CHAPTER III

RESEARCH METHODOLOGY

This part of the study will evaluate and present the technical and economic assessment of solar PV battery charging station compare to diesel battery charging station in Kampot province of the Kingdom of Cambodia by using the methodology is gathered through secondary data. Meanwhile, solar PV battery charging station offers more enormous potentials to contribute to low-carbon electrical systems, which must be included a portfolio of efficiency and clean technologies with zero greenhouse gas (GHG) emission. This study is used to describe other recommendations which mention about the recommendations will be needed to address those problems of technical and economic assessment in Kampot province of the Kingdom of Cambodia. On the other hand, secondary data were also gathered from books, articles, magazines that were published in hard copies as well as those found in the internet. This station should be focused on the solar PV systems sizing, such as how to calculate total watt-hours per day for each appliance used in each household, how to calculate total watt-hours per day needed from the c-Si PV modules, calculate the total watt-peak rating needed for c-Si PV modules, calculate the number of PV panels for this system and solar charge controller sizing. For the detail of this study will be shown the relationship between technical and economic evaluation of PV battery charging station with capacity of 10 kW_p using c-Si PV modules compare to diesel battery charging station in Kampot province, Kingdom of Cambodia as the flow chart diagram below.

Flow chart diagram of thesis methodology

This chart diagram will express the relationship between technical and economic assessment of solar PV battery charging station in Kampot, Cambodia. There are two main objectives of the thesis methodology in the figure 11 as the following:

Objective 1: To analyse the technical and economic assessment of solar PV battery charging station in Kampot, Cambodia as the following:

1. Technical analysis:

1.1 Select location.

1.2 Select PV modules and some materials.

1.3 Calculate and design system of solar PV battery charging station based on the energy needed of each household in Kampot province of the Kingdom of Cambodia.

1.4 Analyse and evaluate data from the system above in order to find the most suitable technical assessment for this study.

2. Economic analysis:

2.1 Find the cost of solar PV battery charging station in Kampot, Cambodia.

2.2 Analyse the economic assessment of solar PV battery charging station compare to diesel battery charging station with the same capacity of 10 kW_p and different original electricity cost.

Objective 2: To propose the most suitable techno-economic assessment from this study to other users and the Royal Government of Cambodia. In this term, we will find the most importance model from this study.

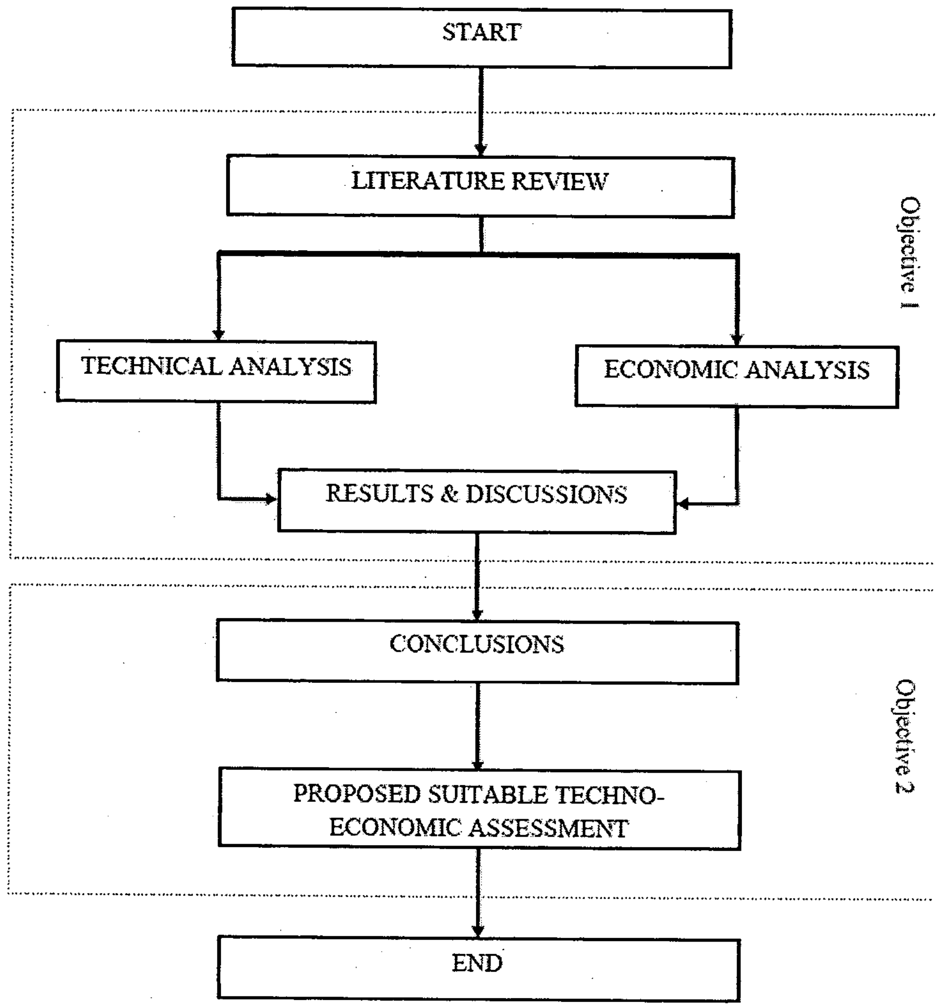


Figure 11 The flow chart diagram of thesis methodology

Research instruments

This study will use some instruments such as PV module, PV array, charge controller, battery storage system, pyranometer, multi-meter, data logger and so on. This system will design and calculate the peak power and charge controller capacity as the following equations.

PV system calculates

This PV system, we can calculate as the following formulas:

$$PV_{peak} = \frac{I_{STC} \cdot E_{el}}{Q \cdot E_{glob}} \quad (1)$$

Where,

PV_{peak} = *Peak power of the PV array under STC, [kWh]*

E_{el} = *Real electric output energy of the system, [kWh/day]*

I_{STC} = *Incident solar radiation under STC, [1 kW/m²]*

E_{glob} = *Annual global solar radiation, [kWh/m²-day]*

Q = *Quality factor of the system (stand-alone system: 0.10-0.40)*

$$C_c = \frac{PV_{peak}}{System\ voltage}$$

(2)

Where,

C_C = *Charge controller, [A]*

System voltage = 12 Volts

Based on the power demand of each household in this province, the calculation of this PV system as below:

Power demand = 40-60 W/customer [2].

Each household is used some appliances about 3.5 hours/day

Energy demand (E_{el}) = [(60 W) (3.5 h/d) = 210 Wh/day

Therefore, the energy demand of each charging string (E_{el}) = 210 Wh/day

The battery capacity of 2 days without sunshine (solar radiation)

C_B = (210 Wh/day * 2 days)/(12 V) = 35 Ah

PV_{peak} = (E_{el}*I_{STC}/E_{glo}*Q)=[(0.210kWh/d)(1kW/m^2)/(5.2kWh/m^2/d)(0.20)]

= 0.201 kW = 201 W

C_C = (201 W/12 V) = 16.75 A

(System voltage = 12 V)

If we will use the PV = 212.3 W_p/module, this system we need to use the PV modules as below:

201 W/(212.3 W/module) = 0.94 ≈ 1 Module.

So, the PV generators are as the following:

PV modules (mono and poly crystalline silicon)

Rated PV module power = 212.3 W_p/module

Each charging string consists of 1 module connected in parallel

Rated power for each charging string (1 module x 212.3W/module)=212.3W_p

Orientation: south-facing and tilt angle is around 10^0-11^0 or more.

Batteries = 6 V-24 V and capacity of 30 Ah – 70 Ah.

PV system designs

The system will use and take some data of PV battery charging station in the Kingdom of Cambodia based upon the energy needed of each household in order to compare and evaluate the technical and economic efficiency. This system will consist of PV array (PV generator), charge controller, energy storage systems, and DC consumer or charger. Charger should be designed one to one (independent charging string), namely its can charge DC to DC chargers that convert the solar system voltage (normally 12V) to the required charging voltage/current of each system (e.g. 6V) are available in the Kingdom of Cambodia's market today. The PV battery charging station is mentioned in the figure 12, which consists of 47 modules of c-Si PV modules with power rated of 212.3 W_p each module, giving total capacity is about 10 kW_p with 47 independent charging strings. They are very useful for ensuring that the load is operating under the suitable voltage and current levels. The figure 12 is shown the PV battery charging station (system).

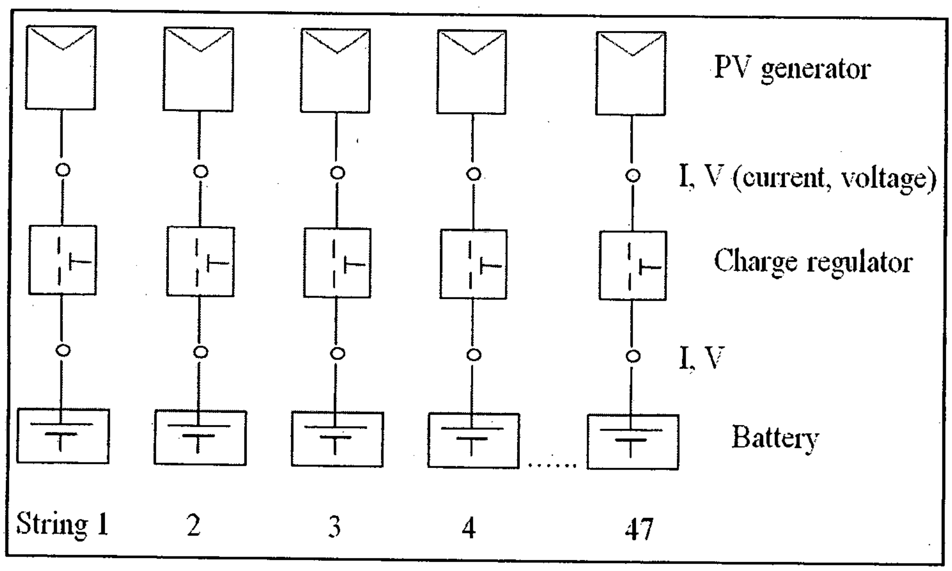
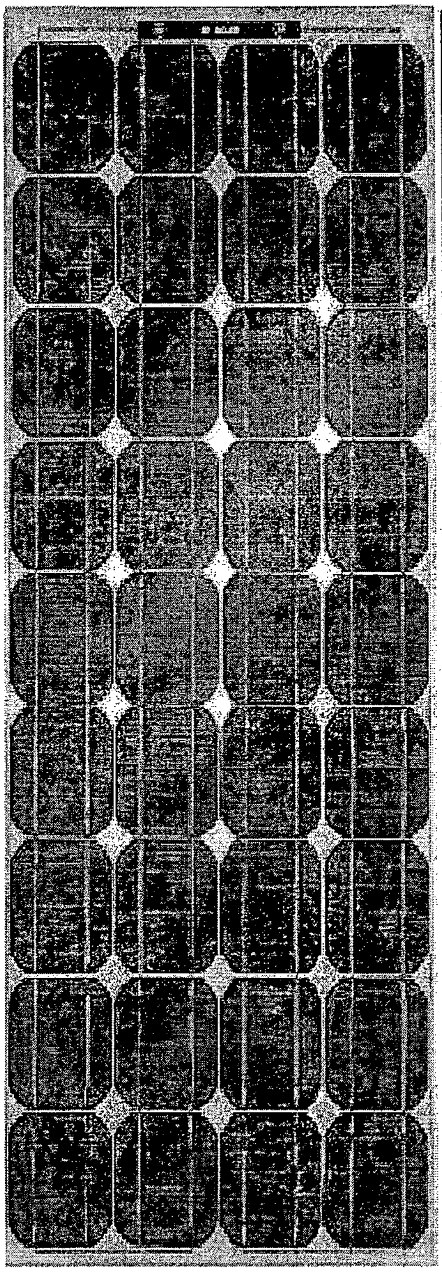


Figure 12 PV battery charging system

According to the actual energy demand of each household in Kampot province is about 40-60 W/customer [2]. PV generators can be connected to the DC battery bank in the same way as it standard battery charging station likes the Figure 12 above. A typical PV battery charging station consists of PV modules, charge controller and other components that can charge a battery bank to supply DC electricity to DC based appliances such as lamp, radio, TV, fan and other appliances. In other words, the string concept for charging, which has been successfully introduced to stand-alone PV systems, can be used in battery charging station as well. The installation design was fixed such as mono or poly-crystalline PV modules which were selected and installed with 47 modules, solar PV module with one side open, rectangle type support was approved, module connectors were used to connect all the output from each module, PV charge controller was installed to monitor the load, all frames and supports were installed as in installation guide, the materials for the frame were steel angle and anchor, concrete angles were carefully installed to support the system and also to prevent rain penetration into ground and the installation was completed as the figure above. In this case, the rated PV module power is about 212.3 W_p per module of c-Si PV modules at PVUSA Test Conditions (PTC), this is much closer to real world conditions and practices, which connected in parallel in order to get high current of each charging string because of the battery charging stations need to increase the current, orientation faced to the south and tilt angle is about 10^0-11^0 or more depend on the actual location in the Kingdom of Cambodia [1]. In this system needs to use a charge regulator in order to protect the batteries from overcharging, the panel from power going back into it from the batteries and to help maintain battery condition by keeping the battery voltage high and if necessary we need to set up the c-Si PV modules with bypass diodes to protect the station shadowed by trees, building and so on. But, the total investment cost of the system is also a little increased.

Solar PV module selection

There are many types of PV modules. In this system, I will select only two types of mono crystalline silicon and poly crystalline silicon PV modules, because of its have highest energy conversion efficiency than other module types and they are also available in local market in the Kingdom of Cambodia today in order to construct a solar PV battery charging station in Kampot province of the Kingdom of Cambodia, which designed and calculated in this chapter. The figure 13(a) and 13(b) are shown the PV module variables as below.



Solar PV Module (Mono c-Si):

Technical specifications

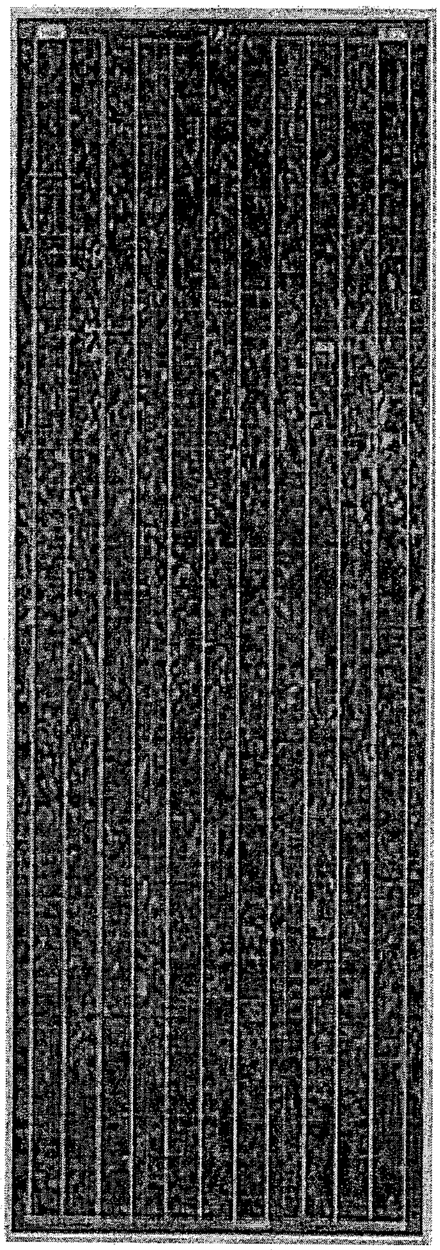
- Module catalogue number: HiS-S240MG
- Rated power @PTC (P_{max}): 212.3 W
- Voltage @ maximum power (V_{mp}): 30.90 V
- Current @ maximum power (I_{mp}): 7.80 A
- Short-circuit current (I_{sc}): 8.30 A
- Open-circuit voltage (V_{oc}): 37.40 V

Dimensions (F= Framed and L= Laminate)

- Length: 164.5 cm
- Depth: 3.5 cm
- Width: 98.2 cm
- Weight: 19.00 kg
- Life time: 20-25 years
- Module efficiency: 14.8%
- Materials warranty: 10 years
- Power warranty (90%/80%): 10/25 years
- Frame colour: Silver
- Back-sheet colour: Black

Figure 13 (a) Solar c-Si PV modules (HiS-S240MG)

Source: Hyundai solar, Korea, 2012



Solar PV Module (Poly c-Si):

Technical specifications

- Module catalogue number: HiS-M235MG
- Rated power @PTC (P_{max}): 212.2 W
- Voltage @ maximum power (V_{mp}): 30.30 V
- Current @ maximum power (I_{mp}): 7.80 A
- Short-circuit current (I_{sc}): 8.30 A
- Open-circuit voltage (V_{oc}): 37.40 V

Dimensions (F= Framed and L= Laminate)

- Length: 164.5 cm
- Depth: 3.5 cm
- Width: 98.2 cm
- Weight: 19.00 kg
- Life time: 20-25 years
- Module efficiency: 14.5%
- Materials warranty: 5 years
- Power warranty (90%/80%): 10/25 years
- Frame colour: Silver
- Back-sheet colour: White

Figure 13(b) Solar c-Si PV modules (HiS-M235MG)

Source: Hyundai solar, Korea, 2012

Economic evaluation

The basic of most engineering decisions is an economic. Designing and building a device or system that functions properly is only part of the engineer's task. The device or system must, in addition, be economic, which means that the investment must show an adequate return. In the study of solar PV battery charging systems, one of the key ingredients is an optimization, and the function that is most frequently optimized is the more potential profits. Sometimes, the designers try to seek the solutions having minimum first cost, more frequently, the minimum total lifetime cost of the facility of each system.

In economics and cost accounting, total cost describes the total economic cost of production is made up of variable costs, which vary according to the quantity of a good produced and include inputs such as labour and raw materials cost, plus fixed costs, which are independent of the quantity of a good produced and inputs that cannot be varied in the short-term, such as buildings and machinery. Moreover, an important function of economic analysis in engineering enterprises is to evaluate proposed investments. A commercial firm must develop a rate of return on its investment that is sufficient to pay corporation taxes and still leave enough to pay interest on the bonds or dividends on the stock that provide the investment capital. The evaluations can become very intricate, and only the basic investment situations will be explained. This fundamental approach is, however, the starting point from which modifications and refinements can be made in more complicated situations. Four essential elements will be considered in investment analyses such as (a) cost, (b) income, (c) operating expense, and (d) salvage value. The rate of return is treated as though it were interested. Based on this mentioned as above, there are two major category costs of solar PV battery charging station as the following:

Fixed cost:

The cost which does not change with the units of production, for example, building rent, debt, land and so on.

Variable cost:

The cost besides the fixed cost and it changes with the units of production, for example, raw materials, labour, office supply cost and other costs.

This study is used some formulas to calculate and evaluate the economic assessment in order to make an evaluation and optimization of the cost and good viability of the solar PV battery charging station. By the other hand, the economic evaluation of the desirability of installing solar PV battery charging stations are generally characterized by low initial costs and high operating costs of conventional systems. For economic evaluation would be used some important equations as the following:

Net Present Value (NPV): is a method for evaluating the desirability of investments can be defined in the equation 3 below.

$$NPV = \sum_{n=0}^{N} \frac{B_n}{(1+i)^n} - \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} = PVB - PVC \qquad (3)$$

Where,

B_n = *Expected benefit at the end of year n.*

C_n = *Expected cost at the end of year n.*

i = *Discount rate.*

n = *Project duration in years.*

N = *Project period.*

PVB = *Present Value Benefit.*

PVC = *Present Value Cost.*

$STC = PVC$.

Internal Rate of Return (IRR): is another time-discounted measure of investment costs. The IRR is clearly defined as that rate of discount which equates the present value of the stream of net receipt with the initial investment outlay. The IRR is less than a discount rate; the project is very regarded as non-economic (less profitable) project, the suitable project, the IRR should be more than a discount rate. The IRR can be calculated in the equation 4.

$$\sum_{n=0}^{N} \frac{B_n}{(1+r)^n} - \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} = 0 \qquad (4)$$

Where,

$r = IRR.$

Benefit to Cost Ratio (BCR): is the division of total present value benefit (PVB) over total present value cost (PVC) as given by the equation 5. The BCR should be more than one in order to indicate the profitable PV power projects.

$$BCR = \frac{PVB}{PVC} \tag{5}$$

Payback Period (PBP): is very strong significantly indicated by the payback period/time of each project to make the NPV of the cash flow, up to the present moment as evaluated by the equation 6. When PBP presents high value (long payback periods/time), so the project is disagreeable in economics. But, the shorter payback period indicates that the better investments for all investors. It is very well known as criteria of PBP value for the availability more than the profitability of the PV projects. The payback period can be calculated as an equation below.

$$PaybackPeriod = \frac{Cost\,of\ project}{Annual cash revenues} \tag{6}$$