.

Most conflicts with the main contractor happened during the inspection process, where the sub-contractor attempted to convince for approval and the contractor tried to squeeze any flaw from the products. Business-wise, each side was taking advantages for either company; the sub-contractor wanted to complete the work and the contractor desired to decrease payment due to defection. One such case arose when both parties argued about the cable length being longer than the design lists.

Due to the unfavourable landscape, one pulled cable was significantly longer than in the design; it exceeded the expected length plus the uncertainty. This raised some concerns in the contractor, and an argument boiled down to technicians from both companies arriving to the trench of that cable and measuring the length. The desire to spot a flaw was apparent, as the contractor’s technicians deliberately measured the length along the trench, neglecting the natural curve of the cable and the excess length for device connections. Such behaviour was unacceptable; Seco-Solar’s technicians reported for false measurements, and a negotiation was agreed upon to have the Executives resolve this matter.

At the end of the whole inspection and follow-ups, both parties agreed to approve the length, but less extra payment for the exceeding length. Consequently, this conflict proved that Seco-Solar’s employees were able to discover false technical actions and willing to reject any unfair treatment from other parties regardless of their rank in the hierarchy.

5.3 Quality control

In reality, the company’s proper training program and the local people’s knowledge from previous Power Plant Projects helped reducing the requirements for redo or repair the defective products. Most of the installation resulted in approval and PCZ’s technical supervisor even praised the work of Seco-Solar. The more preferable tactic for quality control was process control, meaning that the management department made sure that the installation delivered the desired results, rather than just checking the results and fixing them. Chapter 6 will mention the results and outcome, while this chapter gives an example of the most challenging process for Seco-Solar to supervise, the grounding steel between the mounting structures.

Explained in section 4.1.1, the grounding steel between the mounting structures connected and protected the adjacent structures. Since there were about 1,300 structures corresponding to 10,000 panels each zone, and each connection was distinct; it was difficult for Seco-Solar’s engineer, Mr.Sơn, to monitor the work. As early as 6am every day, the young engineer carrying his copy of the design, travelled across the mounting structures in each zone. He marked carefully the completed grounding parts on the design copy, while the Head of the management team divided the work for the labours.

If the grounding pieces for a zone had been completed, Mr.Sơn informed his colleague, also the author of this thesis, to invite the contractor for inspection, which usually meant approval of completion.

However, due to the distinction of each grounding location, there would be some defective and unfinished places. Those places were marked on a design copy and the team decided to fix them after installing for all 17 zones. The strategy was that the defective places demand a unique design for the flat steel; hence it was easier to manufacture a piece for most places, then to produce a piece for unique places. The labours completed the 17 zones with defection for the first time, then, worked on the defection under supervision of Mr.Sơn. This strategy required more supervision from him, but decreased the effort to repair the products in the long run.

6 Results and improvements

It is difficult to decide whether a project is a success; however, some certain functions of it can be judged if they have reached their full potential. To access them, the inspection process should be taken into account. The process served as a loop of repeated activities; first, Seco-Solar invited PCZ on an inspection; then PCZ would decide whether that product was delivered. If it was not, Seco-Solar must readjust, and invite PCZ again; the invitation and acceptance would be repeated until PCZ finally approved the product.

6.1 Grounding system

The main grounding system and the grounding wire should be the smoothest as they both were independent and uncomplicated. The results comfortably satisfied the contractor in the first attempt, and no modification should apply. The appendix 2 section provides some pictures for grounding inspection, as they were required for the report and the payment document.

Figure 25. Grounding flat steel between mounting structures

The flat steel between mounting structures, described in figure 25, got some inspections due to the delay of assembling the mounting structures and the landscape complication. The late completion of structures slowed the grounding insertion and the slope of landscape created imbalance between 2 structures; thereby increasing the length of one side in the steel shape. In the end, the owner and contractors were pleased with the outcome as they approved the inspection. However, a visit to some adjacent Solar Plants suggested an improvement to the process. Instead of flat steel, it was easier to attach the steel wire directly to the structures by welding, eliminating the problem of landscape at the cost of more welding work.

6.2 Electrical devices

Perhaps the inspection of the device installation went the quickest. Since hardly any problems occurred, the process was considered the biggest success in the project.

Figure 26. Installing the Inverter station

Taking the least amount of time and workers, installing the 17 inverter stations, with one in figure 26, was completed in 2 days, including both the process and inspection,. The combiner box installation was slower due to its dependency on the mounting structure completion, but was managed on time for the cable connection.

6.3 Cable installation

The cable laying process was dependent on the excavation and backfilling, with complications of trench layout and cable positions. figure 27 indicates the complex network of cables in a trench. Besides, the cable inspection was distinct from others, as it required not only connection to devices, but also quantity measurements. The connection was comparatively simple, as the worker has qualifications and electrical testing showed positive results. On the other hand, the issue aroused when parties tried to reach an agreement on length of the cables. It was predetermined with expected errors by the design cable lists; however, due to the fluctuated ground level, the lengths varied as the cables connected to the devices at different altitudes.

The situation was similar to the flat steel grounding; the contractor stuck to the design and would not approve the adjustment due to excessive length, while the sub-contractor argued that such adjustment needed applying to match the landscape. While both sides had their merits, all parties came to an agreement ultimately to accept the adjustment, with the contractor taking the loss of materials and the sub-contractor having the installation payments reduced by 10%.

Figure 27. Cabling under mounting structures

All in all, the cabling process did not receive much success with implementing the result. In fact, it took 2 weeks for the mater to be resolved, causing delay in backfilling an electrical testing. Possible improvements included an adaptive measure to combat the slope and a stronger communication. The designer should have taken into account the mountainous landscape then either suggested some flattening methods or expanded the expected error range. Next, the sub-contractor would have informed more clearly the adjustment during the cable laying process and asked for approval.

7 Conclusion

After a rough 8-month period, Sinenergy Ninh Thuan I Solar Power Plant marked its inauguration on July 22nd, 2019. The final operational testing predicted a lasting lifetime of the plant and concluded the hard work and immense effort of the construction and installation parties. In terms of the purpose, the project had reached its destination of constructing a functional 50MW Power Plant, with the designed resources and time. The owner, A2 Technologies, was expecting profits from selling electricity as well as a major change in the local environment.

Regarding the company, Seco-Solar ended up having its desired income from the project and the recognition from other companies. Regardless, the ultimate goal of the CEO had been to train the technical employees and created a reliable solar power engineering team. To evaluate, the on-site team's performance satisfied his expectation; the resource usage was efficient and reasonable, the labor management went smoothly and the technical understanding exceeded the project's demand. More solar power related projects would enhance their skills and strengthen their ability.

Finally, reflecting on the initial goals, the author desired to gain understanding of a management role. Although it was hard to measure this achievement, compliments from his superiors and his colleagues approved his accomplishments. Those compliments, ranging from a simple "What a complex task for such a young man!" praise from one of the labors, to the encouraging "You might go the distance if you keep this pace" from the Head of the team, gave him more confidence to grow in the managing department. On the other hand, his wish to apply the solar energy knowledge was only partially satisfied due to the constructional related nature of the project. It could be explained that a power plant had 3 phases for its lifetime: Design, Construction and Operation. It was towards the completion of the Construction phase that the author participated in; meanwhile the more theoretical challenging phases were the two others. Nevertheless, the author believed to have earned valuable career building experience via working with other team members, trying monitoring the on-site work as well as the material flow, and handling the most sensitive human problems. While there was not a clear method of measuring the changes, it was safe to say that the author entered the project having hardly any knowledge; he left it knowing the basis of project management.

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Power Plant – Some pictures of the process

Figure 28. Seco-Solar's management team and the local labors

Figure 29. The site technicians from PCZ, HH and Seco-Solar

Figure 30. Top view of the Power Plant - taken on April 13th

Figure 31. The control house area - Taken on March 28th

Figure 32. The Power Plant and a nearby lake - Taken on March 28th

Some inspection pictures

The inspection process took the most effort from the team, as they had to ensure both the quality and quantity of the product; once the inspection resulted in approval, pictures were taken for the inspection report in the payment documents.

Figure 33. Trench grounding inspection, with the owner

Figure 34. Inverter station foundation inspection, with the owner

Figure 35. Trench grounding inspection after the rain

Figure 36. Trench grounding inspection at connection points

Figure 37. Inspection of grounding steel between structures

Figure 38. Cable crossing river inspection