Performance Evaluation AC Solar Home Systems in Thailand: system using multi crystalline silicon PV module versus system using thin film amorphous silicon PV module

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ABSTRACT

There are more than 200,000 AC output solar home systems (AC SHS) installed in Thailand form 2004 to 2006. Two types of PV module are used in this massive installation, multicrystalline silicon (mc-Si) PV module and thin film amorphous silicon (a-Si) PV module. Two type of charge controllers suitable for each type of PV module are installed to control of charging from PV modules to deep cycle lead acid battery. The system with mc-Si PV module uses shunt interrupting design or On-Off charger controller while the system with a-Si PV module uses DC-DC converter with maximum power point tracking (MPPT) algorithm charge controller due to high PV output voltage from a-Si PV module. The AC SHSs are operated by allow to full daily energy yield form PV to charge their batteries without maintenance of batteries and with maintenance of the battery to observe the in system performance in both conditions. The performance of these two AC SHSs are monitored and analyzed by using IEA PVPS TASK 2 performance evaluation model.

Keywords: *Performance Evaluation, Stand Alone PV System, Solar Home System*

1. INTRODUCTION

Thailand mega-project 200,000 SHS's uses two types of PV module, mc-Si and a-Si, which have different output voltage at maximum power (V_{Pmax}). The mc-Si (36 cells) PV module has V_{Pmax} at 17.2 Vdc which is suitable to charge battery which has nominal voltage 12Vdc. The cost effective charger controller for this type of PV module is shunt interrupting or On-Off charger controller [5] thus On-Off charger controller is selected by most manufacture to use with mc-Si PV module in this project. The a-Si PV module has higher V_{Pmax} at 44 to 68 Vdc which is not suitable to charge battery with nominal 12 Vdc thus SHS with a-Si PV module requires voltage conditioner such as DC-DC converter to change V_{Pmax} to suitable voltages for charging 12 Vdc battery. Since this type of charge controller has to convert DC voltage which mean the input part of the charge controller connected to PV module and the output part of the charger controller connected to the battery are separated thus the good charge controller integrates the Maximum Power Point Tracking (MPPT) algorithm into the input part which is called MPPT charge controller. In this paper we will evaluate the system performance of AC SHS using mc-Si with On-Off charger controller and a-Si with MPPT charge controller.

Two SHSs, mc-Si PV module with On-Off charge controller and a-Si PV module with MPPT charge controller are set up in Bangkok with other BOS, deep cycle lead acid battery, square wave inverter and resistive load, to evaluate performance of two type SHSs in warm climate condition such as Thailand.

The systems are operating without any maintenance of battery and maintenance of battery by refill distills water every month. The performance evaluation model introduced by IEA PVPS TASK 2 is applied to evaluate result data [1,2].

2. AC SOLAR HOME IN THAILAND

The AC SHS system installed in Thailand's mega-project consists of PV module 120 Wp , charge controller with charge current 10 A, square wave output inverter 150 Watt, deep cycle battery 125 Ah 12 Vdc. The installation sites are in remote area of warm climate and high humidity environment locate in Thailand between latitude 5° 45'N to 20° 30'N and longitude 97° 20' E to 105° 39' E.

The proposed and installed systems consist of several PV modules power rating depend on manufactures and the PV module have to be assembled or manufactured in Thailand. There are two types of PV modules proposed to used in this project which are:

1) mc-Si PV module with 36 cells type, power rating 120 Wp (Solartron) or 123 Wp (SHARP) with V_{Pmax} around 17 Vdc.

2) a-Si PV module, power rating 40 Wp x 3 (BSC) or 64 Wp x 2 (KANEKA), power rating 120 Wp or 124 Wp with V_{Pmax} around 44 Vdc and 68 Vdc respectively.

These two types of PV module which require different type of charge controller to charge battery which has nominal voltage 12 Vdc in the system. Both types of AC SHS use the same deep cycle flooded type battery capacity 125 Ah @ 20 hours discharge rating and square wave output inverter to convert DC power form 12 Vdc battery to AC power at 220 Vac,rms and supply to load which are two set of fluorescent lamps 10 Watt with electronics ballast. The AC SHS is prepare to be use with color television and other type of appliances under 150 watt of power rating and loads have to be capable to use with square wave output of the inverter. The configuration if these two systems are shown below (Fig 1).

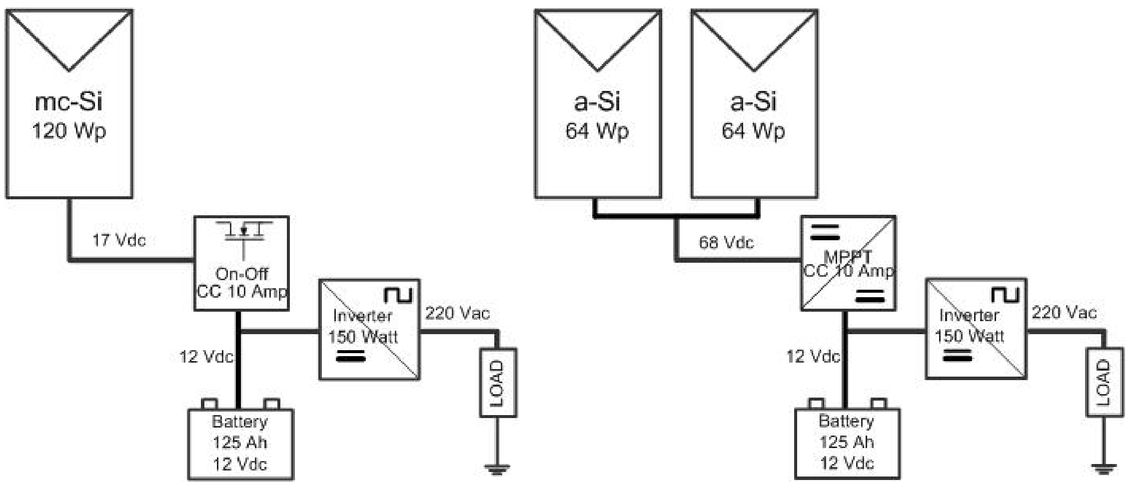

Fig. 1 Solar Home System using mc-Si PV module with On-Off charge controller and a-Si PV module with MPPT charge controller

3. EXPERIMENTAL SYSTEM CONFIGURATION

The test systems consist of two SHS's. The mc-Si PV module 123 Wp with PWM charge controller, 150 Watt modify sine wave inverter, 125 Ah 12 Vdc battery and 100 watt linear load. The a-Si PV module 64 Wp x 2 = 128 Wp with MPPT charge controller, same model of inverter and battery as shown in the

Fig 2 and the picture of the PV modules installation and equipments are shown on Fig 3.

The recorder is set to record solar irradiance, ambient temperature, mc-Si and a-Si module temperature as environmental data. Both mc-Si and a-Si PV are measured value of module output voltage and current every 5 seconds as well as voltage and current that the systems charge and discharge the batteries. AC power and energy consumed by load are also recorded.

The systems are set up by exposing mc-Si and a-Si PV module for 2 months before start recording the data and analyzed in this paper. The Batteries in both systems are fully charge before initial starting and are forced to deliver stored energy to 100 watt resistive load through inverter until the battery voltage reaches low voltage cut off (10.5 Vdc). The batteries are prepared to have enough storage for energy produced by PV module on the next operating day.

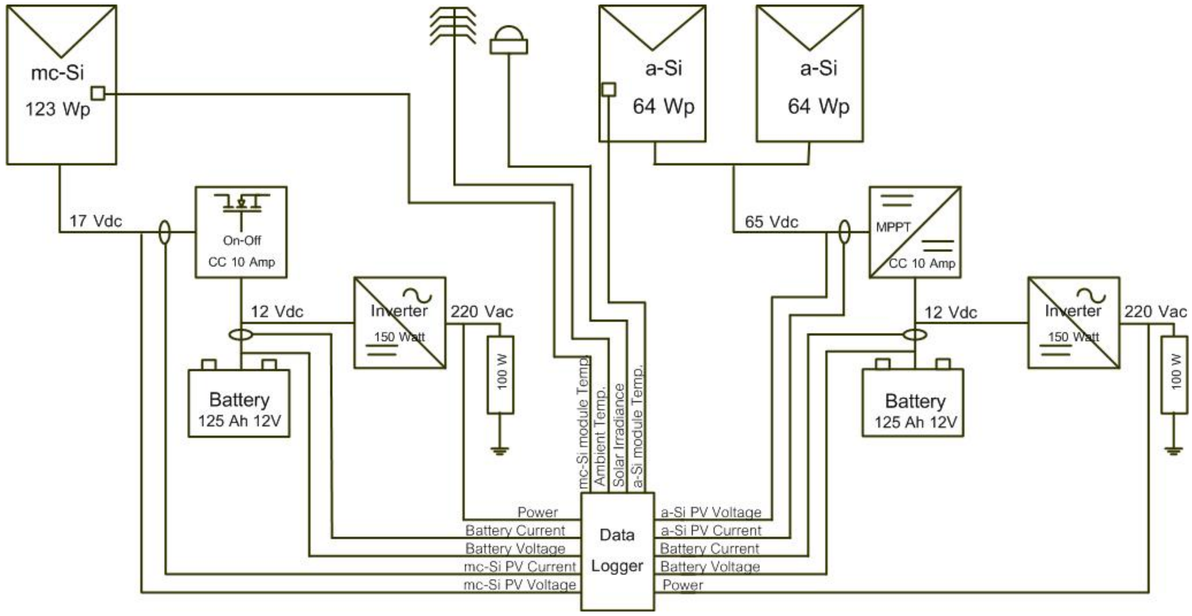

Fig. 2 Experimental system configuration

3.1 PV modules characteristic

Two type of PV module used in AC SHS are mc-Si PV module and a-Si PV module whose specification are shown in the Table 1. In this performance evaluation the PV module from SHARP and KANEKA are use to represent mc-Si PV module and a-Si PV module respectively

Table 1 Characteristics of PV module proposed to use in AC SHS project in Thailand

Module Characteristic	mc-Si		a-Si	
	Solartron	SHARP	BSC	KANEKA
Power Rating @STC (W_p)	120	123	40	64
Open Circuit Voltage (Volt)	21.5	21.3	62.2	96
Short Circuit Current (Amp)	7.45	7.9	1.16	1.17
Voltage at MPP (Volt)	16.9	17.2	44.8	68
Current at MPP (Amp)	7.1	7.16	0.9	0.94
Power Temperature Coefficient (% of degree C)	Not specify	-0.52	-0.2245	-0.26
Module Efficiency (%)	12%	12.6%	5.09%	6.8%
Area (m^2)	0.979	0.992	0.790	0.950

3.2 Solar charge controller

In a small stand alone PV system such as SHS the effectiveness of harvesting energy form the sun highly depends on the suitability of choosing charger controller to work with PV module. There are several types of charger controller designed to use with PV power system in the market. According to the charge controller survey by Photon Energy magazine among 38 manufactures and over 260 models of charge controller only 3 types of algorithms used in these charge controllers, interrupting or On-Off (series or shunt), Pulse Width Modulation (PWM series or shunt) and MPPT charger controller [4]. The principle of charger controller operation and recommend practice of charge controller is also discuss in [3].

The charger controller which is used with mc-Si PV module AC SHS in Thailand are using “Interrupting (On-Off) algorithm” or “Pulse Width Modulation (PWM)” which may be series or shunt regulator. The On-Off series regulator uses electronics control electromechanical switch (relay) or electronics switch (Silicon Control Rectifier (SCR) or Filed Effect Transistor (FET)) to connect or to disconnect PV module output from the battery terminal when charger want to charge or to stop charging the battery. The On-Off shunt regulator also uses the types of switch to short output of PV module when the controller do not want PV module to charger the battery and leave the shunt switch open when it want to charge battery. The PWM charger whether series or shunt regulation works in the same operation beside it use higher frequency of switching thus only electronics switch is used in this type of charger.

Both small On-Off and PWM in SHS whether they are series or shunt charge controller uses battery voltage as an input parameter to control the shunt or series switch to be turn on and to be turn off. The switches will be turn on or be turn off to charge battery according to the algorithm described above when battery voltage is lower than set point and stop charge battery when the battery voltage is reach voltage indicated that battery is fully charge. The basic series or shunt regulator are shown in Fig 4.

The On-Off charger may have two set points which is voltage regulation (VR) set point and voltage regulation reconnection (VRR) set point or use other techniques discussed in [3] such as “modify constant voltage” which change VR to what is called “Boost Charge” to enhance the performance of charging.

PWM algorithm which may be PWM series or PWM shunt regulation uses electronics control switch only to turn on and to turn off control switch in variable frequency, 500 Hz to 1 kHz or higher with a variable duty cycle to maintain battery charging voltage close to the set point [4]. The PWM algorithm allows battery to be charged at the state near fully charge in precise voltage and produce less heat. The simple diagram of PWM charger is shown in Fig 5.

Fig. 3 Experimental Systems at Bangkok, Thailand

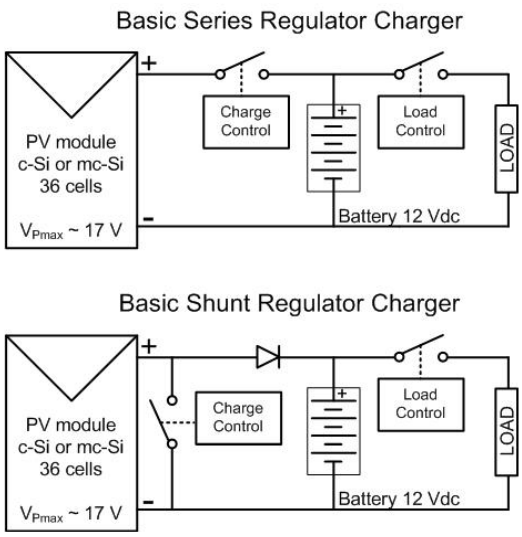

Fig.4 Basic series and shunt regulator

The AC SHS with a-Si PV module can not use simple On-Off or PWM charger since this type of PV module has high voltage at maximum power (V_{Pmax}) as shown in Table 1. The high V_{Pmax} is not suitable to charge battery by directly connect to terminal of nominal 12 Vdc battery. To adjust a-Si PV module's output voltage down to the suitable charging voltage level of the battery a DC to DC converter which converts high DC voltage input to low DC voltage output or "buck converter" is applied to this charge controller.

The charger with DC to DC converter allow separation controlling between PV module's current and voltage and battery charging current and voltage by using high frequency transformer. By separating to high DC voltage side and low DC voltage side the voltage level of PV module which is maximum power (V_{Pmax}) and the voltage level of nominal battery voltage can be different.

At the input of DC to DC converter attached to the output of PV module, the PV's maximum power (P_{Pmax}) searching algorithm called maximum power point tracking (MPPT) is embedded into the controller. The algorithm capable to search for the current and voltage at the present solar irradiance that allow the PV module to supply maximum power at any solar irradiance by adjusting current at input of DC to DC converter and calculated output power then adjust current to search for the maximum output power.

At the output of DC to DC converter there is a suitable voltage level for charging battery. Since the output of DC to DC converter can be freely control form input the charger can apply multi stage charging method which enhance battery charging performance. This type of charger controller is call "MPPT charger controller" . The basic diagram of the MPPT charge controller is shown in Fig 6.

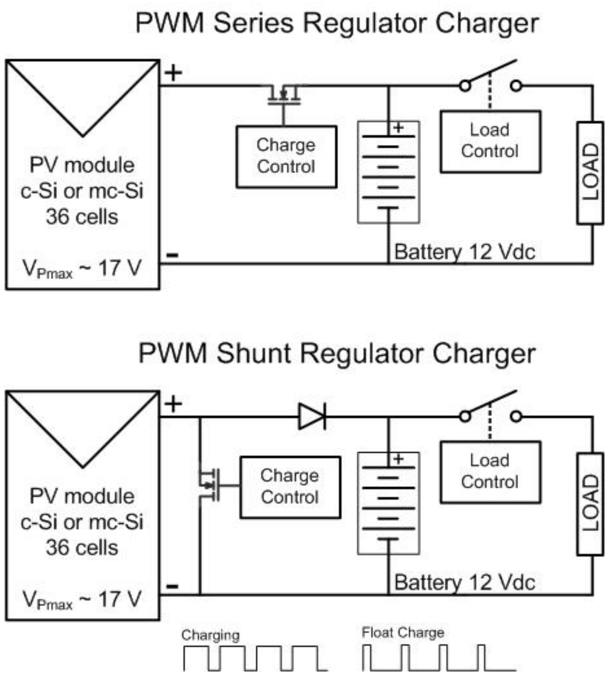

Fig. 5 PWM series and shunt charger

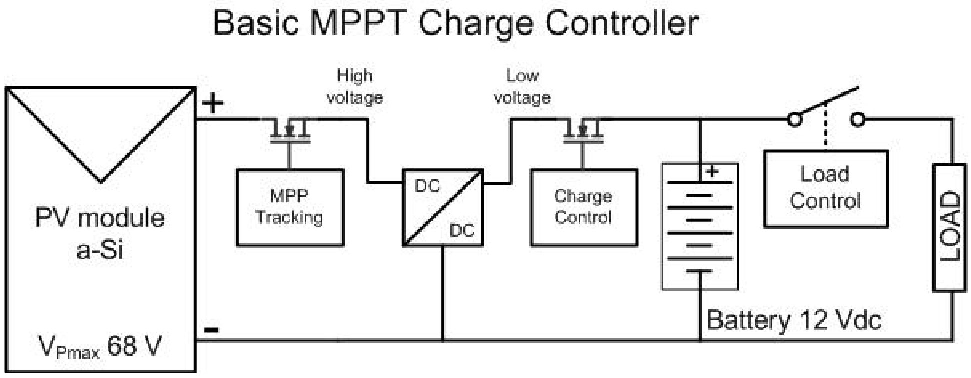

Fig.6 Maximum Power Point Tracking (MPPT) Charger

The advantage of MPPT charge controller is the PV voltage terminal can be independently controlled separately and not directly depend on the battery voltage. The MPPT charger allow PV module to operate at optimal voltage which is V_{Pmax} at present irradiance to get maximum PV module power at that time. This MPPT algorithm allow the PV module used with MPPT charger to deliver higher energy yield than on-off charger which PV module voltage is operated by the influence of battery voltage directly. Fig 7 shows the difference between PV module voltage and battery voltage of the system using a-Si PV module form KANEKA with MPPT charger and mc-Si PV module form SHARP with on-off charger. Both module characteristics are shown in Table 1.

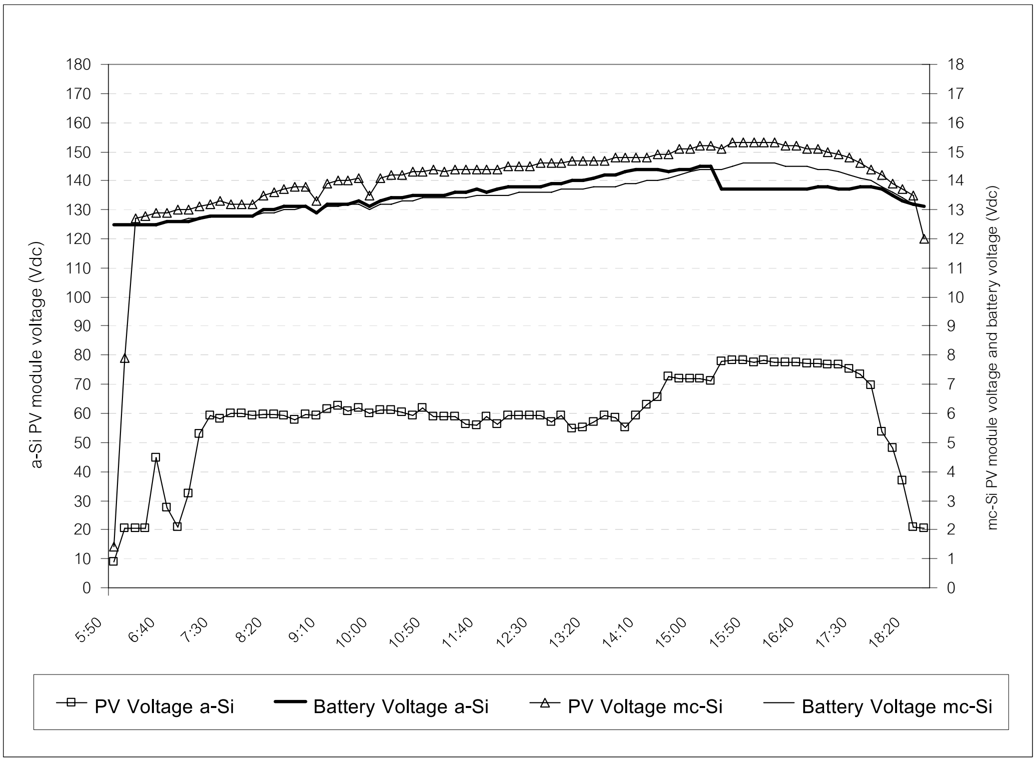

Fig. 7 The PV module voltage and battery voltage

The PV terminal voltage of a-Si PV module is almost stable around 60 Vdc during normal charging (bulk charging) due to the MPPT algorithm was tracking for maximum power from irradiance at that time. The PV terminal voltage of mc-Si PV is increased due to the battery voltage rises when battery is charged thus the mc-Si PV voltage may not be at the point that the mc-Si PV module can provide maximum power at that irradiance.

The calculation of V_{Pmax} of a-Si and mc-Si PV module voltage using measured parameter which are irradiance, ambient temperature and back of PV modules temperature data are performed by using performance characterization procedure introduced by Sandia National Laboratories [8]. The comparison between calculated V_{Pmax} of each PV module and measured PV modules terminal voltage are shown in Fig 8.

The results show that during a day of charging process the system using on-off charger operates with mc-Si PV module charge battery with PV module terminal voltage different form the VPmax of the module for most of the time during the day of operation while the system using MPPT charger make a-Si PV module voltage be close to the V_{Pmax} of the PV module at most of the time beside in the morning and at the evening when the irradiance it lower than 100 W/m2. During the time that the battery is fully charge which the MPPT charger do not need maximum power form the a-Si PV module the MPPT charger reduce energy that it took from PV by drawing lower current which make the PV voltage drift from V_{Pmax} to other level.

3.3 Battery

The battery use in this AC SHS is specified in project specification to be deep discharge cycle service type lead acid battery. This battery is flooded vent type which is modified from a standard motive power or traction battery used in golf carts battery. It has 6 cells with nominal voltage 12 Vdc with capacity 125 Ah @ 20 hours rating with almost same out looking of car battery in local market.

3.4 Inverters

The inverters is the device that invert DC electrical power stored in the battery or produced form PV module to AC electrical power. The inverter specified in project have to invert DC energy form 12 Vdc to 220 Vac with output voltage wave form in step wave or square wave with power rating not lower than 150 Watt. The efficiency of inverter is specified not less than 80% at full 150 Watt resistive load.

4. PERFORMANCE EVALUATION PARAMETERS

The two solar home system will be compared their performance by using parameters suggested by IEA PVPAS Task 2. The parameters usually used to assess the performance of stand alone system are the following [1,2]:

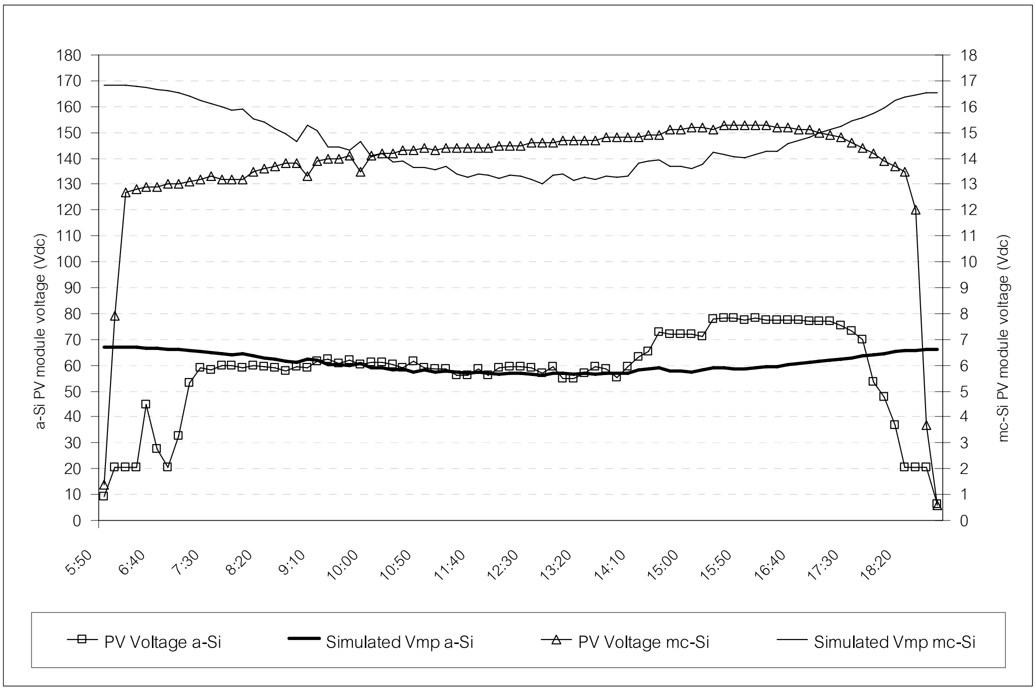

Fig. 8 Comparison between measuring PV terminal voltage during charging and calculated V_{Pmax} of PV modules at the time of charging

YA = EA/Po (kWh/Wp.d)	: Array yield	(1)
YR = Ht/GSTC (kWh/Wp.d)	: Reference yield	(2)
Yf = EPV/Po (kWh/Wp.d)	: Final yield	(3)
EPV = EL/(1+EBU/EA) (Wh)	: PV energy consumed	(4)
LC = YR-YA (kWh/Wp.d)	: Capture losses	(5)
LS = YA-Yf (kWh/Wp.d)	: System losses	(6)
PR = Yf /YR	: Performance ratio	(7)

When:

P_o : Peak Power (W_p)
H_t : Mean daily irradiation in array plane (kWh/m^2.d)
G_{STC} : Reference irradiation at STC (1 kW/m^2)
E_A : Array output energy (kWh/d)
E_L : Energy to loads (kWh/d)
E_{BU} : Energy from back-up system (kWh/d)
E_{POT} : PV array potential energy (kWh/d)

Performance Ratio (PR) is the parameter used in representing the capability of energy production potential of the system. Higher PR is mean better system design and lower PR value mean production loss due to design or technical problem [5]. The value of PR is load consumption dependent which means that not suitable design between PV and load may lead to low PR value.

IEA TASK 2 has introduced additional indicators called "Used Factor" (UF) which defined as:

$$UF = E_A / E_{POT} \quad (8)$$

In Stand Alone Systems E_{POT} is determined by measuring the PV array energy even during disconnections [2].

$$\eta_{SYS} = Y_f / Y_A \quad \text{: system efficiency} \quad (9)$$
$$\eta_{PROD} = E_{POT} / P_o.Y_R \quad \text{: production efficiency} \quad (10)$$
$$PR/UF = \eta_{SYS}.\eta_{PROD} \quad (11)$$

Normally in the system EPOT is not monitor thus UF could not determine IEA TASK 2 also introduce another coefficient called "Production Factor" (PF) which use the parameter at STC specify by manufacture to determine it as follows.

$$PF = E_A / (Po.H_t/G_{STC}) = Y_A/Y_R \quad (12)$$
$$PR/PF = \eta_{SYS} = Y_f / Y_R \quad (13)$$

5. RESULT OF EVALUATIONS

5.1 Environmental Characteristics

At the experimental location, 13° 39’ 54” N and 100° 38’ 01” in Bangkok, Thailand where the recorded minimum and maximum of daily average ambient temperature is recorded 31.44°C and 42.44°C respectively with annually average of 38.52°C. The minimum daily irradiation is 1.65 kWh/m^2.day and maximum is 6.94 kWh/m^2.day with average of 4.84 kWh/m^2.day. The ambient temperature is as high as 42°C during summer season form March to May and the daily average ambient temperature is not lower than 30°C for the whole year at the test location. The solar irradiance, ambient temperature and temperature at back of PV modules of the experiment systems on one clear sky day is shown in Fig 9.

Temperature measure at the back of PV module of a-Si PV module is higher than temperature measured at the back of mc-Si PV module. The temperature at the back of PV module has the same trend line indicate the trend of daily irradiance. Yearly profile of daily ambient temperature, irradiation, and back of PV module temperature of the test system are shown in Fig 10.

5.2 Battery Charging Characteristics

The battery voltage and current characteristic during a day of charging on a clear sky day of the AC SHS using a-Si with MPPT charge controller with DC to DC converter comparing with the system using mc-Si with On-Off charge controller is shown in Figure 11 and the battery charging power and charging energy are also shown in Figure 12.

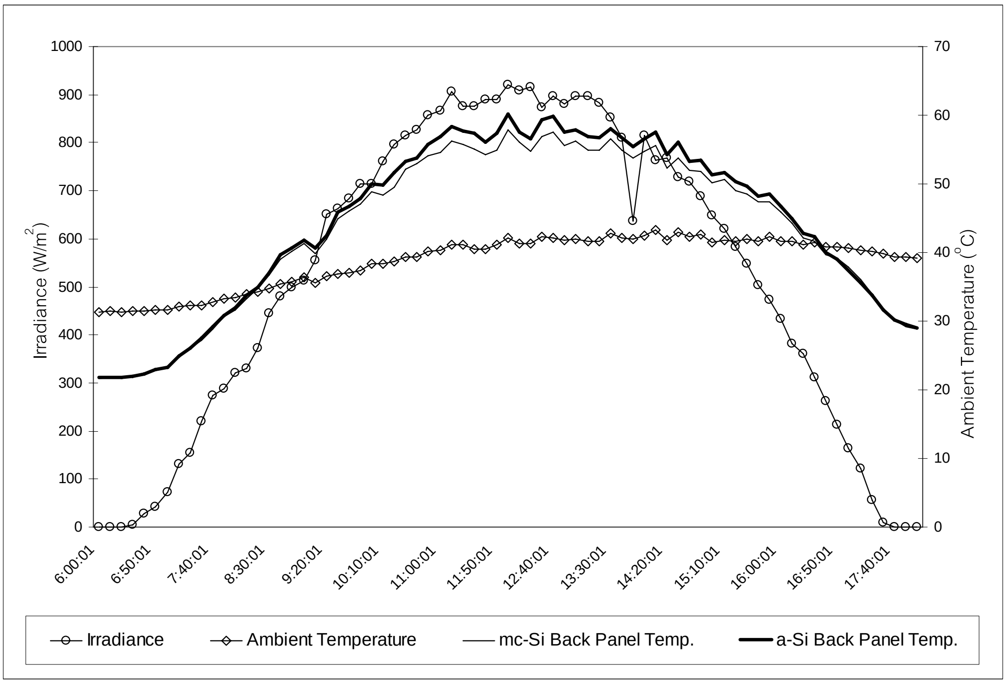

Fig. 9 Irradiance, ambient temperature and back of PV module temperature of mc-Si and a-Si PV module in a clear sky day at experimental site.

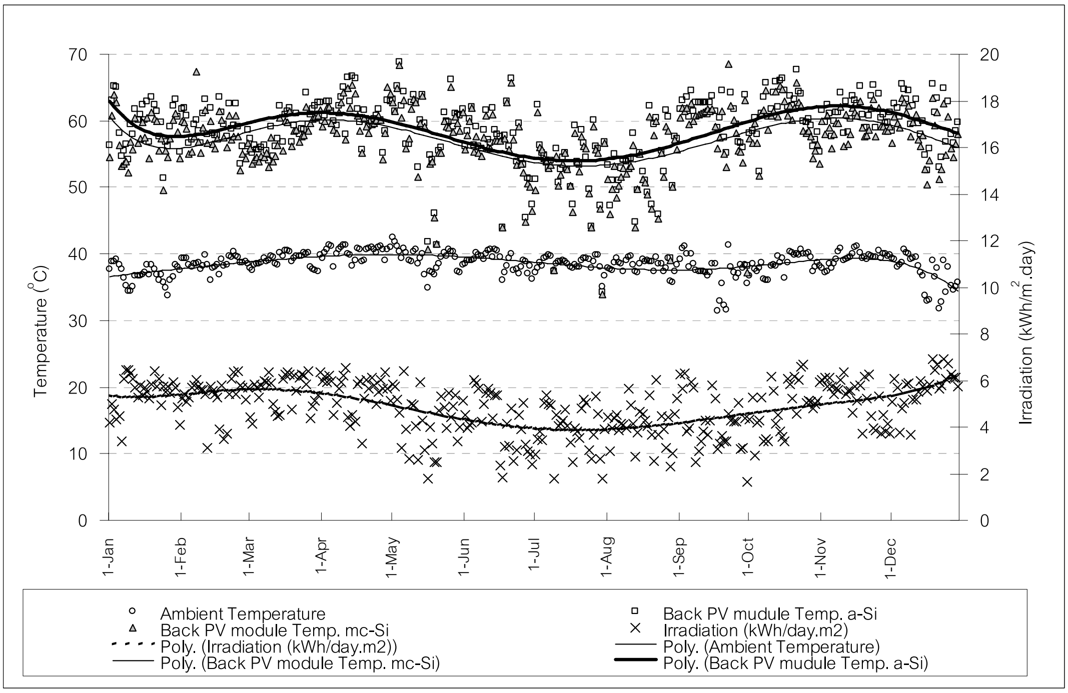

Fig. 10 Daily maximum ambient temperature, back of PV modules temperature and daily irradiation at experimental location in a year.

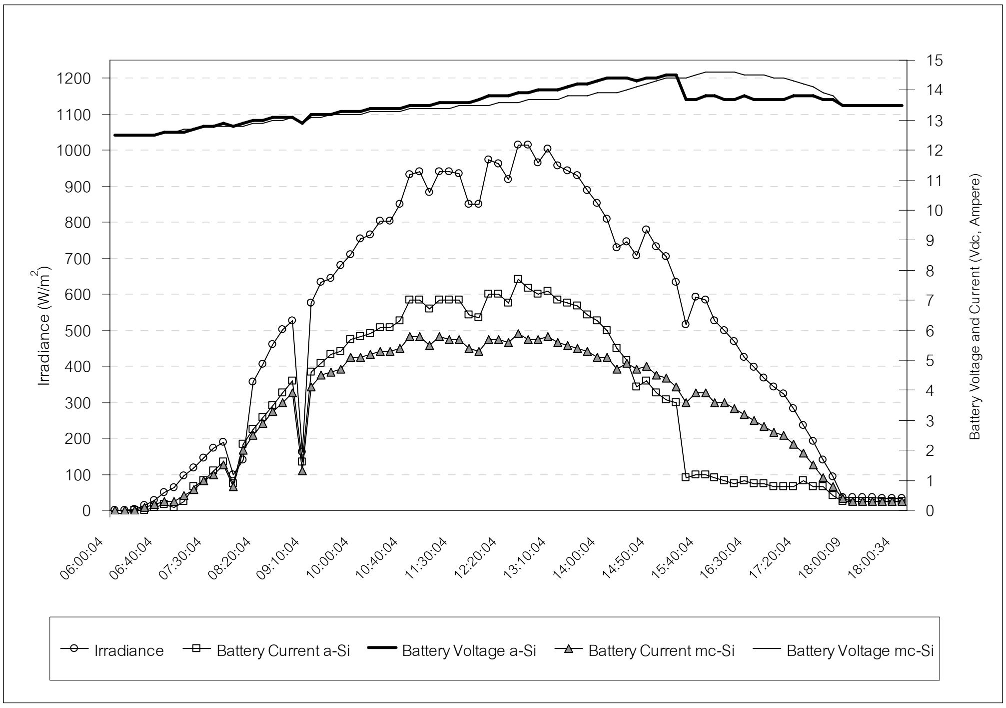

Fig.11 Battery charge voltage and current of a-Si PV module with MPPT charger and mc-Si PV module with on-off charger.

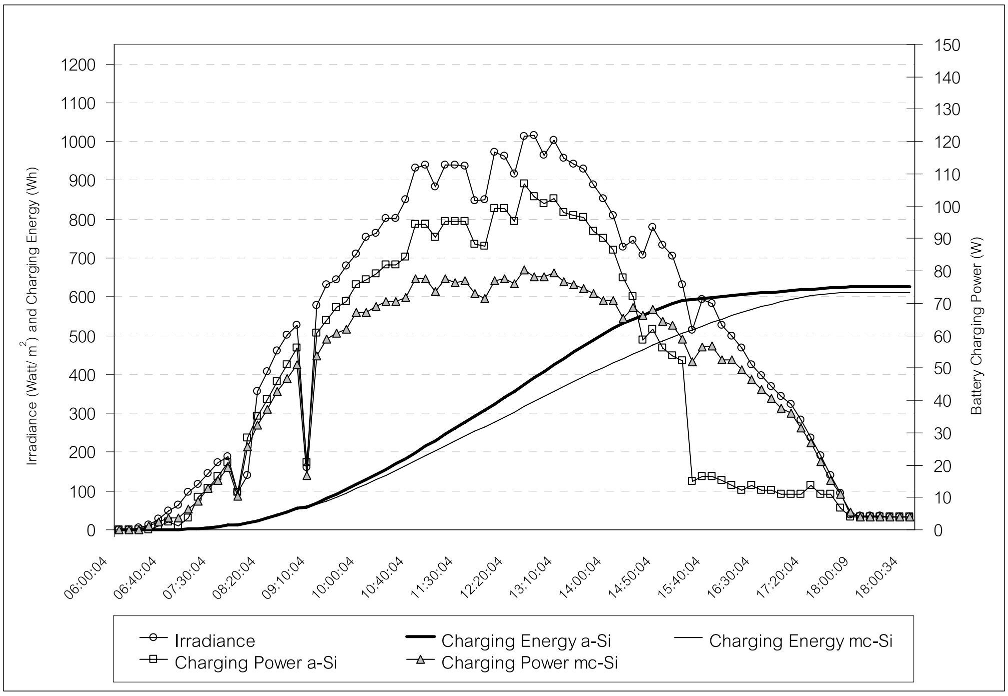

Fig. 12 Charge Power and Charge Energy of a-Si PV module with MPPT charger and mc-Si PV module with on-off charger.

According to the information of the manufacture of both chargers the regulation set point of each charger are

MPPT charger: Boost charge regulate voltage = 14.5 Vdc
Boost charger time for 2.5 hours
Start count boost charge time when >14.0 Vdc
Float charger voltage at 13.6 Vdc

On-Off charger: Boost charge regulate voltage = 15.15 Vdc
Boost charge for 2.5 hours
Start count boost charge time when >15.0 Vdc
Float charge voltage at 14.4 Vdc

On the day of evaluation the observed result show that the battery charging power of a-Si PV module with MPPT charger is higher than the system using mc-Si with On-Off charger during 8:00 to 14:30 which is the time that MPPT charger perform “bulk-charge” to inject highest current that it can get form PV at any irradiance to the battery. The battery voltage reach 14.00 Vdc at first time about 13:00 which charger start boost charger counter 2.5 hours form 13:00 to 15:30 which the charger enters “boost-charge” which the charger voltage is controlled and the current is limited down to the values that will not make battery voltage go higher than the set boost charge voltage. From 15:30 the MPPT charger going to “float-charge” which the battery charging voltage is limited to 13.8 Vdc. The charge current from both system are in the same trend of irradiance of the day.

The a-Si PV with MPPT charger push current to its battery for 43.4 Ah from morning until 15:30 and the battery voltage reach full battery set point them it enters float charging for the rest of the day to charge another 2.1 Ah until the irradiance is become zero. The total charge current is 45.5 Ah.

The mc-Si PV module system with On-Off charger charges battery with lower current since the PV connected to battery is operate between 12 Vdc to 14.5 Vdc which is the voltage that PV can not provide maximum power to battery. On the same day the mc-Si PV system with On-Off charge controller can charger battery for 38.7 Ah from morning until 15:30 and 6.1 Ah for the rest of the day with out going to float charging. The total charge current is 44.8 Ah.

It is indicated in Fig 12 that the whole day charged energy from both a-Si PV module system and mc-Si PV module system to batteries are almost same 625 Wh and 612 Wh respectively since the MPPT charge controller limit power form PV to battery due to the battery is fully charged. The a-Si PV module system could produce more energy on that they if there is higher battery capacity to receive the energy.

The efficiency of charger is also recorded for 15 months and exhibited in Fig 13. The result show that the efficiency of on-off charger is generally above 93% while the efficiency of MPPT charger is only around 83%. The lower efficiency of MPPT charger is the result from lost at the DC-DC converter inside.

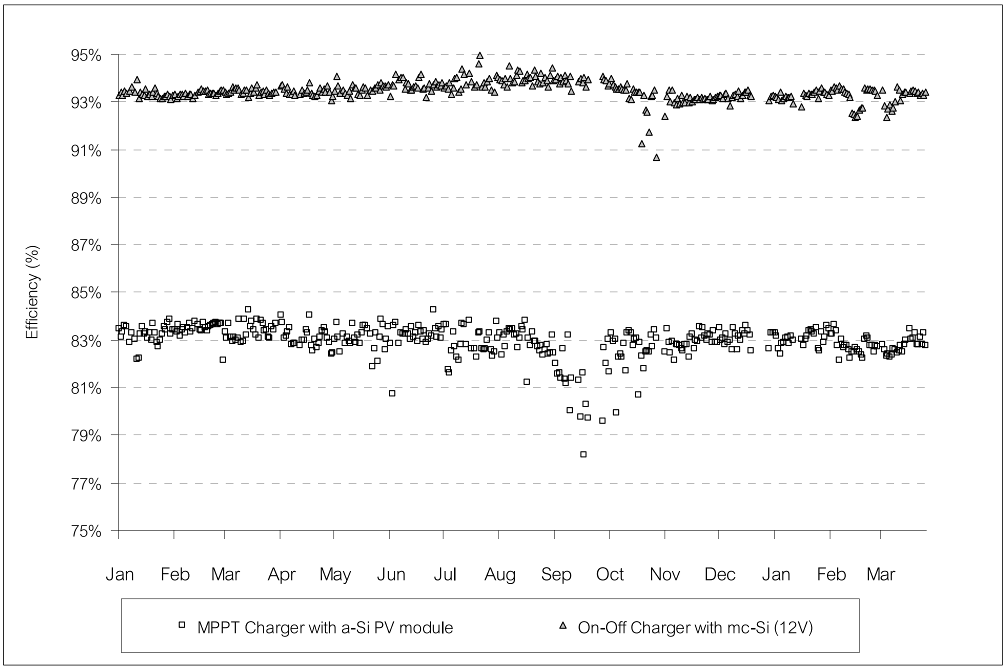

Fig. 13 Efficiency of On-Off Charger and MPPT charger

5.3 System performance evaluation

Both systems are operate without any maintenance on PV modules, batteries, charge controllers, inverters and loads to see the real performance under condition close to the worst case. There is no distill water be added to the batteries since the experiment start. The battery remain operate for 9 months before completely fail.

The new batteries for both system are replaces on the 10 months and the experiment is going on with distill water added to maintain batteries every 30 days.

a. Array Yield (Y_A) evaluation

The energy produced by PV module per peak power (Wp) of the module or "Array Yield" (Y_A) from system using a-Si PV module is higher than the system using mc-Si PV around 20% at the beginning of experiment and Y_A of both systems have trend to be lower from the affect of battery has no maintenance. The system with a-Si has trend to be lower while system with mc-Si has stable Y_A after 15 months of operating the system as shown in Fig 14. This phenomenon occurs in the process of a initial stabilization of a-Si.

b. Efficiency of storage device

The battery charging energy and discharging energy on each day is recorded and calculated for battery efficiency. During the first 9 months that battery had no maintenance (no distill water were added to the batteries) the energy charged to the batteries can be store and discharged to be used by inverter for about 80% of charged energy at the beginning of experiment and reduced to lower than 20% in 9 months and finally the batteries can not store energy. After both AC SHS the systems were replaced with new batteries the efficiency of batteries are recorded at about 80%. The batteries were maintain by checking electrolyte level and distill water were added every month the records show reducing of the efficiency in the first 3 months and stable at about 75% as shown in Fig 15.

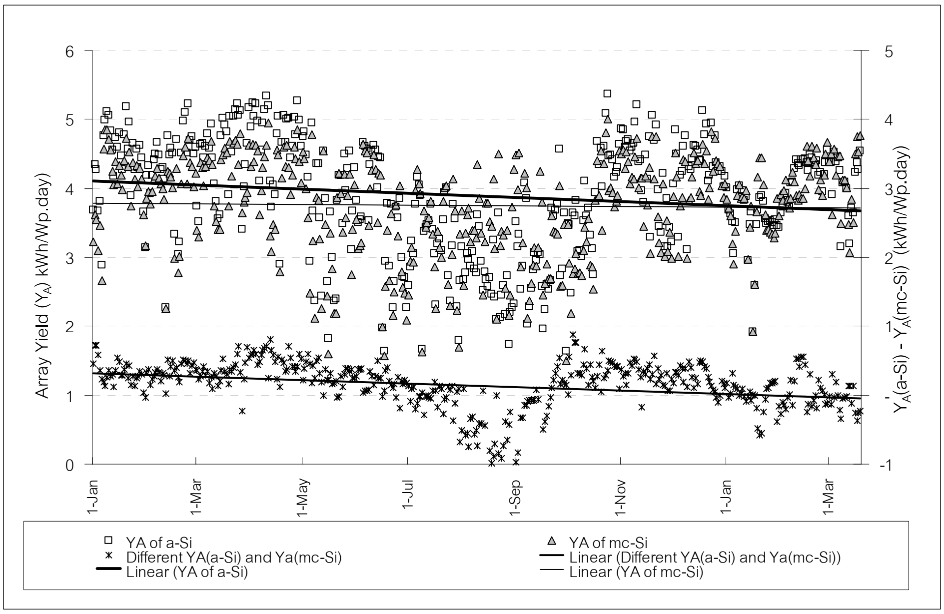

Fig. 14 PV array energy yield (YA) and the different between YA of a-Si PVmodule system and mc-Si PV module system of operating as AC SHS for 15 months

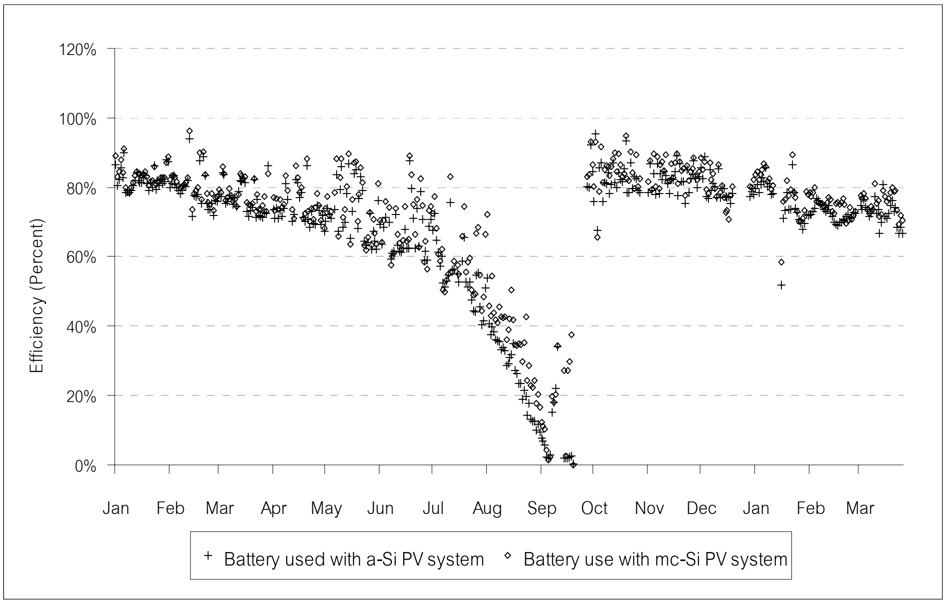

Fig. 15 Efficiency of energy storage calculated form daily charging energy and discharging energy

c. Array Output Energy (E_A)

The Array Output Energy (E_A) generated form a-Si PV SHS is higher that E_A form mc-Si SHS for 10% to 18% form start of the experiment until the battery efficiency dropped to about 40% (as shown in Fig 15) which at that time the E_A of mc-Si is shown higher. By evaluation of the recorded data at the period the result show that this situation is created form charger controller of a-Si PV SHS stop charging the battery due to the battery voltage reach set point after charging for short time. After replace new battery E_A of a-Si PV SHS is higher than mc-Si PV SHS again as shown in Fig 16.

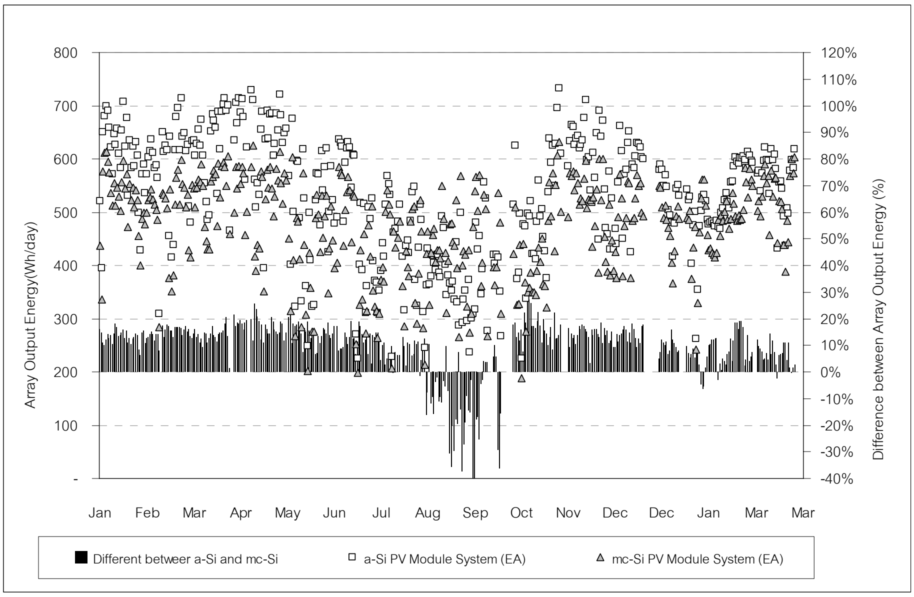

Fig. 16 Array output energy (E_A) of a-Si PV SHS and mc-Si PV SHS

d. Production Factor (PF) and System Efficiency (η_{SYS})

The production factor of a-Si PV system is higher than mc-Si PV system during the normal battery condition but the system efficiency of mc-Si PV system is higher than a-Si PV system due to higher loss in MPPT charge controller as shown in Fig 17.

e. Performance Ration (PR) and Final Yield of the System (Y_f)

The performance ration (PR) of both system are about same at 0.45 to 0.5 and lower when battery has low efficiency. The Final Yield (Yf) of both systems also about same figure beside during low battery efficiency that the a-Si PV system shows lower Yf since the MPPT charger stop charging from detecting high battery voltage in short time after charging battery while on-off charger keep pushing current to the defective battery due to high charge set point. The PR and Y_f of both systems recorded for 15 months of operation are shown in Fig 18.

6. CONCLUSION

The a-Si PV module SHS with MPPT charger controller installed at warm climate environment such at experimental location in Thailand deliver higher energy output as shown by its Array Output Energy (E_A), Array Energy Yield (Y_A) and Production Factor (PF) than the system using mc-Si with on-off charge controller. Both systems charge their produced energy into batteries which the charge efficiency of each system is depend on the charge controller topology.

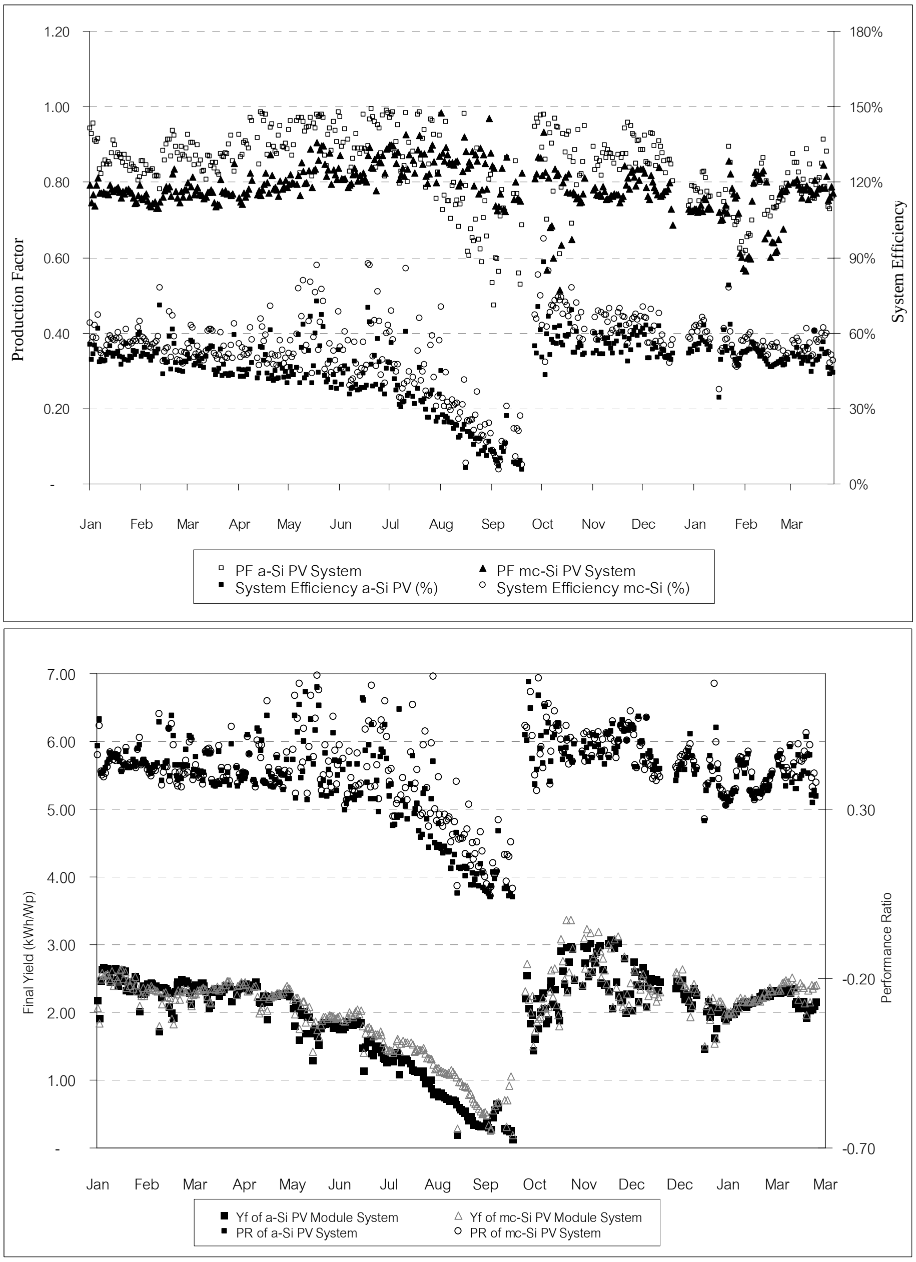

Fig. 18 Final Yield (Y_f) and Performance Ration (PR) of the experiment systems

The a-Si PV SHS with MPPT charger can deliver maximum power from PV module with precise maximum power track ability at most of the charging period while the mc-Si PV SHS with on-off charger can not deliver maximum power form mc-Si PV module due to the PV module voltage is determined by battery voltage which is different point that the PV module can delivery maximum power at most of charging period. The MPPT charger has lower efficiency than on-off charger for about 10% which make the Final energy yield (Y_f) and Performance Ratio (PR) of both system are about same.

The SHS with a-Si PV module can be improved to get higher Final energy yield(Y_f) by adjusting charge set point since the MPPT charger reach boost charge at about noon and stop boost charge about 2 hours later which the boost charge set point can be increased to higher level and the boost charge time can be set to be longer for battery using in cycle use application such as solar home application. The charge efficiency of MPPT charger should be improve to gain more benefit form MPPT algorithm. The loss on DC to DC converter which is the most important loss in MPPT charger should be reduced to allow the system to charge battery with higher current and gain higher Y_f which will make the SHS with a-Si PV become attractive alternative SHS beside the system using crystalline silicon PV module.

The system should have basic maintenance by refill distill water to maintain electrolyte of the battery since it can operate without maintenance on for only about 6 months before the storage efficiency is reduced to less than 50%. The difference of array yield (E_A) between a-Si PV module and mc-Si PV module is reduced when systems are installed and operate for 15 months.

Acknowledgement

Author would like to thank KANEKA Corporation, Japan for the close cooperation on experimental equipment and data which provided to SERT. This paper is an outcome of the joint research between KANEKA and SERT.

References

[1] International Energy Agency, Operational performance, reliability and promotion of photovoltaic systems, Report IEA-PVPS T2-03:2002, 2002.
[2] International Energy Agency, Analysis of Photovoltaic Systems, Report IEA-PVPS T2-01:2000, 2000.
[3] International Energy Agency, Recommend Practice for Charge Controller, Report IEA-PVPS T3-05:1998, 1998.
[4] Photon Energy magazine Jan 06 issue
[5] Sandia National Laboratories, Batteries and Charge Control in Stand-Alone Photovoltaic System-Fundamentals and Applications, January 15, 1997.
[6] Mayer, D. and Heidenreich, M., Performance analysis of stand alone PV systems form a rational use of energy point of view.
[7] Vervaart, M.R. and Nieuwenhout, F.D.J., Solar Home System: Manual for the design and modification of Solar Home System component, January 2000.
[8] David L. King, Jay A. Kratochvil, and William E. Boyson, Sandia National Laboratories, Fields Experience With A New Performance Characterization Procedure For Photovoltaic Arrays, July 6, 1998.