

#### 4.4 Individual PV system

The houses in Fedre and Katoura have stone walls and dried mud roof. Houses were scattered throughout the village and the individual PV system was introduced. But, based on the results of a village survey, the average income of Katoura was found to be higher than Fedre, and usage demand of appliances is also greater than Fedre, hence the scale of the PV system is 200(W) for Fedre and 300(W) for Katoura.

A fresh water well was dug in Rasem Al Shikh and the water situation of this village improved. Thus, the desalination system was shifted to Kalif from Rasem Al Shikh. At the same time, the individual medium scale PV system was shifted to Kalif. It was judged to be effective to introduce PV system in Kalif due to the timing of electrification using the grid and comparison of villagers' living standards. Also, the sustainability of the system in the future and improving living standards were taken into account.

Kalif has 28 houses. Inside the village, groups of two to three houses are dispersed. Power supply from the grid line needs a large investment and is not economical. Therefore, the individual medium scale PV system was introduced. The annual income of Kalif is higher than both Fedre and Katoura, and many electric appliances are expected to be introduced. Therefore, the PV system is a 500(W), AC 220(V) power supply. However, because there are dispersed groups of two to three houses, one system is shared by two to three houses.

##### 4.4.1 Basic system design and assumptions

The assumptions and the selection of system equipment based on this design are described below.

- 1) The premised conditions to design the individual system
- 2) Types of electric appliance used by villagers and power consumption
- 3) Assumption to decide capacity of PV array and battery

##### (1) Assumptions

For the individual system, it is decided that the design would be based on the following fundamentals after discussions on the basic concept with SSRC/HIAST PV group.

- a. The PV system capacity design is based on the average lowest insolation month.
- b. The inclination of the PV array is 35 degrees based on the average insolation. At

this angle, the power generated will be maximized throughout the year.

c. The power supply is

1) Small-scale system : DC12(V)

2) Medium-scale system: AC220(V)-50(Hz) single phase(Input:DC24(V) )

d. PV array installation is roof-top or at the front of house.

e. Battery is put into a box installed outside.

f. Days of autonomy are assumed to be three days, and the depth of discharge of batteries is set at 70%.

g. Major materials such as PV module and controllers are selected from among Japanese products.

h. For the time being, Japanese batteries are being introduced. These batteries are estimated to be replaced by Syrian products after five to seven years.

## (2) Assumptions about demand

The individual PV system were outlined to the villagers of Fedre, Katoura, and Kalif. An interview survey was carried out on types of electric appliance, number of appliances, and required hours of use, etc. The results of this survey and the socio-economic survey were combined and discussed with SSRC/HIAT.

As a result, in Fedre and Katoura, the output power is DC and the types of electric appliance are limited. Both villagers were asked to use the same appliances, but the villagers of Katoura have slightly longer usage hours than Fedre. Power demand in the minimum insolation month for Fedre and Katoura is assumed in Table 4.4-1 and Table 4.4-2 respectively. For Kalif, the power supply is AC and some villagers want to use a washing machine in daytime. Thus, power demand is assumed in Table 4.4-3. Moreover, regarding the consumption of electric appliances, market survey results were used.

Table 4.4-1 Assumptions of power demand in Fedre

	Load	Consumed power of each appliance	Number	Consumed power(W)	Efficiency	Practical consumed power(W)	Using time	Daily consumed power (kWh/day)
Nighttime	Light	20	3	60	0.8	75	3	225
	Radio	4	1	4	0.8	5	3	15
	Cassette	15	1	15	0.8	19	2	38
	TV B&W	12	1	12	0.8	15	3	45
Consumed power								323

Table 4.4-2 Assumptions of power demand in Katoura

	Load	Consumed power of each appliance	Number	Consumed power(W)	Efficiency	Practical consumed power(W)	Using time	Daily consumed power (kWh/day)
Nighttime	Light	20	3	60	0.8	75	4	300
	Radio	4	1	4	0.8	5	3	15
	Cassette	15	1	15	0.8	19	4	76
	TV B&W	12	1	12	0.8	15	3	45
Consumed power								436

Table 4.4-3 Assumptions of power demand in Kalif

	Load	Consumed power of each appliance	Number	Consumed power(W)	Efficiency	Practical consumed power(W)	Using time	Daily consumed power (kWh/day)
Nighttime	Light	20	4	80	0.8	100	4.5	450.0
	Radio	4	1	4	0.8	5	3	15.0
	Cassette	15	1	15	0.8	19	2	37.5
	TV Color	50	1	50	0.8	62.5	3	187.5
Consumed power								690.0
Daytime	washing machine	160	1	160	0.8	200	2	400.0
Consumed power								400.0

## (3) Actual design and selection of equipment

For an individual small-scale PV system, DC appliances and night-time load usage is estimated. As a result, demand is assumed in Table 4.4-1 and 4.4-2. On the other hand, for the individual medium scale PV system, AC power appliances are used and demand is assumed in Table 4.4-3. The basic system design of individual systems was based on the assumptions of power demand in these tables, insolation data at 35 degrees in Aleppo of Table 4.1-1, and decision method on the capacity of PV array and battery in Chapter 4.1. The actual design of the individual system was also made according to the design concept.

For the actual design, an investigation was carried out on the materials, which are PV modules, array structure, battery, inverter for medium scale and controller, and their suitable selection is an important factor for the long life of the PV system. Therefore, circumstances such as dust and air pollution and weather conditions were taken into account.

① Individual small-scale PV system for Fedre and Katoura

a. PV array

From the assumption of small-scale PV system,

Assumption of night-time demand in Fedre : 323(Wh/Day)

Assumption of night-time demand in Katoura : 436(Wh/Day)

When the power consumption of loads per day is balanced with the output of PV system at the minimum insolation of 3.3(kWh/m<sup>2</sup>/Day), the required PV capacity P (W) are

Fedre PV array capacity :  $P(W) \approx 200(W)$

Katoura PV array capacity :  $P(W) \approx 283(W)$

Actually, a Poly crystal type PV module was selected for the small-scale system. The terminal voltage for full battery charge is assumed to be about DC15(V). The PV array consisted of the following:

Fedre : One series x Four in parallel connection

Katoura : One series x Six in parallel connection

The houses of both villages are made of stone and their structures are strong, PV array was installed on top of roof that is no obstacles to make shade. The output specification of the PV module is shown as follows.

Model	Maximum output P <sub>max</sub> (W)	Open-circuit voltage V <sub>oc</sub> (V)	Short-circuit current I <sub>sc</sub> (A)	Optimum operating voltage V <sub>op</sub> (V)	Optimum operating current I <sub>op</sub> (A)
LA361K51S	51.0	21.2	3.25	16.9	3.02

b. Capacity of battery

Based on data for days of autonomy in Table 4.1-2, there are three days of autonomy. The depth of discharge is 70(%) and the system is stopped to supply power. Based on this concept, it was decided to use one battery of Unit capacity: 12(V)-200(Ah), 2.4(kWh).

A lead acid battery specially for PV use and with a long record of use was introduced. The Japanese battery of this system is planned to be replaced by a Syrian battery after five to seven years, so compatible battery to the Syrian battery was selected and used.

The batteries were installed outside houses because of the generation of hydrogen. They were installed in a box to avoid direct sunlight, rain, and dust, etc.

## ②Medium-scale system in Kalif

### a. PV array

Based on the assumption for demand in Table 4.4-3

Daytime load :400(Wh/day)

(washing machine is used in daytime once every three days)

Night-time load: 690(Wh/day)

Based on the assumption of demand, PV array capacity was calculated under the same concept as the small-scale system. As a result, PV capacity P(W) is about 496(W).

The actual system adopts three types of module: single crystal, poly crystal, and amorphous type PV module. Poly crystal and amorphous type PV modules were procured in Japan. From the viewpoint of encouraging of local industry, single crystal type modules were purchased from the SSRC/HIAST PV group, which is the leader in technology development in Syria.

Since the terminal voltage of battery at full charge is DC 30V, a PV array of 500(W) consists of two panels in series and five panels connected in parallel. Thus, the PV array connection is slightly different depending on the type of PV module.

In Kalif, some houses are built of stone and some of dried mud. Some houses cannot install the PV array on the roof. Hence it was decided to use a roof-top type. For houses on which a PV array cannot be installed on the roof, a ground-installation type PV array was used.

The outputs of each type of module under standard conditions (Insolation :1(kW/m<sup>2</sup>), temperature of module: 25(°C)) were shown below.

Table 4.4-4 Specification of output for PV module and array

	Single crystal SSRC (Module)	Polycrystal KYOCERA (Module)	Amorphous SANYO (Module)	Single crystal (Array) (2S*7P)	Polycrystal (Array) (2S*5P)	Amorphous (Array) (2S*5P)
Voc(V) Open-circuit voltage	21.8	21.5	24.0	41.6	43.0	48.0
Isc(A) Short-circuit current	2.78	3.35	3.39	19.5	16.8	17.0
Vop(V) Optimum operating voltage	17.5	16.5	18.6	35.0	33.0	37.2
Iop(A) Optimum operating current	2.23	3.20	2.85	15.6	16.0	14.3
Pmax(W) Maxim output	39.0	54.1	53.0	546.0	528.0	532.0

**b. Battery capacity**

According to this assumption that the number of days of autonomy is three and power supply is stopped at 70% of depth of discharge, the capacity of battery was studied.

The input voltage of the inverter is DC24(V), depending on the input voltage of inverter. Two DC12(V) batteries should be connected in series and three in parallel. These batteries form one unit.

The actual battery is smaller than the centralized system and the specification is shown below. It was decided to install the batteries outside a house, and they were put into a box to avoid direct sunlight, rain, and dust.

Model	Voltage	Capacity	Weight	Quantity of electrolyte solution
12CT-110	12(V) At the time of full charge : 15.6(V) At the time of discharge stop : 11.4(V)	110(Ah) (100-hr rate)	37(kg) (including electrolyte solution)	4(liter)

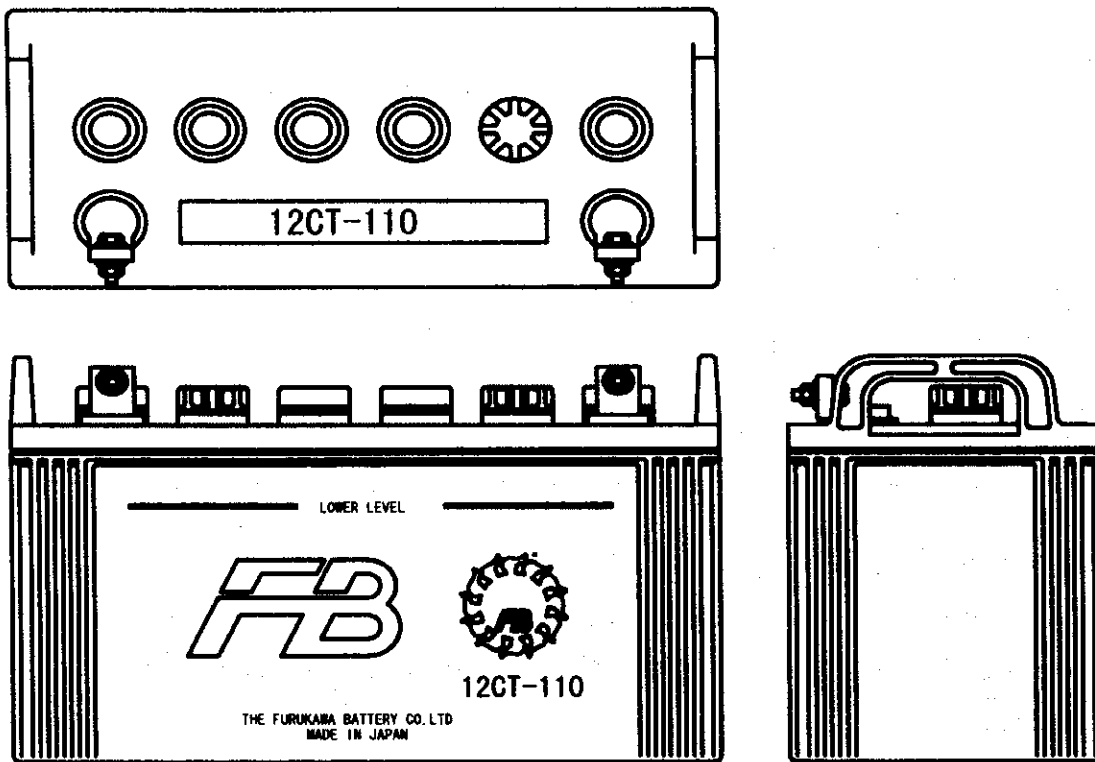


Fig.4.4-1 Battery specification for medium-scale system

#### c. Charge/discharge controller

The operation control that power generated by PV array is stored and power discharged to the load at night is managed by this controller.

The controller is provided with over-charge and over-discharge prevention circuits to protect the battery. The controller is also provided with a circuit that prevents a reverse current from flowing when insolation is low and the voltage of PV drops.

The controller of the small-scale system was purchased in Japan. But the controller of the medium-scale system with the specification shown in Table 4.4-5 was purchased from SSRC/HIAST PV group, because SSRC/HIAST PV group has the technology to design and produce these electronics products. This technology will be utilized in the future.

Table 4.4-5 Respective charge/discharge point of controller for small-scale system

Item		Standard
System rating (battery voltage)		12 VDC
Input	Allowable voltage	24 VDC
	Allowable current	30 ADC
Output	Rated voltage	12 VDC (fluctuating range 11.4~15V)
	Allowable current	30 ADC
Overcharge preventive circuit	Charge stop voltage	15.0VDC $\pm 2\%$
	Charge restart voltage	12.8VDC $\pm 5\%$
Over-discharge preventive circuit	Discharge stop voltage	11.4VDC $\pm 2\%$
	Discharge restart voltage	12.5VDC $\pm 5\%$

PV + and PV- indicate the terminal voltage of a PV array. BT+ and BT- indicate the terminal voltage of a battery. LD+ and LD- on the right indicate the terminal voltage of a load. The Z marks on both ends are lightning arresters for a surge absorber.

Each LED indicates each control action. Green LED 1 shows overcharge. Red LED 2 shows overdischarge, and the switch X opens to stop operation of the system.

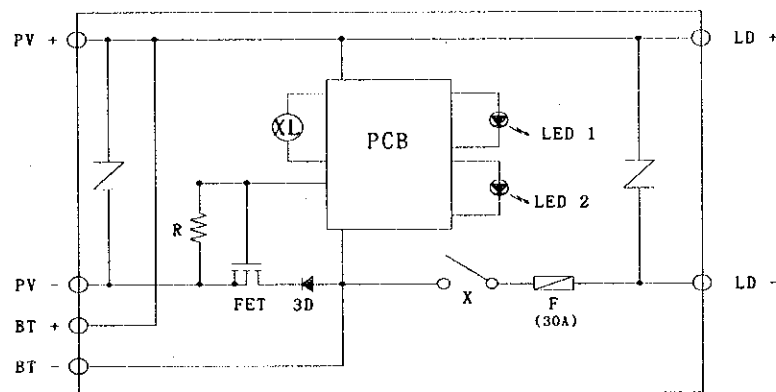


Fig.4.4-2 Outline of control circuit of controller for small-scale system



Table 4.4-6 Setting value of controller for medium-scale system

Overcharge prevention		Overdischarge prevention	
Charge stop	30.0(V)	Discharge stop	22.8(V)
Charge restart	25.6(V)	Discharge restart	25.0(V)

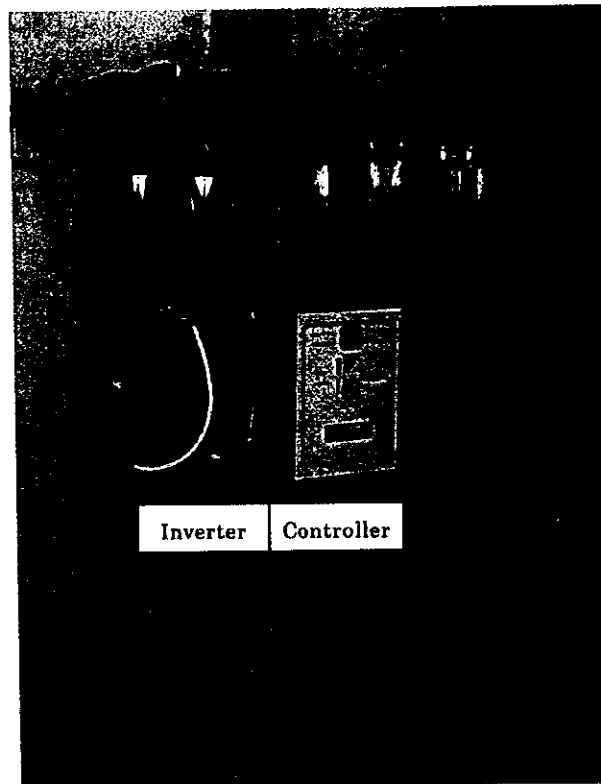


Fig.4.4-3 Outline view of controller for medium-scale system

d. Inverter (only for medium-scale system)

Medium-scale system for Kalif is an AC system and an inverter is necessary to convert from DC to AC. When the inverter was selected, independent operation type and model considering system scale were taken into account. Also, the protection function for a rush current to start a washing machine etc and surge current were considered.

The inverter selected has a capacity of 500(W) and voltage at input side is DC24V and at output side is AC220V-50Hz, single-phase, two-wire. The selected model is generally available and easy to procure in the market. When a washing machine or a motor etc. is started, twice or more of rating power is momentarily necessary. This inverter selected has twice of rushing capacity for the rated power and has a protection function for more than twice the rushing power.

Table 4.4-7 Specification of inverter selected

Item	Specification
Output power capacity	800W
Rate input voltage	DC24(V)
Output voltage	AC220(V) 1 phase 2wire 50(Hz)
Power conversion efficiency	$\pm 0.8\text{pf}$

#### ⑤ In-house wiring

The in-house wiring facilities of an individual system were made to meet the standards of Syria and the following items requested by the villagers, as well as safety, convenience, and material durability take into account.

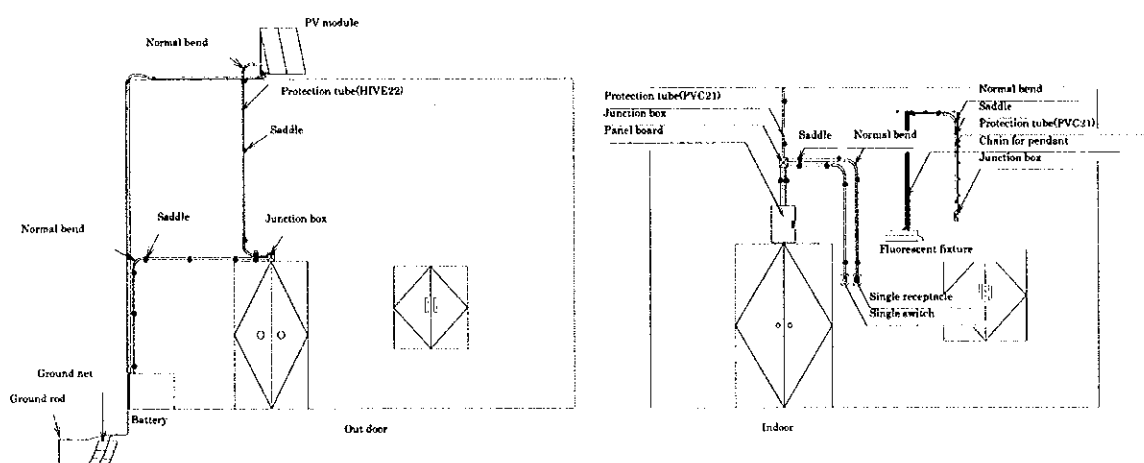
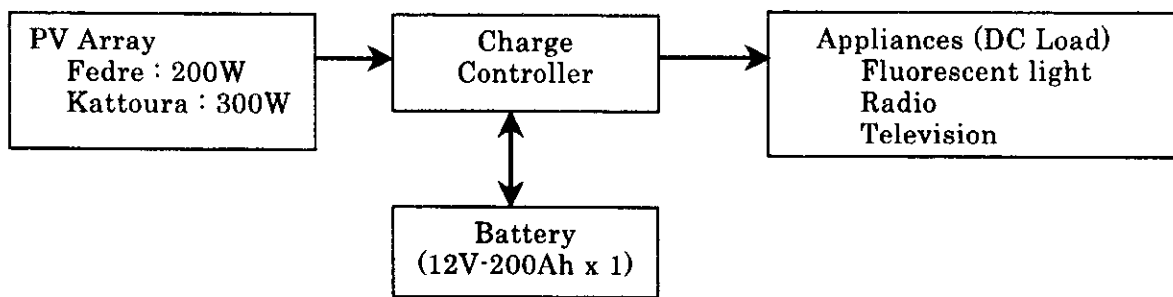


Fig.4.4-4 In-house wiring

- 1) Switch and wall outlet are installed near the entrance of the room for convenience.
- 2) Each room in the house is provided with a 18W fluorescent lamp. Brightness is about 20~30Lx.

#### (4) Configuration of individual PV system

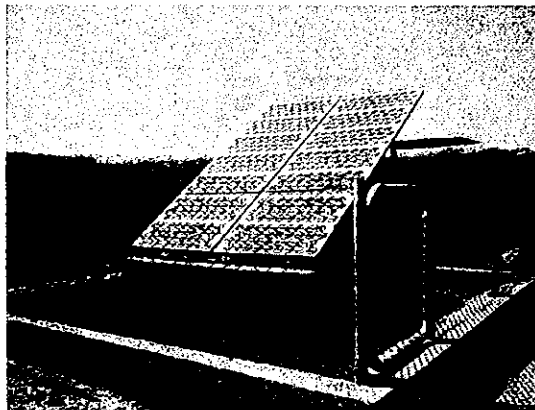
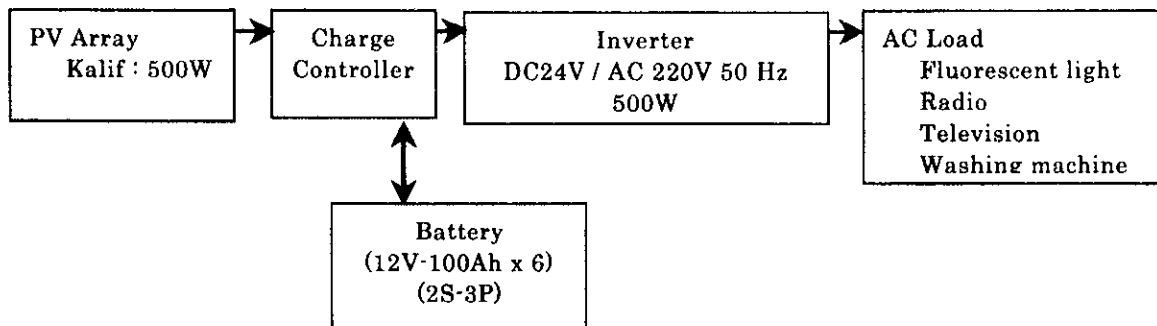
The small-scale system of Fedre and Katoura have the same system configuration but different PV array capacities : 200(W) for Fedre and 300(W) for Katoura. AC system with an inverter was selected for the medium-scale system of Kalif. Therefore, the system configuration is different from the small-scale system.



(Fedre)

(Katoura)

Fig.4.4-5 Configuration of individual small-scale PV system and landscape



(Ground installed (SSRC/HIAST PV module))



(Roof top installed)

Fig.4.4-6 Configuration of individual medium-scale PV system and landscape

To reduce the cost of the medium-scale system, it was decided to utilize the PV module and system equipment manufacturing technologies of the SSRC/HIAST. As a result, the SSRC/HIAST was responsible for producing some of the system components. This manufacturing and technical expertise of the SSRC/HIAST will be transferred to the private sector in Syria in the future. Concretely, the following materials were procured from the SSRC/HIAST.

- 1) Mono crystal PV module : for seven systems (equivalent to 3.5(kW))
- 2) Controller : for all systems (17 sets and spare)

#### 4.4.2 Assistance with system installation and technical guidance

Installation of the individual systems was executed as well as the centralized system. The differences with the centralized system are described below.

##### (1) Organization of installation

- 1) Construction of a foundation was required only for the PV group because large-scale leveling, array foundation and structure like that of the centralized system were not necessary.

2) Improvements to the technology of the SSRC/HIAST were seen from the results of installing the centralized and DC system. The subcontracting cost was decreased because the SSRC/HIAST designed and assembled the structure.

(2) Assistance with installation work and technical guidance

For actual installation, technical assistance and guidance were provided noting the following items in addition to those for centralized system installation.

	Item	Specific operation
1	Array foundation work	①DC system for each house was constructed with concrete on the roof-top of the house. ②AC system was constructed on the ground or roof-top of the house according to type of house
2	Fabrication of array stand	①Array stand of DC system was fabricated with L-type section imported from Japan ② Array stand of AC system was fabricated from design to processing at the site ③Array was fixed at an angle of 35 degrees
3	Installation of panels	① Controller, Inverter, and circuit breaker were put in a box, which was fixed on a wall ②Box was set up after making internal connections

#### 4.4.3 Power demand and supply situation

An interview survey was conducted on electric appliances, number of appliances, and hours of use. The results of this survey and a socio-economic survey were combined and discussed with the SSRC/HIAST PV group. Then, the individual system was designed and system scale was decided.

As a result, the system for Fedre was an individual DC system with a PV capacity of 200(W). On the other hand, the system for Katoura was also an individual DC system, but PV capacity was 300(W) and was a little larger than that of Fedre.

An individual AC system was introduced for Kalif. PV capacity is 500(W), which is larger than the DC system of Fedre and Katoura. The number of systems introduced was 17 for 25 houses. Therefore, one system was shared by more than one house.

Power consumption of these systems is not measured for respective houses using watt hour meters. Instead, average houses were selected based on family make-up and room arrangement for Zarzita and a data logger was provided to log power consumption data.

(1) Basic concept of power supply and demand

① Individual small-scale PV System

The power supply of an individual small-scale PV system is controlled by the charge/discharge controller. The basic concept of system operation is described below.

a. General household

- 1) Basically, in a small-scale system, the power generated in daytime is stored in a battery, and supplied to the load at night-time.
- 2) Power is not supplied in daytime in principle.
- 3) Power saving is explained to the villagers when power is used.

b. School

- 1) The day-time load of the school system is forecast. Power supply for the load corresponds to power generated of PV and battery.
- 2) Power is not supplied in night-time in principle.
- 3) Power saving is explained to the villagers when power is used.

The power supply from an individual small-scale PV System is controlled by the charge/discharge controller. Examples are shown below.

< Example of system operation >

The power generated in daytime is stored in a battery through the controller and has no relation with weather. Power is supplied to the load in daytime and night-time.

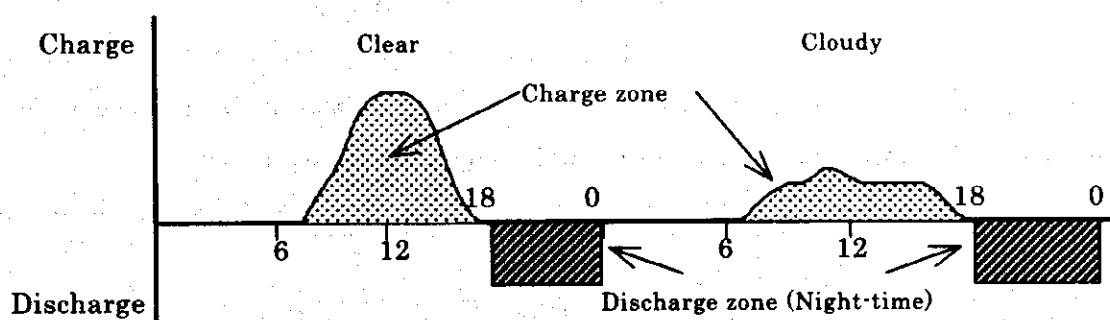


Fig.4.4-7 Example of system operation (Individual small-scale system)

② Individual medium-scale PV system (AC system)

- 1) The power generated in daytime is stored in a battery and power is supplied to the load during night-time. However, limited loads such as washing machines can be used in daytime.

- 2) Power is not supplied to the load in daytime when the weather is bad.
- 3) In terms of system operation, regarding daytime consumption in good weather, efficient usage is explained to the villagers. Power saving is explained to the villagers when power is used.

The power generated in daytime is stored in a battery through the controller and has no relation with weather. Power is supplied to the load in daytime and night-time. System control is managed by the controller.

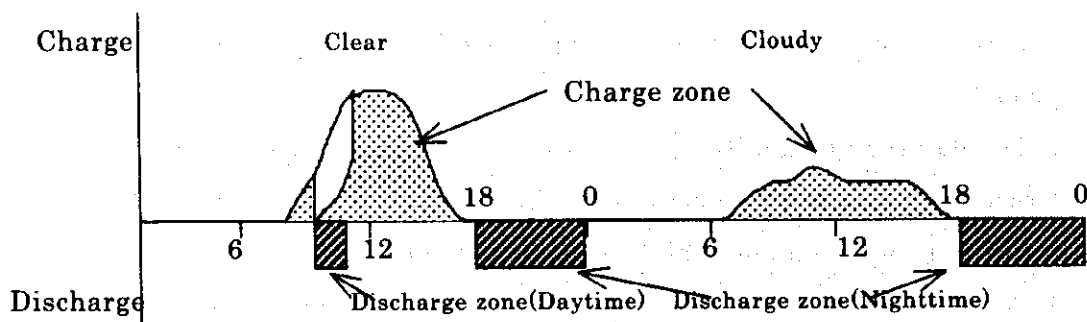


Fig.4.4-8 Example of system operation (Individual medium-scale system)

## (2) Demand of individual small-scale PV System

### ① Comparison between design demand and actual demand

Power demand per day is assumed as follows. (details are given in Table 4.4-1 and 4.4-2)

Fedre total of power consumption = 323(Wh/Day)

Katoura total of power consumption = 436(Wh/Day)

The data obtained from the data logger to understand actual operating situation were analyzed and evaluated. The actual power consumption in No.1 house of Fedre and No.4 of Katoura is converted into a daily amount as shown below.

Table 4.4-8 Amount of daily power consumption for each house of small-scale system

	97				98											
	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Fedre No.4	156	181	204	181	209	179	160	142	114	111	63	124	121	117	163	25
Katoura No.1	194	232	225	39	228	286	229	223	212	185	184	242	230	252	283	210

	99												20							
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Fedre No.4	106	128	171	217	133	110	173	224	-	-	-	268	194	166	175	224	236	182	167	170
Katoura No.1	-	-	-	86	155	150	247	327	288	435	520	396	280	292	304	321	297	294	272	312

② Comparison between estimated, actual generated power, and actual consumption

The insolation data obtained by the meteorological station in the centralized system were used and possible power generation of Katoura (DC300W) and Fedre (DC200W) is assumed. This possible (estimated) power generation and actual power consumption (converted to monthly consumption in Table 4.4-8) of representative houses recorded by data loggers since start of operation was compared. The parameters are as follows.

a. Possible power generation (estimated)

: Possible power generation estimated from insolation data

b. Actual power generation

: Total charged power from PV to battery. Total night-time consumption by villagers and floating charge.

c. Household power consumption

: Total power consumption at night by villagers

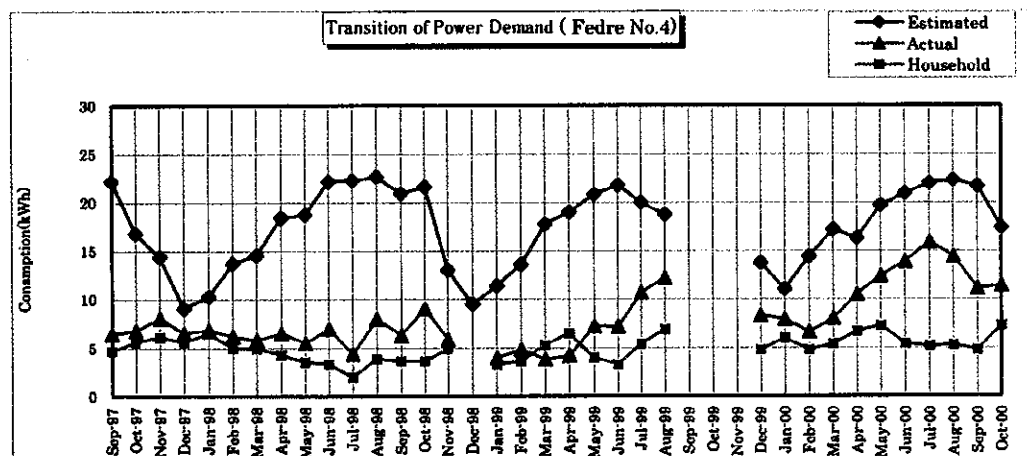


Fig.4.4-9 Transition of actual power supply and demand in Fedre No.4

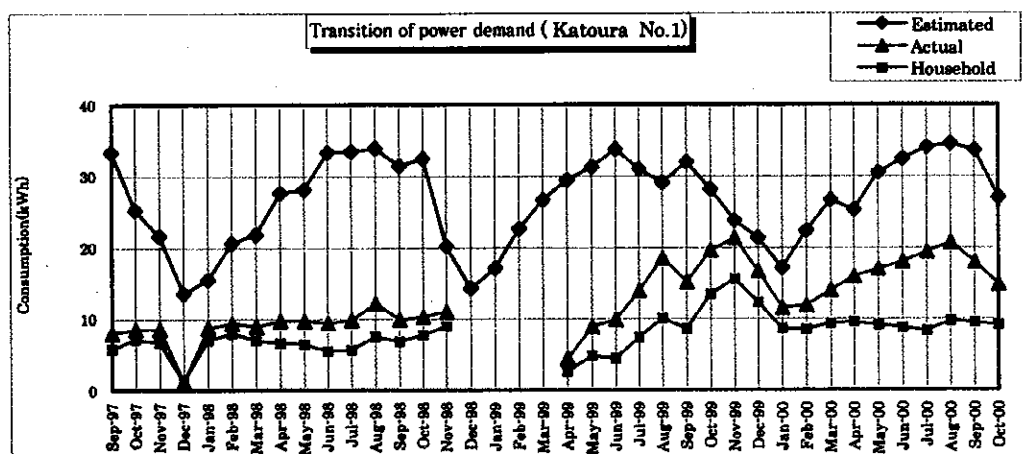


Fig.4.4-10 Transition of actual power supply and demand in Katoura No.1



Data for Fedre No.4 in December 1998 and Katoura No.1 during January to March 1999 were not recorded. After this, data were collected normally again. Therefore, the lack of data was because the batteries were low.

Compared with actual and assumed power consumption in both villages, in the case of Fedre No. 4, there were no differences in winter when insolation was low, but in summer, more power was generated. On the other hand, in the case of Katoura No.1, estimated power had some margin. The consumption of Katoura villagers was greater than that in Fedre, but the rated system capacity of Katoura (300W) is larger than the Fedre system.

However, these two houses were representative houses in both villages and the consumption trend of these houses is not same as that in all houses. There are much higher consuming houses and much lower consuming houses in both villages. In particular, in Katoura which is close to the grid line, more houses had fluorescent lamps installed, so, consumption of Katoura will increase in the future. Thus, it is necessary to note this increasing trend.

## ②State of use of PV system

The individual small-scale systems are not provided with a watt hour meter. However, to study actual records of generation and consumption, data loggers were installed in two selected houses of each village. The data obtained were analyzed to study the utilization factor of the individual PV system.

### a. Fedre system

The house in which a data logger was installed is relatively small, comprising one room. In this house, power is used for lighting, TV and radio. The data collected by the logger were compiled by month and the utilization rate of insolation was studied using the collected data. The utilization rate fluctuates month by month. From November to January in winter, the utilization rate varies around 70% and in July when insolation is higher, and utilization rate is down to 20%. From this utilization rate, generating capacity is larger than consumption and a stable power supply can be expected for the time being.

### b. Katoura system

The data loggers of this village are also installed in two houses. One of the

houses comprises one room. This is a relatively small house in comparison with the house in the village. In Katoura, the system capacity is larger than that of Fedre by 100(W). Thus, a 300W system is provided in each house. The utilization factor of insolation obtained from monthly data is shown in Table 4.4-9. As the system is larger than that of Fedre, the utilization rate of a Katoura house in winter is around 60%, which is a little low. Therefore, the system has some margin and stable power supply can be expected for the time being. The trend of utilization rate and surplus power in summer is indicated.

Table 4.4-9 Utilization rate of individual PV system (Fedre and Katoura)

Individual PV system (200W, Fedre)

Month			Fall			Winter			Spring			Summer			Ave.
			9	10	11	12	1	2	3	4	5	6	7	8	
Generated Power Assumption	a	[kWh]	18.9	14.3	12.3	7.7	8.8	11.7	12.4	15.7	16	18.9	19	19.3	15
Generated Power (Charge Power)	b	[kWh]	6.4	6.8	8	6.5	6.8	6.2	5.8	6.5	5.5	6.9	4.3	7.9	6
Consumed Power (Discharge Power)	c	[kWh]	4.7	5.6	6.1	5.6	6.5	5	4.9	4.3	3.5	3.3	2	3.8	5
Utilization rate	b/a*100	[%]	34	48	65	84	77	53	47	41	34	37	23	41	49
Surplus power	a-b	[kWh]	12.5	7.5	4.3	1.2	2.0	5.5	6.6	9.2	10.5	12.0	14.7	11.4	8.1
Average DOD of Battery	c/(2.4*30)*100	[%]	7	8	8	8	9	7	7	6	5	5	3	5	6
Average DOD (Maximum Use)	a/(2.4*30)*100	[%]	26	20	17	11	12	16	17	22	22	26	26	27	20

Individual PV system (300W, Katoura)

Month			Fall			Winter			Spring			Summer			Ave.
			9	10	11	12	1	2	3	4	5	6	7	8	
Generated Power Assumption	A		28.4	21.5	18.4	11.6	13.2	17.5	18.6	23.6	24	28.4	28.5	28.9	22
Generated Power (Charge Power)	b		8	8.5	8.6	5.4	8.7	9.4	8.9	9.8	9.7	9.4	9.8	12.2	9
Consumed Power (Discharge Power)	c		5.8	7.2	6.8	5.2	7.1	8	7	6.7	6.6	5.6	5.7	7.5	7
Utilization rate	b/a*100	[%]	28	40	47	47	66	54	48	42	40	33	34	42	43
Surplus power	a-b	[kWh]	20.4	13.0	9.8	6.2	4.5	8.1	9.7	13.8	14.3	19.0	18.7	16.7	12.9
Average DOD of Battery	c/(2.4*30)*100	[%]	8	10	9	7	10	11	10	9	9	8	8	10	9
Average DOD (Maximum Use)	a/(2.4*30)*100	[%]	39	30	26	16	18	24	26	33	33	39	40	40	30

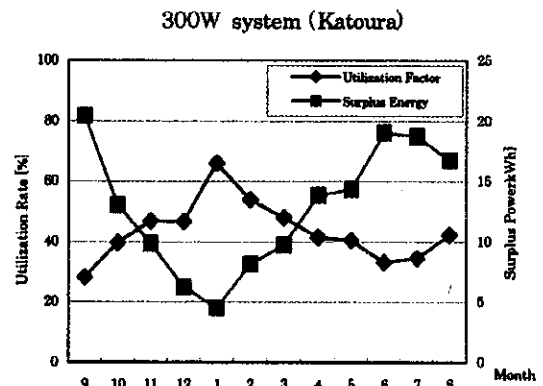
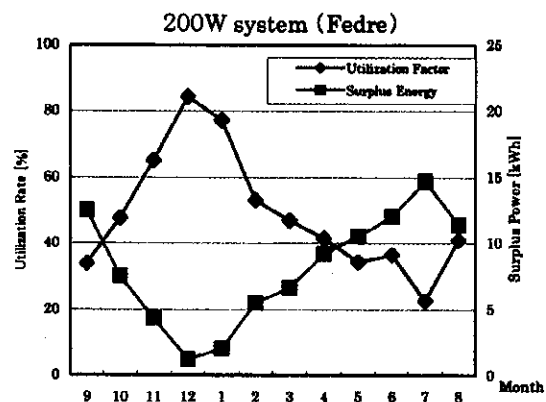


Fig.4.4-11 Situation of operation of individual PV system

#### ④ Situation of power consumption in the monitoring house

Among the houses installed with a data logger, one house was picked up from representative houses in each village and the operation situation was evaluated. Here, the monthly power consumption of each house installed with a data logger is evaluated in detail.

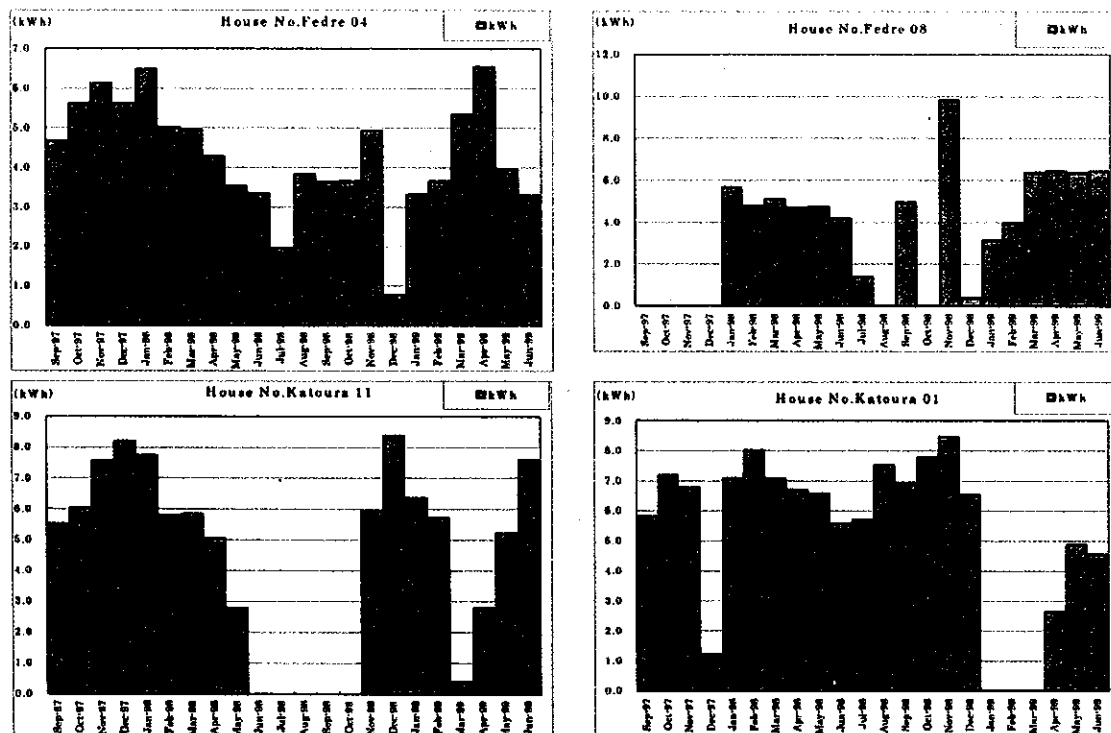
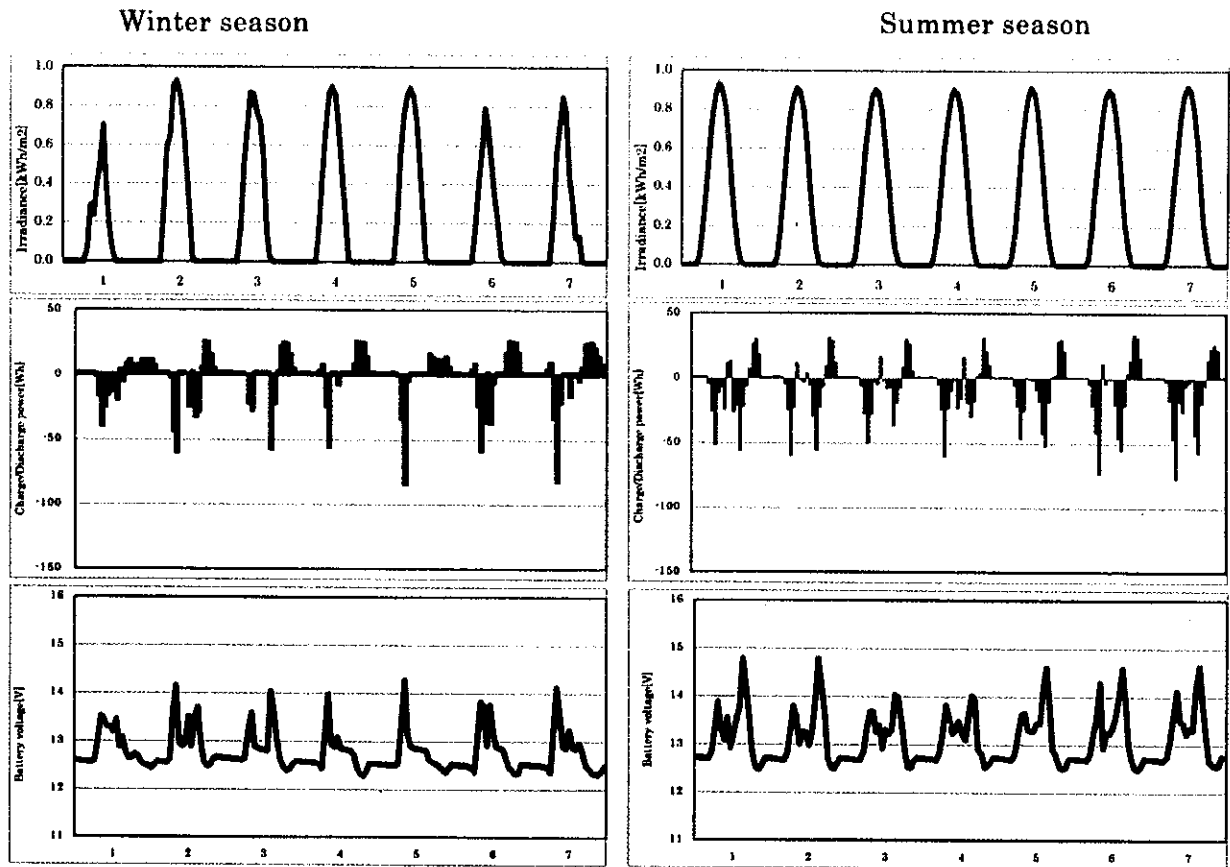


Fig.4.4-12 Monthly total power consumption

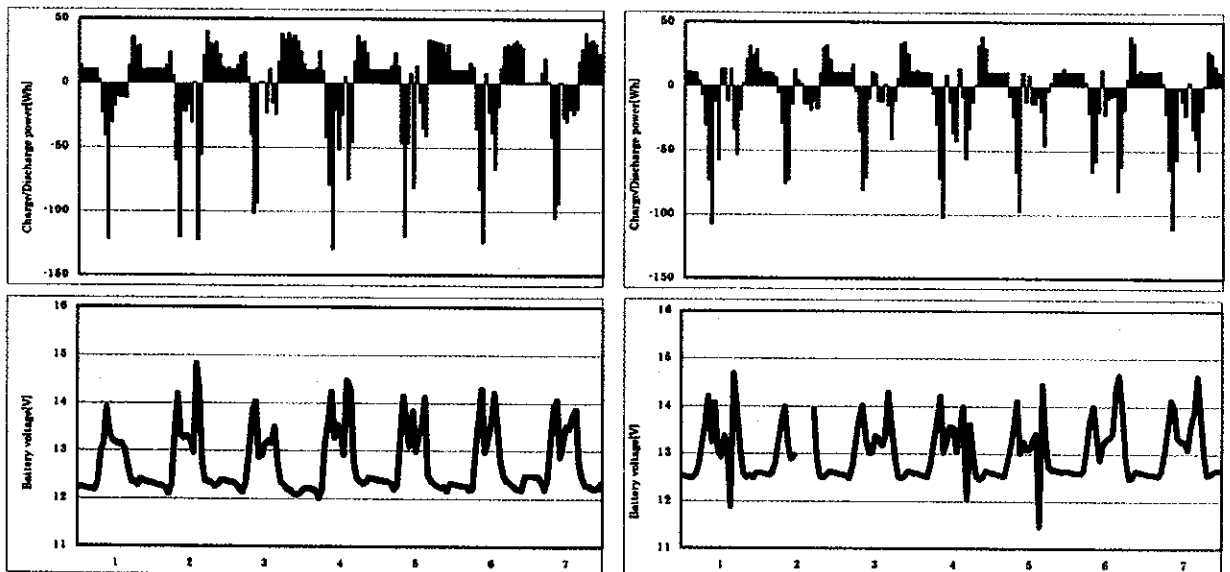
In addition, the weekly operating situation in summer and winter is shown in Fig.4.4-13. The trends of electric appliances in Fedre and Katoura are shown in Fig.4.4-14 and 4.4-15 respectively as well.

##### a. Operating situation in summer and winter

At the top of the figure are insolation data; to the left is winter and to the right is summer. The next graph is the weekly operating situation in winter and summer of Fedre No.4 and Katoura No.1. The upper part is the power charged and discharged. The bottom part is the trend of battery terminal voltage. According to these data, for Fedre No.4, the terminal voltage of a battery in winter is lower than that in summer, even winter consumption is smaller compared to summer. Moreover, in Katoura No.1, when demand of winter is even higher than summer demand, the system did not stop. In both cases, the system did not stop and continued to operate.



House No.04 (Fedre)



House No.01 (Katoura)

Fig.4.4-13 Weekly operating situation in winter and summer

### b. Situation of electric appliances

In Fedre, since system installation, the number of electric appliances was not increased. Only a 5(W) incandescent is used as a night lamp. On the other hand, in Katoura, radio cassette and B&W TV use slightly increased. In particular, the installation of 18(W) fluorescent lamps mainly used for livestock sheds sharply increased.

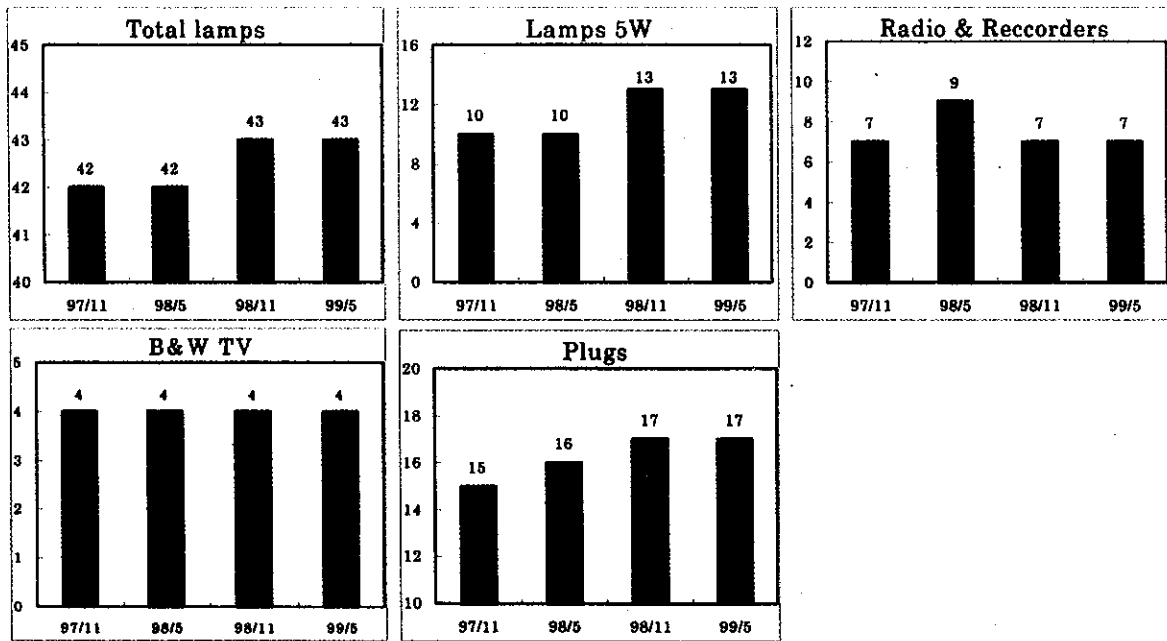


Fig.4.4-14 Electric appliances in Fedre

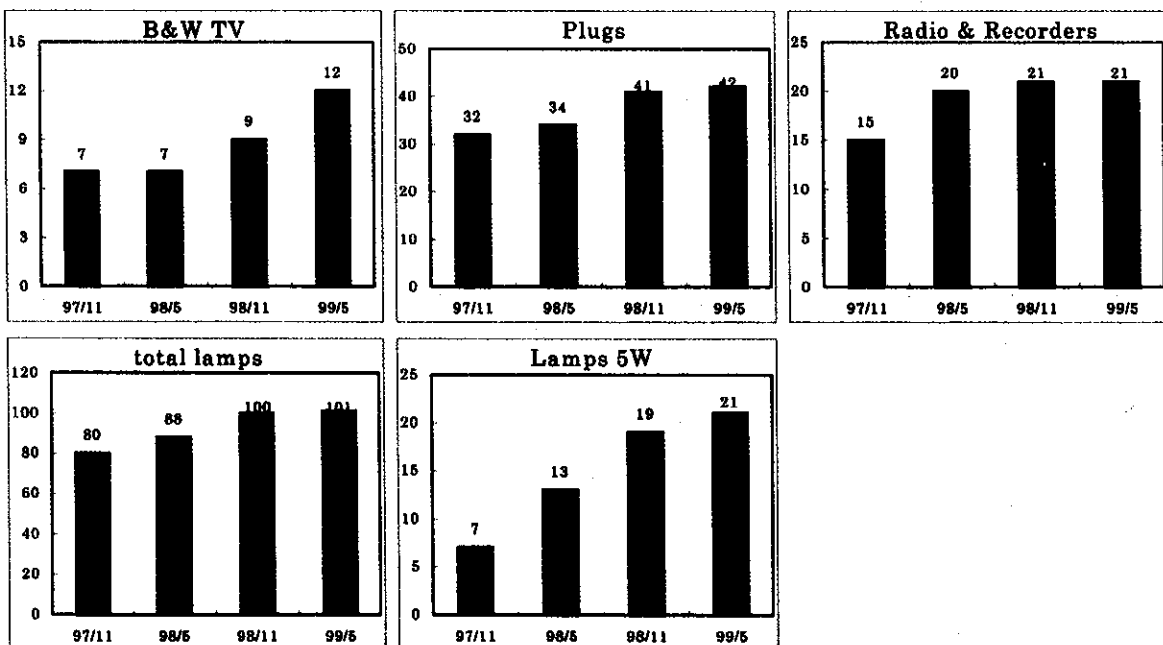


Fig.4.4-15 Electric appliances in Katoura

## ⑤Evaluation of DC system operation

The operation of the systems of both villages can be evaluated as follows. However, when power generated in daytime during summer is studied for more effective use, installation of a small inverter to power a washing machine was proposed. If such ideas are executed in the future, the system will be much utilized with improved living standards and the villagers can be expected to better understand the PV system.

### a. Operation of Fedre system

Although the battery voltage is low overall in winter, power could be supplied to the load, the system did not stop and it continued to operate from commissioning until the present.

It was also found that improved weather improved battery voltage.

There have been few changes in the ownership of fluorescent lamps, radio cassette, and B & W TVs. Other appliances were not introduced.

This suggests that the villagers have been operating their appliances properly in accordance with the guidance of the SSRC/HIAST, and they are satisfied to use lighting, radio, and TV for the time being. In addition, this village is relatively far from Dartazze, which is electrified by the grid, and there is little cultural exchange. The income of villagers is also considered.

However, each house uses a 5 (W) incandescent lamp as a night light, as in Zarzita.

### b. Operation of Katoura system

Compared to Fedre, the Katoura system is a larger capacity PV array and the load consumption is almost the same as Fedre. As a result, the battery voltage recovers faster under the same weather conditions.

As the output of the PV system in Katoura is larger than that of Fedre, the daytime power consumption in Katoura is greater.

Radio cassette and B&W TV use slightly increased, but installation of 18(W) fluorescent lamps mainly used for livestock sheds sharply increased. Even in winter, the system continued to feed power without failure. This village is close to Dartazze, which is electrified by the grid, and has many means of transportation. Thus, the villagers are familiar with the convenience of electricity. Since the start of operation, electric appliances have been introduced and

consumption can be expected to increase, therefore, careful monitoring is required.

### (3) Situation of medium-scale system

Since Aug 1998, the individual medium-scale AC systems in Kalif started continuous operation. The operating condition is described below.

#### ① Comparison of design and actual power demand

Total power consumption per day is assumed as follows.

Daytime consumption : 400(Wh/Day)

(Washing machine use in daytime is once a three days)

Night-time consumption : 690(Wh/Day)

In the medium-scale AC system in Kalif power consumption is not measured for each house. Seventeen sets for twenty-five houses were installed and one system is shared by more than one house. A typical sharing group was chosen and data loggers were installed. The data collected from the logger was analyzed and analyzed data were considered to be the average consumption of this village. The actual consumption per day in Table 4.4-10 is converted from the data collected for House No.1, No.2, and No.6 as an example.

Table 4.4-10 Power consumption per day of representative house in AC system

(unit : Wh)

No	98 9	10	11	12	99 1	2	3	4	5	6	7	8	9	10	11	12	00 1	2	3	4	5	6	7	8	9	10
1	1000	923	1173	668	483	649	669	566	473	516	740	820	926	1027	-	-	-	842	901	840	946	434	758	873	756	1143
2	1492	1586	855	806	402	678	-	-	-	-	617	1035	1310	1277	1084	1014	677	827	705	713	-	-	1314	1368	1274	1138
6	672	739	627	532	345	318	536	463	326	473	-	-	-	-	-	-	-	554	-	-	564	625	653	626	805	801

#### ② Comparison of estimated power generation and actual consumption

The insolation data obtained by the meteorological station in SSRC/HIAST were used and possible power generation of Kalif assumed. This possible(estimated) power generation and actual power consumption (converted to monthly

consumption on Table 4.4-10) of representative houses recorded by data loggers since the start of operation were compared. The parameters are as follows.

a. Possible power generation (estimated)

: Possible power generation estimated from insolation data

b. Actual power generation

: Total power charged from PV to battery. Total night-time consumption by villagers and floating charge.

c. Household power consumption

: Total power consumption at night by villagers

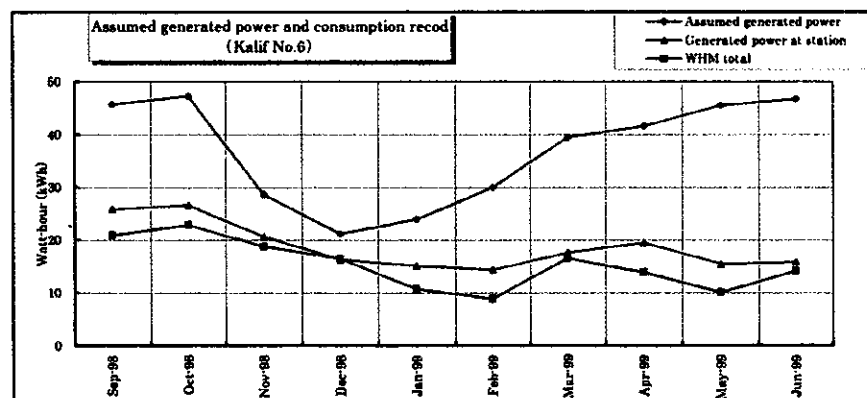


Fig.4.4-16 Transition of actual power supply and demand in Kalif No.6

### ③Evaluation of usage

The system of Kalif is 500(W) AC system and one system is shared by more than one house. A watt hour meter is not provided which is the same as for the small scale system. However, operation data obtained from the data logger installed in representative house are collected and analyzed to study utilization rate.

As a result, power supply and demand were almost balanced in winter. The system meets the designing condition and did not stop. However, toward summer, the power generated increased according to the insolation and power supplied is greater than consumption. Therefore, power generated can be expected to be used effectively. For example, a small-scale inverter is introduced and used to operate a washing machine and a small water pumping system for an underground water tank etc.



Table 4.4-11 Utilization rate of medium-scale system (AC system) in Kalif

			month			Fall			Winter			Spring			Summer			Ave.
						9	10	11	12	1	2	3	4	5	6	7	8	
Generated Power Assumption	a	[kWh]	45.7	47.2	28.7	21.2	24.0	29.9	39.5	41.6	45.5	46.7						
Generated Power (Charge Power)	b	[kWh]	25.9	22.7	17.6	13.9	12.9	12.3	15.0	16.6	13.3	13.5						
Consumed Power (Discharge Power)	c	[kWh]	20.9	22.9	18.8	16.5	10.7	8.9	16.6	13.9	10.1	14.2						
Utilization rate	$c/a \times 100$	[%]	45.7	48.5	65.5	77.8	44.6	29.8	42.0	33.4	22.2	30.4						
Surplus power	a-c	[kWh]	24.8	24.3	9.9	4.7	13.3	21.0	22.9	27.7	35.4	32.5						
Average DOD of Battery	$c/(15.84 \times 30) \times 100$	[%]	4.4	4.8	4.0	3.5	2.3	1.9	3.5	2.9	2.1	3.0						
Average DOD (Maximum Use)	$a/(15.84 \times 30) \times 100$	[%]	9.6	9.9	6.0	4.5	5.1	6.3	8.3	8.8	9.6	9.8						

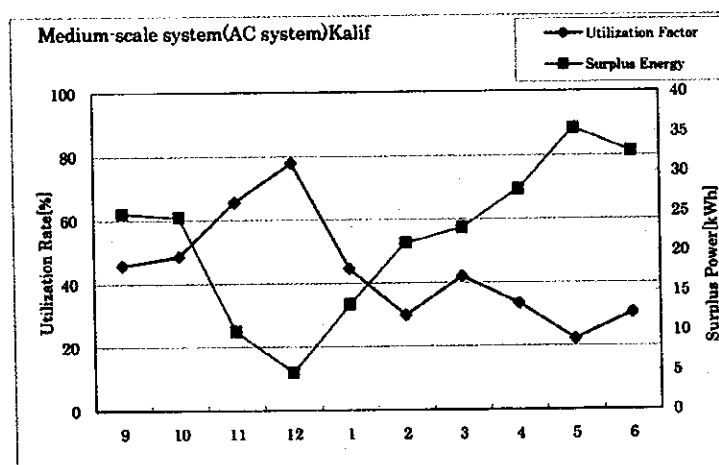


Fig.4.4-17 Operation of medium-scale system

#### ④ Situation of monitored house

##### a. Operation in summer and winter

House No.2 was selected from among houses in which data loggers were installed, and operation during one week in summer and winter was studied based on the data collected. Power consumption increases in summer and decreases in winter, but the system operated without any failures in both season.

##### b. Situation of electric appliances

Since the start of operation, the situation of electric appliances has been continuously surveyed. As with three villages in the north, 5(W) incandescent lamps are installed as night lamps. However, other appliances did not increase.

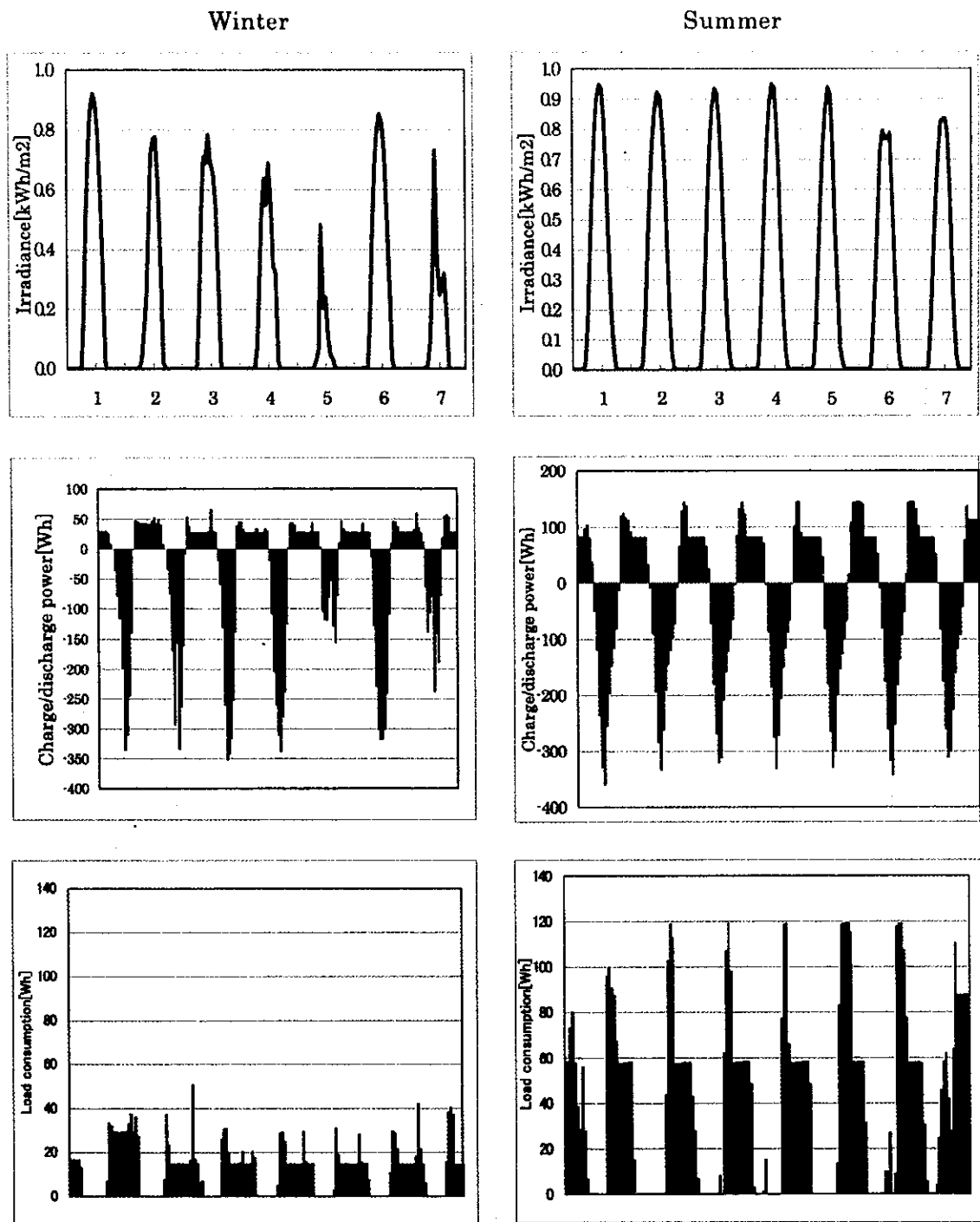


Fig. 4.4-18 Weekly operation of House No.06 in summer and winter

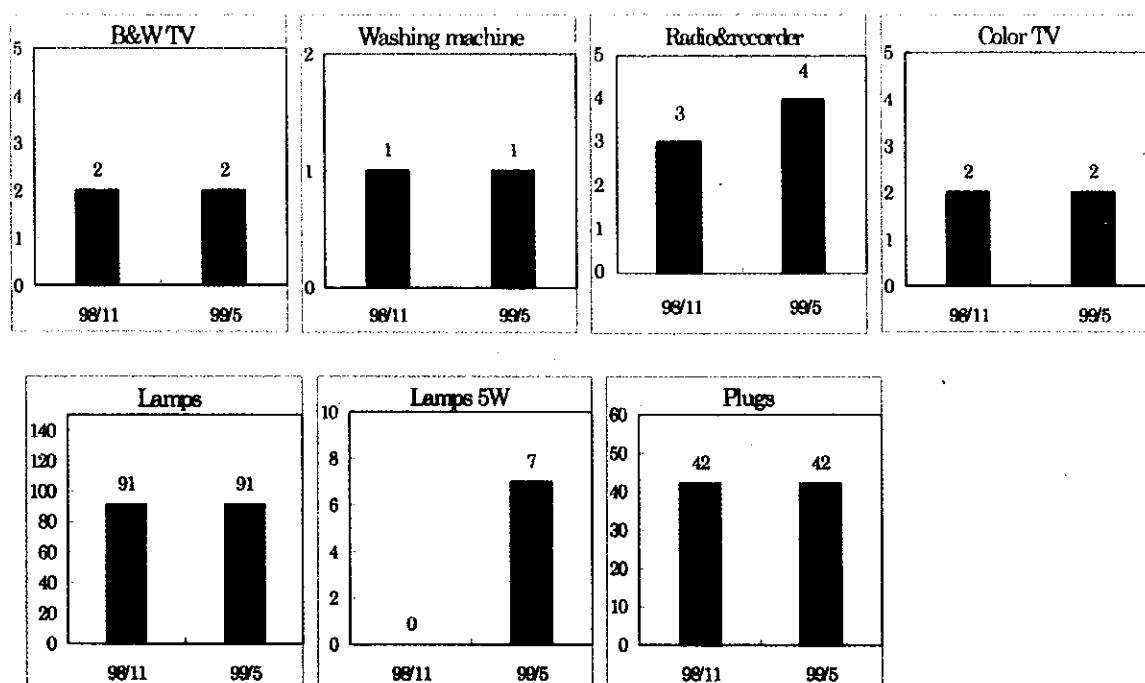


Fig.4.4-19 Situation of electric appliances

#### 4.4.4 Maintenance

The basic maintenance items are the same as in the centralized system. Here, the items of individual systems only are described. The results of maintenance are also described.

Table 4.4-12 Maintenance item of individual system

Equipment	Item	Inspection	Objective system
Electric generation system	Battery	Cleaning of batteries case	DC AC
	Inverter	The checkup of performances on terminal voltage and indicated lamp Cleaning of panel inside and outside	AC

##### (1) PV array

PV modules, structures and cables were in good working condition.

Depend on weather conditions, the open circuit voltage of PV array is as follows.

Small-scale : 19.2(V)~20.8(V)

Medium-scale : 38.3(V)~40.0(V)

These voltages are the normal range and the electric circuit has no damage.

## (2) Controller

The controller, breaker, and LED of the small-scale system procured in Japan had no problems, nor were there any problems with system control. In addition, the controller of the medium-scale system, which was made by SSRC/HIAST, is working well and has no problems.

## (3) Inverter (only for medium-scale system)

This inverter is used particularly for the medium-scale AC system and can be purchased in the general international market. These inverters are also working well, providing stable output of AC220V.

## (4) Battery

In the small-scale system, the average quantity of distilled water in 1998 batteries used was about 9% of total quantity, and this was reasonable. However, in 1999, about 40% of total quantity, which is the same as the centralized system, was refilled.

Regarding the medium-scale system, the solution was greatly depleted in summer. Some of battery boxes were left outside and exposed to direct sunshine. In summer, the insides of boxes is heated up as atmosphere temperature rose and this temperature rise is one of reasons accelerating water evaporation. Therefore, in July 1999, a small roof was installed on the box to intercept direct sunshine and to prevent heat build-up. As a result, the quantity of water supplied in summer from May to September remained the same. It is considered that the water quantity of the other system increased, and the small roof was effective.

From this maintenance result, there are requests to inspect batteries once a month only during summer(May to October).

Table 4.4-13 Filling of distilled water for battery

Year	Village	Sep +Oct	Nov +Dec	Jan +Feb	Mar +Apr	May +Jun	Jul +Aug	Water ℓ / year	Water ℓ / batt·year
Sep/97 to Aug/98	Fedre	2.75	0.5	0	0	4.5	1.2	8.95	0.75
	Katour	4	3	0	0	9	0.6	16.6	0.66
	Kalif								
Sep/98 to Aug/99	Fedre	6.1	5.45	0.5	6	11.25	15.5	44.8	3.7
	Katour	6.7	10.5	1.7	11.5	19.75	29	79.15	3.2
	Kalif		27.5	3.5	10.5	53.5	51.3	145.8	1.62
Sep/99 to Aug/2000	Fedre	15							
	Katour	25							
	Kalif	53							

#### 4.4.5 Problems and trouble-shooting

Since the start of operation, the situation of problems and troubleshooting was monitored and the equipment was found to have no problems. The only failure was a light tube in a small-scale system. The medium-scale system suffered no problems. An interview survey revealed that one tube was replaced in one year. Failures and troubleshooting are listed below. No problems have occurred in Kalif.

##### < Blacking of fluorescent tube >

A survey was carried out to clarify the reason for the blacking tube in cooperation with SSRC/HIAST.

As a result, the reason considered to be as follows.

- 1) This problem was found during maintenance in May. In winter, the voltage of battery terminals is lower than in summer because of low insolation. Therefore, the workable voltage range of electronics ballast purchased in the local market is narrow.
- 2) Performance of local electronics ballast varies greatly.

Therefore, the study team carried out a market survey in Japan and ordered sample ballast. The ballast was installed and the situation was monitored. In winter, the sample ballast worked well and there are no failures. Therefore, July 1999, all local ballast was replaced with Japanese ballast. Subsequent operation was good.

Table 4.4-14 Fedre system problem and trouble-shooting

Date	House No.	Fault	Cause	Repair
20/8/97	1	Lamp is out of order	Fire.	Change complete lamp set.
8/11/97	7	Lamp is out of order	Lamp is on for long time.	=
9/5/98 5/9/98	1	one fluorescent lamp is blackened. its brightness is weak. it sounds.		Change terminals position
	3	change EC for one lamp at 8/5/98 although it was out of order one month ago		
	4	one fluorescent lamp is blackened but it is working.		
	8	Change one fluorescent lamp 20 days ago		
	9	3 lamps are blackened one lamp doesn't work		
	12	Change terminal position for one lamp after 2 months, then change the lamp at 8/5/98		
	10	one lamp was blackened	they change it	

Table 4.4-15 Katoura system problem and trouble-shooting

Date	House No.	Fault	Cause	Repair
Sep/97	9-2	Lamp is out of order.	E.C is damaged	Change The E.C
1/10/97	21-1	Battery Is out of order.	One Cell Is damaged	Change The Battery.
Oct /97	10-2	Plug Is out of order.	It is Loosed	Tightening
9/11/97	12	Terminal Is Corroded.	Humidity	Cleaning
7/1/98	2	Outside lamp is out of order	Lamp is damaged	
=	9-1	=	=	
=	11	One lamp is only working at day time	Change E.C with other one	
=	19	One lamp is out of order	Lamp is damaged	
=	21-1	Outside lamp is out of order	Complete set is taken out	
3/3/98	1			Battery box needs a lock
=	2			2 lamps are changed 2 weeks ago
=	6			They remove the corridor lamp because of wind. and Battery box needs a lock
=	9-1			One cover of the battery is lost
=	9-2	2 lamps are out of order		
=	10-2	one lamp was changed 3 times and is broken		
=	18			2 lamps are changed 1 month ago, and one lamp is removed to another place 50m far.
=	19	one lamp is out of order		
=	20 Mosque	One lamp is sounding		
=	23			2 lamps are changed 2 month ago.

E.C: Electronic Circuit.

Table 4.4-16 Kalif system problem and trouble-shooting

Date	House No.	Fault	Cause	Repair
9/1998	10(17)	Inverter is off	Short in lamp set	Remove the shortness
12,17/9/98	13 (23+24)	Load is off from 5am to 10am	Not enough charging	It prepared itself when sun shines.
14,15,16,17/9/98	14 (25+26)	Load is off from 5am to 11am	Not enough charging	It prepared itself when sun shines.
18/9/1998	14 (25+26)	Load is off from 10pm to 11am	Not enough charging	It prepared itself when sun shines.
21/9/1998	14 (25+26)	Load is off from 5am to 10am	Not enough charging	It prepared itself when sun shines.
11/1998	11 (20)	Two lamps don't work	Flourescent lamps are out of order	
1,2,3,4/1/1998	2 (2+3)	Load is off from 9pm to 9 am	Not enough charging	It prepared itself when sun shines.
6,7,8/12/1998	12 (22)	Load is off	Not enough charging	It prepared itself when sun shines.
6,7,8/12/1998	13 (23+24)	Load is off	Not enough charging	It prepared itself when sun shines.
6,7,8/12/1998	14 (25+26)	Load is off	Not enough charging	It prepared itself when sun shines.
5/10/1999	8	Inverter was broken	water drop into the inverter	Not yet, because their were no available spare parts in the local market

EC: electronic circuit

#### 4.5 Evaluation of each PV system

##### 4.5.1 Situation of operation

###### (1) Centralized PV system

After commissioning, there were notable additions of 100W and 10W incandescent lamps by villagers.

Fluorescent and the incandescent lamps are brighter than kerosene lamps and these lamps are safe and convenient. Therefore, at the first stage, demand for lighting increased. When villagers understood the convenience of electricity, electric appliances for entertainment applications such as radio-cassette, and B&W or color TV were purchased. Then electric appliances to reduce women's daily work such as washing machines and irons increased.

In addition, recently, big power-consuming appliances such as refrigerators and fans have been increasing to improve living conditions.

The convenience of electricity pervaded the daily lives of the people, shifting them away from the inconvenience without electricity in favor of an improved quality of life with electricity.

The increase of appliances is evidenced by a sharp rise in power consumption from approx. 2,600kWh/2 months at the beginning and about 70% of the design load (approx. 4,000kWh/2 months) to 4,700kWh/2 months.

Moreover, in July to August 1999, consumption was 7,200kWh/2month. The trend of average consumption is increasing, but the system has some margin.

###### (2) Individual PV system

In Fedre, based on the situation for electric appliances, the number of lamps, radio-cassettes, and TVs did not increase and the other appliances were not introduced. The villagers of Fedre followed the guidance of SSRC/HIAST and used their load appropriately. There is some demand to use washing machines, but the villagers were satisfied to use lighting, radio, and TV for the time being.

In Katoura, radio cassette and B&W TV use slightly increased, but in particular, installations of 18(W) fluorescent lamps mainly used for livestock sheds sharply increased. However, the system did not fail even in winter. This village is close to

Dartazze which is electrified by the grid and there are many means of transportation. Therefore, Katoura villagers understand the convenience of electricity. It is estimated that the introduction of appliances and consumption is increased, and it is necessary to monitor the situation carefully. In the future, limits of capacity and DC system are expected to be experienced. The introduction of various appliances is expected, and it will be required to convert to an AC system.

In Kalif, the system has been operated for about one year. During this period, the equipment has had no noticeable problems. This system is AC, however, electric appliances have not increased as in Zarzita. Only 5(W) incandescent lamp use increased.

In Kalif, about half of the houses are vacated in the dry season (summer) as people work away from their homes.

During their absence, the system continues to charge the batteries without a balancing discharge, which accelerates water evaporation from the battery.

It was thus proposed to reduce the inspection cycle to once a month during the summer same with the other system. Continuous charging and no discharging reduced battery life. In a vacant house, the charge circuit is turned off, but it is necessary to study permanent countermeasures that separate part of the system and convert it to a portable system.

#### 4.5.2 Situation of maintenance

The situation of maintenance in this project has been monitored since commissioning. Based on the results, the technological level of SSRC/HIAST was found to be quite high and the outcome of technology transfers for design, installation, and trial operation was effective. Thus, maintenance technology and procedures are excellent, and data were smoothly collected and analyzed.

Therefore, in the future, if all system management is transferred to the Electric Authority, the sustainability of the installed system will be maintained by the related Authorities under the supervision of SSRC/HIAST.



#### **4.6 Technology transfer**

In the future, when a PV system is introduced into Syria, the assumptions for electric appliances and determination of system scale that balances demand and power generated by insolation are important. Based on this basic design, to install an actual system, it is necessary to select of system equipment and installation procedure. In addition, the various technologies which sustain operation management for as long as possible and maintenance are necessary to maintain the PV system. Technology transfer in this project is outlined below.

##### **4.6.1 Design of PV system**

To decide the scale of the PV system, a basic design is necessary. To improve this technology, basic and actual designs of system to be introduced were executed in cooperation with SSRC/HIAST, and the following technology was transferred.

##### **(1) Procedure of basic design**

- 1) Assumption of electric appliances and demand
- 2) Concept of losses for controller, inverter, and wire
- 3) Basic design procedure for PV system using insolation data and procedure to decide scale of system
- 4) Measurement and utilization of insolation data such as global, inclination, and diffused

##### **(2) Actual design**

- 1) Configuration of PV system and functions of each items of equipment
- 2) Procedure of PV array configuration and selection of battery based on basic design
- 3) Selection procedure for system equipment
- 4) Procedure for designing PV array structure and selecting miscellaneous materials (wire and SW etc)

##### **4.6.2 Installation procedure and final inspection**

During 1997 to 1998, installation of centralized, individual, and power units of the desalination equipment was executed. Through this installation and inspection, the following guidelines were given.

(1) System installation work

- ① Transportation and storage of equipment and materials
- ② Procedure to make a time schedule, and safety and schedule management
- ③ Explanation of outline of system components and their functions in system configuration
- ④ System installation work

a. PV arrays

- 1) Method of installing PV modules.
- 2) Method of wiring modules, method of configuring array and wiring.
- 3) Procedure for installing structure and foundation.

b. Controllers and Inverters

- 1) Procedure for installing and wiring equipment

c. Battery

- 1) Basics of installation
- 2) Basics of filling battery solution, and method of checking level of solution.

d. Distribution network and in-house wiring facilities

- 1) Function and roles of distribution equipment and materials delivered from Japan
- 2) Methods of pole installation and assembly, and procedure for wiring distribution network.
- 3) Basics of wiring lead wire
- 4) Basics of installing SW board and fluorescent lamps in each house
- 5) Basics of in-house wiring

(2) Inspection

In relation to inspections during and after installation of centralized PV system and individual systems and power unit for desalination plant, technical guidance on the following items was provided.

① PV Array

- 1) Methods of measuring open-circuit voltage and operating voltage (module, sub-array, and array), and methods of judging pass or failure.

- 2) Methods of measuring operating current (sub array and array), and method of judging pass or failure.
- 3) Visual inspection (appearance) and judgment of pass or failure.

#### ② Controllers and inverter

- 1) Methods of visually inspecting appearance (such as damage to the box and overheating).
- 2) Checking indication lamps and instruments.
- 3) Method of measuring insulation resistance (insulation resistance at DC and AC sides).

#### ③ Battery

- 1) Methods of measuring terminal voltage and specific gravity.
- 2) Methods of checking solution level and refilling distilled water.

#### ④ Distribution line and In-house wiring

- 1) Methods visually inspecting appearance
- 2) Methods of measuring withstand voltage and insulation resistance.
- 3) Method of measuring voltage at various parts (wall outlet and terminal of lamps).

#### (3) Arrangement of drawings

In the future, to maintain system introduced by SSRC/HIAST smoothly, equipment list and drawings is prepared.

#### (4) System operation

The study team provided technical guidance on operation methods, routine inspection, and periodic inspection of PV systems (centralized, individual, and power unit of desalination) after the start of operation. The operation and management manual was reviewed based on the results of maintenance.

#### < Items for guidance >

- a. Centralized, individual small-scale, medium-scale, and power units of the desalination plant
  - 1) Normal system startup/shutdown procedures.

- 2) Methods of responding to failure and system stoppage.
- 3) Methods of controlling charge/discharge of batteries, and methods of modifying preset control voltages.
- 4) Method of equalizing battery charge
- 5) Safety during operation.
- 6) Routine and periodic inspection.

b. Data logging system to monitor system operation

- 1) Handling procedure for data logger.
- 2) Methods of collecting and analyzing data.
- 3) Utilization of collected data.

#### 4.6.3 Equipment introduced to improve PV technology and evaluation

Meteorological observation system is required for obtaining insolation and other meteorological data that are indispensable for designing PV systems, whereas a battery testing system is indispensable for checking batteries, which have a great bearing on the performance of a PV system. All of these instruments will add to the capabilities of SSRC/HIAST as a leading technological institution in Syria. Detailed below are the results obtained by these instruments and how to utilize them.

(1) Meteorological observation system

Meteorological observation system collects insolation and other meteorological data in SSRC/HIAST and Zarzita, and is also used for various applications including evaluations of possible outputs of PV systems. The following is an outline of the meteorological observation system installed and the results of analyses of meteorological data collected by it so far.

① Outline of meteorological observation system

One set each of meteorological observation system has been installed at SSRC/HIAST and the centralized PV system in Zarzita. The specification of the meteorological observation system installed and the measuring items are described below.

a. SSRC/HIAST system(Fig.4.6-1)

The configurations of the SSRC/HIAST system and measurement items are summarized in Table 4.6-1 below.

Table 4.6-1 Components and measurement items of SSRC/HIAST system

Item	Sensor	Transducer	Data logger	Remarks
Insolation on horizontal surface	Pyranometer Type : MS-801	3-channel integrator (analog type) Type:CT150-3	Analog inputs: 8 channels Pulse input: 1 channel  Type:LS-3000ptV	Installed angle: Horizontal
Insolation on a tilted surface	Pyranometer Type : MS-801			Installed angle: 35 degrees
Diffused insolation	Pyranometer Type : MS-801			With a shading facility
Amount of rainfall	Tipping bucket type Type:RS-102	Pulse isolator Type:PI-110		

b. Zarzita system(Fig.4.6-2)

The configurations of the Zarzita system and measurement items are summarized in Table 4.6-2 below.

Table 4.6-2 System components and measurement items of Zarzita system

Item	Sensor	Transducer	Data logger	Remarks
Insolation on a tilted surface	Pyranometer Type : MS-801	1-channel integrator (analog type) Type:CT150	Analog inputs: 8 channels Pulse input: 1 channel Type:LS-3000ptV	Installed angle: 35 degrees
Wind vane	Wind direction transmitter (single vane) Type : VR236	Wind direction/wind speed transducer Type:WS104		
Anemometer	Wind speed transmitter (three-cup system) Type : AG860			
Thermometer/hygrometer	Temperature/humidity sensor Type:HMP35D			Temperature/humidity transducer Type:HM150VS

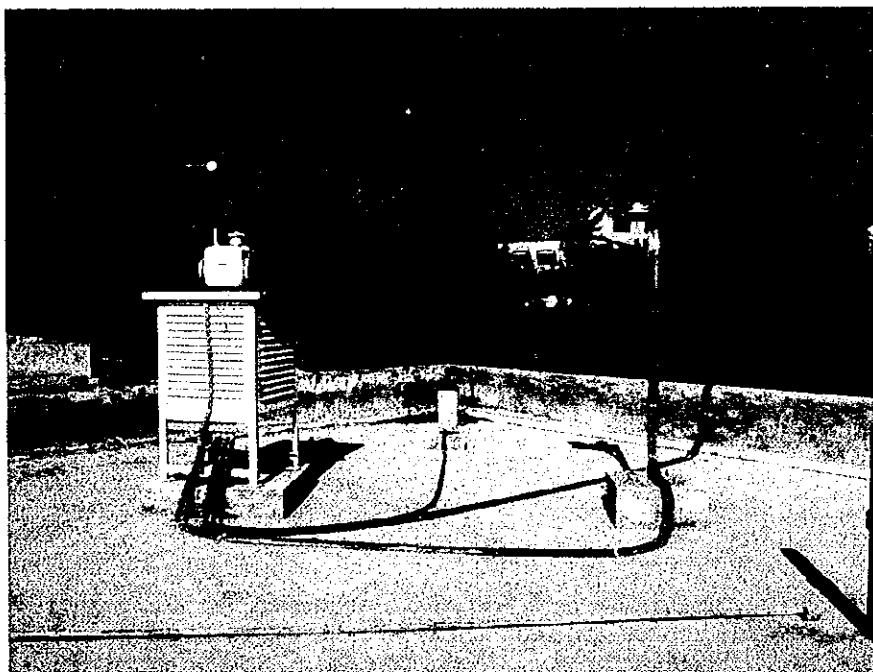


Fig.4.6-1 SSRC/HIAST system

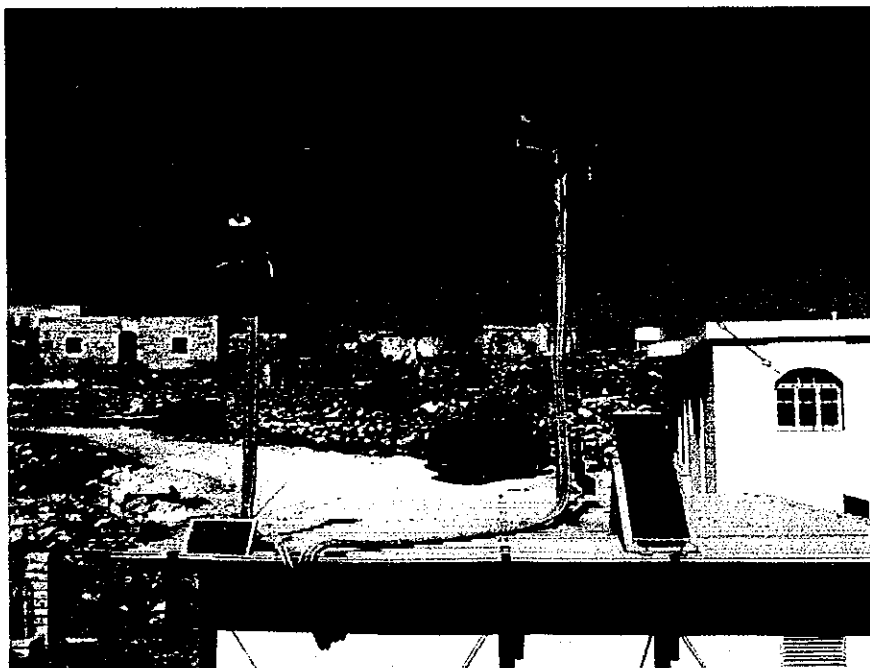


Fig.4.6-2 Zarzita system

## ②Analyzing meteorological data

The data collected from data loggers of each meteorological station were analyzed and used to evaluate the power generated by installed PV system. In the future, these data will be utilized for system design when introducing PV system.

### a. Insolation data

The daily average insolation data collected by the pyranometers installed at SSRC/HIAST and Zarzita system are described. See Fig. 4.6-4 and 4.6-5.

#### 1) SSRC/HIAST system

During April to August, insolation on a horizontal plane exceeded that of an inclined plane. During the rest of the year, the situation was reversed. It is evident that for the purpose of improving PV efficiency, the angle of the PV array should be minimized during summer, increased in winter. Usually, the PV arrays are used in a fixed inclination to maximize daily average insolation throughout the year. In this case, the PV system can generate sufficient power.

Beams of sunshine reach Earth's surface after experiencing absorption and diffusion on their way through the atmosphere. That component of direct sunshine is called the direct insolation. The component of beams that reach the Earth's surface after scattering or reflection is called the diffused insolation. The total of direct and diffused insolation is global insolation.

Diffused insolation is much weaker than direct insolation. Global insolation, for which direct insolation ratio is higher than that of diffused insolation is used for PV power generation. According to diffused insolation data collected from the SSRC/HIAST system, the ratio of diffused insolation component to the global insolation on a horizontal plane in Syria is as low as 10-15%, except during part of the rainy season. Compared to diffused insolation in Japan, which accounts for some 50%, insolation of Syria is more suitable for PV power generation.

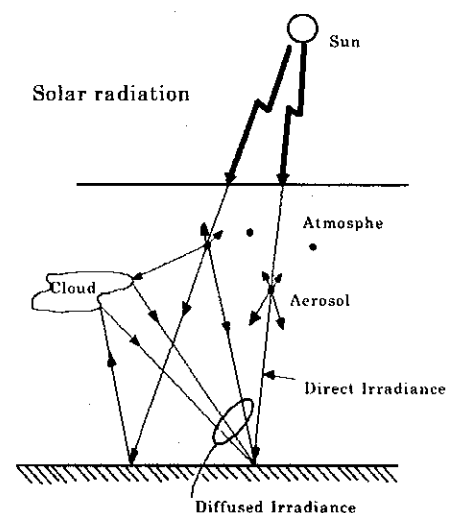


Fig.4.6-3 Diffused irradiance

## 2) Zarzita system

The pyranometer installed at the centralized PV system in Zarzita measures only tilted angle insolation. The inclination is set at  $35^\circ$ , which is the same angle as the PV array of the centralized system. The pyranometer installed on the rooftop of SSRC/HIAST is also at the same inclination, but its insolation reading is a little lower than that of Zarzita. The SSRC/HIAST system is installed in the outskirts of Aleppo and is affected by air pollution due to dust and emissions.

### b. Temperature and humidity data

Temperature and humidity data are collected only at the centralized system. The daily temperature and humidity readings obtained are organized into monthly averages for graphical representation. For Zarzita, which is located at an elevation of about 600m, the average temperature falls to around  $5^\circ\text{C}$  in winter, and there are days when the minimum temperatures run below  $-10^\circ\text{C}$ . In the summer of 1998, generally high temperatures were recorded throughout Syria, and a maximum temperature of approx.  $40^\circ\text{C}$  was recorded in Zarzita. For humidity data, 80% or more was recorded in December and January in winter. In summer, humidity dropped to 40~50%.

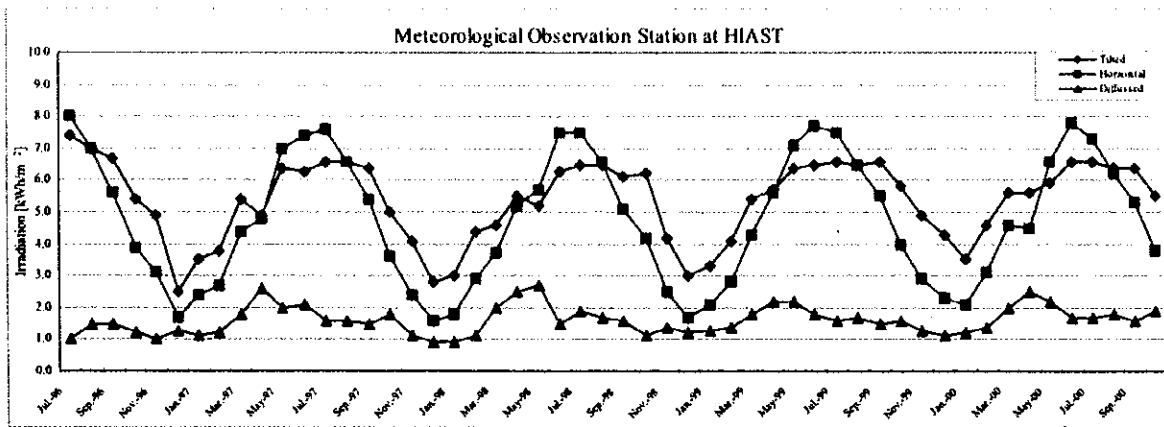
### c. Rainfall data (See Fig. 4.6-8.)

Rainfall is measured only on the rooftop of SSRC/HIAST. According to the data obtained, 1997 saw relatively high rainfall of about 400mm, but rainfall in 1998 was low. In either year, no rainfall was recorded in summer. It is found that humidity increases with an increase of rainfall.

### d. Wind direction and wind velocity data (See Fig. 4.6-10)

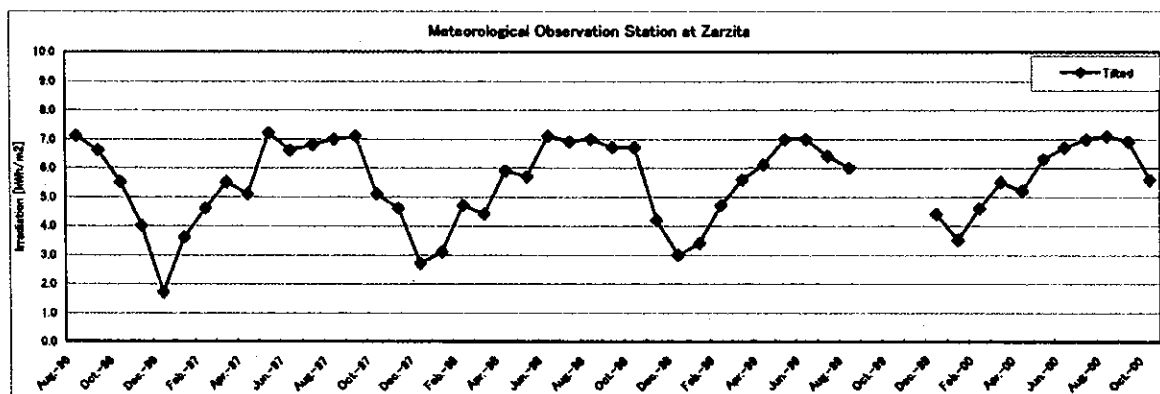
Wind direction and velocity data are collected only at site for the centralized system. Namely, instantaneous wind direction and velocity data are integrated every 10 minutes, and the integrated values are used to calculate average and maximum wind velocities and wind directions. Wind velocities of 2 to 4(m/s) are average and the maximum average is no more than 6(m/s). On the other hand, wind directions are represented by the distribution every 10 minutes. Roughly, westerly winds prevail in summer, and north-easterly winds prevail in winter. Throughout the year, westerlies are usual, but the prevailing wind changes.





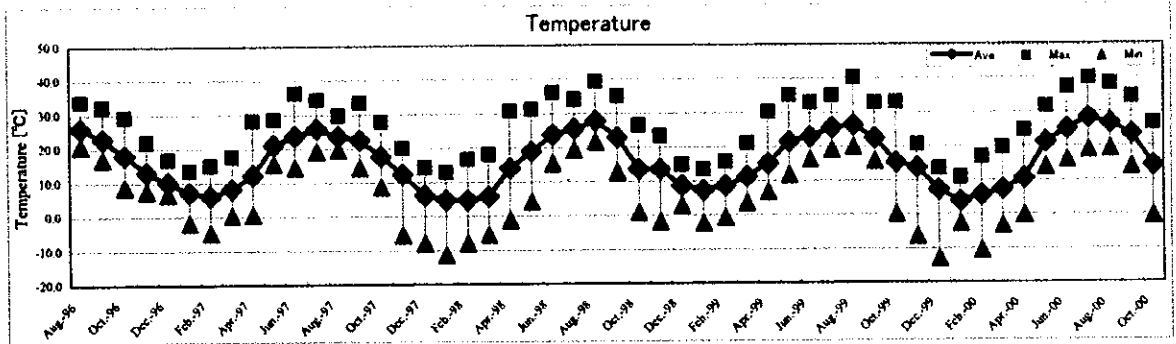
Insolation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Tilted	96						7.4	7.0	6.7	5.4	4.9	2.5	5.6
	97	3.5	3.8	5.4	4.9	6.4	6.3	6.6	6.4	5.0	4.1	2.8	5.2
	98	3.0	4.4	4.6	5.5	5.2	6.3	6.5	6.1	6.2	4.2	3.0	5.1
	99	3.3	4.1	5.4	5.7	6.4	6.5	6.6	6.6	5.8	4.9	4.3	5.5
	00	3.5	4.6	5.6	5.6	5.9	6.6	6.6	6.4	6.4	5.5		5.7
Horizontal	96						8.0	7.0	5.6	3.9	3.1	1.7	4.9
	97	2.4	2.7	4.4	4.8	7.0	7.4	7.6	6.6	5.4	3.6	2.4	4.7
	98	1.8	2.9	3.7	5.2	5.7	7.5	7.5	6.6	5.1	4.2	2.5	4.5
	99	2.1	2.8	4.3	5.6	7.1	7.7	7.5	6.5	5.5	4.0	2.9	4.9
	00	2.1	3.1	4.6	4.5	6.6	7.8	7.3	6.2	5.3	3.8		5.1
Diffused	96						1.0	1.5	1.5	1.2	1.0	1.3	1.2
	97	1.1	1.2	1.8	2.6	2.0	2.1	1.6	1.6	1.5	1.8	1.1	1.6
	98	0.9	1.1	2.0	2.5	2.7	1.5	1.9	1.7	1.6	1.1	1.4	1.6
	99	1.3	1.4	1.8	2.2	2.2	1.8	1.6	1.7	1.5	1.6	1.3	1.6
	00	1.2	1.4	2.0	2.5	2.2	1.7	1.8	1.6	1.9			1.8

Fig.4.6-4 Insolation data (SSRC/HIAST)



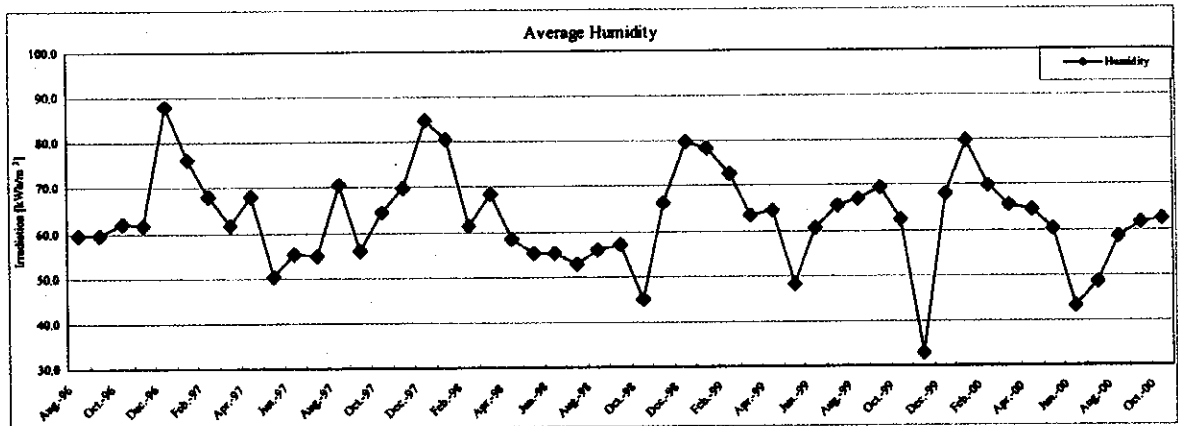
Insolation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
Tilted	96							7.1	6.6	5.5	4.0	1.7	5.0
	97	3.6	4.6	5.5	5.1	7.2	6.6	6.8	7.0	7.1	5.1	4.6	5.5
	98	3.1	4.7	4.4	5.9	5.7	7.1	6.9	7.0	6.7	6.7	4.2	5.5
	99	3.4	4.7	5.6	6.1	7.0	7.0	6.4	6.0			4.4	5.6
	00	3.5	4.6	5.5	5.2	6.3	6.7	7.0	7.1	6.9	5.6		5.8

Fig.4.6-5 Insolation data (Zarzita)



Temp.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
96	Ave.							26.0	22.9	18.1	13.2	10.1	18.1
	Max.							33.9	32.5	29.3	22.0	17.0	33.9
	Min.							20.8	17.0	8.7	7.7	6.8	6.8
97	Ave.	7.2	6.1	8.2	12.3	21.1	23.7	25.9	23.6	22.5	17.6	12.4	15.6
	Max.	13.7	15.1	17.6	28.3	28.6	36.4	34.4	29.9	33.6	28.0	14.4	36.4
	Min.	-1.8	-4.7	0.5	0.7	15.6	14.6	19.2	19.8	14.4	8.7	-5.5	-7.9
98	Ave.	4.7	4.8	5.9	14.1	19.0	23.8	25.6	27.9	22.9	13.6	13.6	15.4
	Max.	13.0	16.9	18.2	30.9	31.4	36.3	34.2	39.4	35.2	26.4	23.4	39.4
	Min.	-11.4	-7.9	-5.5	-1.2	4.3	15.4	19.4	21.7	12.8	1.0	-1.8	-11.4
99	Ave.	7.4	8.8	11.3	15.1	21.6	22.9	25.5	26.3	22.5	15.3	13.8	16.5
	Max.	13.7	15.9	21.3	30.4	35.3	33.0	35.1	40.4	33.0	33.2	20.8	40.4
	Min.	-2.2	-0.6	3.7	6.9	12.0	16.4	19.2	20.1	15.9	0.3	-6.3	-12.9
00	Ave.	3.9	5.7	7.4	10.6	21.2	25.1	28.3	26.6	23.6	14.2		16.7
	Max.	11.1	17	19.7	24.8	31.8	37.3	40.0	38.3	34.6	26.8		40.0
	Min.	-2.5	-10.6	-3.4	-0.2	13.9	16.0	18.9	19.3	14.1	-0.5		-10.6

Fig.4.6-6 Temperature data (Zarzita)



Humidity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
96								59.5	59.5	62.0	61.5	87.8	66.1
97	76.1	68.0	61.7	68.1	50.1	55.3	54.9	70.5	56.0	64.3	69.7	84.6	64.9
98	80.4	61.4	68.5	58.5	55.3	55.3	52.6	56.0	56.9	45.0	66.3	79.7	61.3
99	78.2	72.5	63.3	64.6	48.0	60.4	65.7	67.1	69.5	62.4	32.8	67.9	62.7
00	79.6	69.7	65.7	64.4	60.1	43.0	48.6	58.3	61.5	62.4			61.3

Fig.4.6-7 Humidity data (Zarzita)

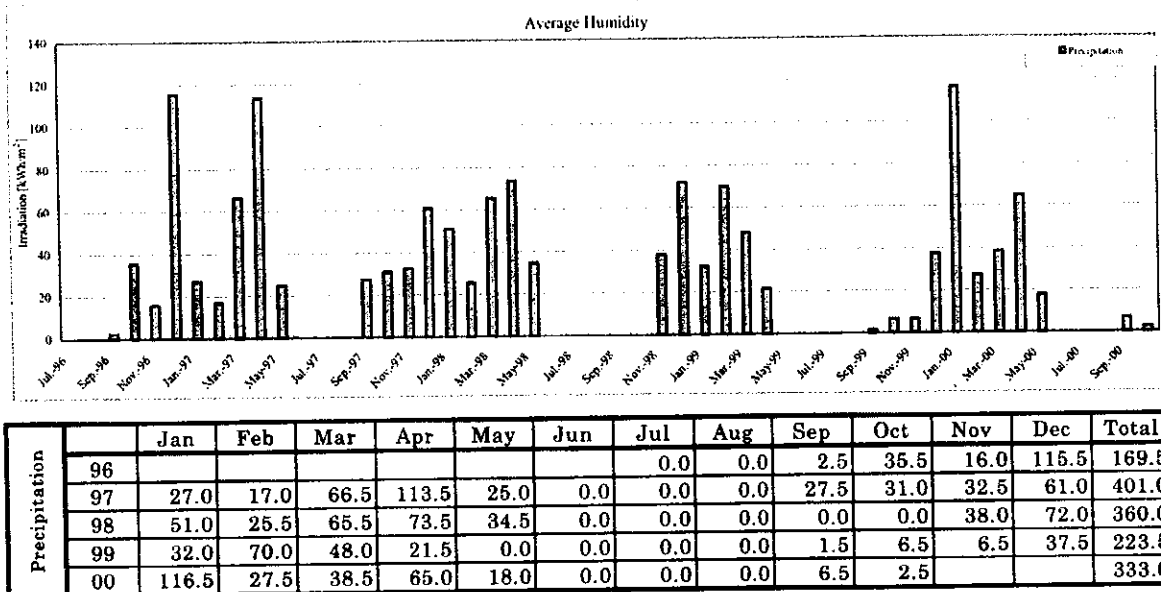


Fig.4.6-8 Rainfall data (SSRC/HIAST)

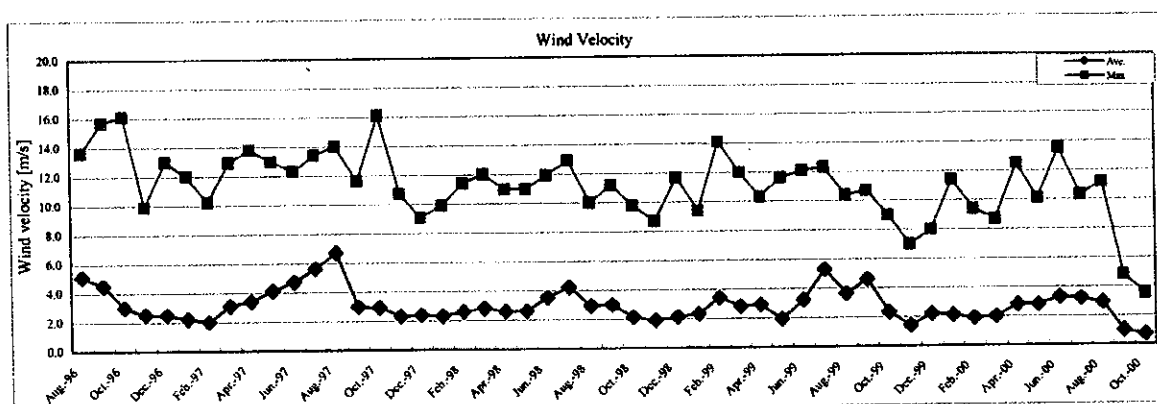
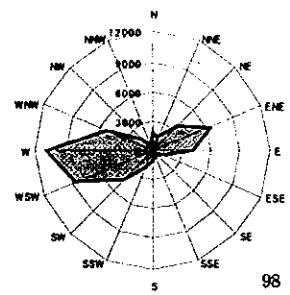
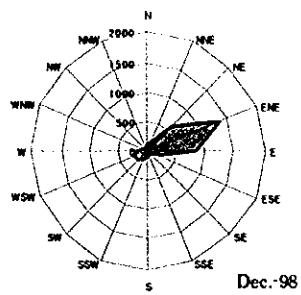
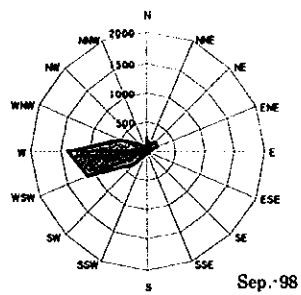
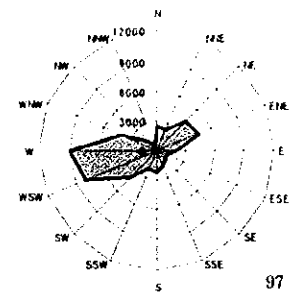
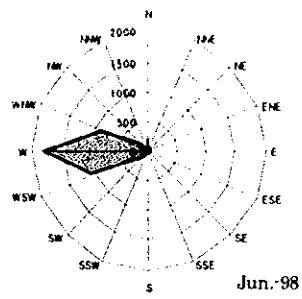
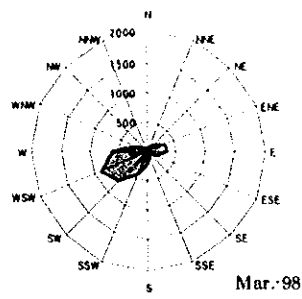


Fig.4.6-9 Wind velocity (Zarzita)



(1) Representative month in 1998

(2) Yearly

Fig.4.6-10 Wind direction (Zarzita)

### ③ Operation management and maintenance

After start-up, technical training for daily visual inspections and points for inspection with meteorological station. The items of visual inspection are as follows.

Table.4.6-3 Visual inspection items for main system components

Instrument name	Inspection items
Pyranometer (tilted, horizontal)	<ul style="list-style-type: none"><li>· Presence of damage to the sensing block dome.</li><li>· Presence of contamination on the sensing block dome.</li></ul>
Diffused radiation meter system (Pyranometer)	<ul style="list-style-type: none"><li>· Presence of damage to and/or contamination on the sensing block dome.</li><li>· Presence of the shadow over the sensing block (whether the shadow is constantly present or not).</li></ul>
Controller	<ul style="list-style-type: none"><li>· Presence of damage to and deformation of the shadow generating block, presence of damage to and deformation of the arm.</li><li>· Check for smooth operation of rotating parts and sliding parts.</li><li>· Presence of any looseness in mounting parts.</li></ul>
Rain gauge	<ul style="list-style-type: none"><li>· Presence of clogging of the water collecting block due to dirt, foreign matter, etc.</li></ul>
Wind vane and anemometer	<ul style="list-style-type: none"><li>· Presence of damage to and/or deformation of the blade of the wind vane.</li><li>· Presence of damage to and/or deformation of the wind receiving block (three-cup type) of the anemometer.</li><li>· Check of smooth operation of the wind vane and anemometer (whether they rotate smoothly).</li><li>· Presence of any looseness in mounting parts.</li></ul>
Thermometer and hygrometer	<ul style="list-style-type: none"><li>· Presence of any looseness in mounting parts.</li></ul>

### ④ Effective utilization of the meteorological system in the future

It was originally planned to install a meteorological station at the centralized system site to collect data on insolation, temperature, wind velocity, etc., for the purpose of evaluating the outputs of centralized and individual systems. However, when the PV system is introduced in Syria using the results of this project, it is recommended to organize the data of this meteorological station into a database. The following example of effective use is studied.

#### a. Pyranometer system

Whenever a PV system is introduced, the basic design must be prepared using insolation data and the scale is decided. Generally, insolation has universality with few differences among areas. It is important to develop a database using

data from three roof-installed pyranometers of SSRC/HIAST. This database will be utilized to introduce PV systems in Syria. On the other hand, the monitoring system installed at Zarzita is useful to evaluate the power generated by the centralized and individual systems. However, it is effective for the Zarzita system to be relocated to another area like Al Badia and to collect on-site data for future utilization.

**b. Temperature / humidity and wind direction and velocity**

It is general practice to collect wind direction and velocity data at a place where a wind turbine is to be installed. If there is a candidate site for a wind turbine plant, a wind direction and velocity observation instrument may be relocated there and used effectively for data logging. If there is no such site, the system at Zarzita should be relocated to SSRC/HIAST, because Zarzita is topographically special. The same may be applied to the temperature / humidity.

**c. Rainfall gauge**

Generally, rainfall data is utilized to estimate groundwater and evaporation. As with wind direction and velocity, the rain gauge should be relocated to Kalif where the pumping and desalination system is installed.

**(2) Battery performance testing system**

The battery of this project will be replaced with a local battery after its service life was expired. When the batteries are due to be replaced, new batteries should be selected from among those of a local manufacturer or imported batteries. The battery performance testing system has been designed to enable SSRC/HIAST to evaluate the performance of local and imported batteries. The data collected from this system will be useful to improve the performance of local batteries and production technology of local manufacturers.

**① Outline of battery performance testing system**

The battery performance testing system consists of a charge/discharge power supply, measurement and control, data processor, and thermostatic chamber. As the system used the measurement and control part and charge/discharge power supply in combination, it can test up to three 12V batteries with respect to constant-voltage/constant-current charge and constant-current discharge. Each test

can be accomplished either automatically or manually, whichever is preferred. In automatic mode, the computer in the data processor makes a test pattern, and the computer in the measurement and control part performs test control and data logging according to the test pattern. In addition, the system is integrated into a local area network (LAN) with a server unit at its core, so it is possible to change parameter settings, measurements and data logging, all on a real-time basis.

Table.4.6-4 Specification of battery performance testing system

Component		Specification	
Power source for Charge/discharge	Constant Voltage / constant current charge & discharge power source (TYS-32PS1500)	Operation condition	Constant voltage / constant current charge, constant current discharge power source
		Output voltage range	0 ~ 50 [V]
		Output current range	-30 ~ +30 [A]
		Constant voltage stability	Within $\pm 0.5\%$ of output voltage FS.
		Constant current stability	Within $\pm 0.5\%$ of the respective range FSs, 1, 10 and 30A.
		Power source	AC200 [V] $\pm 10\%$ 1 $\phi$ (50/60[Hz])
		Dimensions	W430×H660×D550 [mm]
Measurement control unit	Measurement control unit (TYS-32TU1500)	Number of channels	5 (One channel is used now.)
		Measurement items	Battery voltage : 0 ~ 50 [V] 1 point Power source output voltage : -10 ~ +10 [V] 1 point Power source output current : -10 ~ +10 [V] 1 point Temperature : -50 ~ 200°C 2 points Extended voltage (for specific gravity) : -5 ~ +5 [V] 1 point Extended voltage : 0 ~ 50 [V] 3 points
		Power source	AC100 [V] $\pm 10\%$ 1 $\phi$ (50/60[Hz])
		Dimensions	W480×H200×D550 [mm]
Measurement control unit	Computer for measurement and control	Display	15inch Color MF-8515E II
		Computer	C P U : D X IV (63MHz) H D D : 415MB R A M : 2MB F D D x2, C D x1 PC-9801BX4/U2
	Uninterruptible power supply (BU504XLIV)	Power source	100[V] 50/60Hz
		Capacity	500VA
		Power source	AC100 [V] $\pm 10\%$ 1 $\phi$ (50/60[Hz])
	Temperature/Voltage Box	Range of measurement	-50 ~ 200°C 16 ch
		Sensor	Thermal Couple T type
	Gravimeter (P 1)	Power source	(-50 ~ 200[°C] / 0 ~ 5[V]) AC100 [V] $\pm 10\%$ 1 $\phi$ (50/60[Hz])
		Range of the specific gravity	1.100 ~ 1.400



Fig.4.6-11 Battery performance testing system

## ②Performance testing of batteries

In the PV system, the battery is used to store the power generated in daytime and to supply power to the load at night. Therefore, one charge/discharge cycle per day is repeated, so a cycle service battery is necessary. The performance of the battery in terms of charge/discharge current and temperature, etc., need to be understood. Testing of battery capacity and service life is underway in accordance with the battery performance testing procedure specified in Japanese Industrial Standards (JIS) as agreed upon with SSRC/HIAST.

### <Test items>

There are many factors that indicate the performance of a lead acid battery including:

- Storage energy :Storage capacity
- Energy intensity :Discharge current, discharge voltage, etc.
- Duration available :Service life
- Ease of handling :Mechanical strength, charging efficiency, self-discharge rate, operating temperature range



The most important factors are capacity and service life. The unit of capacity is Ampere Hour (Ah), but it fluctuates with time rate of discharge and temperature. On the other hand, service life is affected by type of battery and usage conditions. Regarding capacity and service life test, the following pattern used is based on the JIS standard.

#### a. Storage capacity test

The storage capacity test is carried out under the following conditions to measure the discharge time for a specified final discharge voltage and calculate the product of this time and five-hour rate discharge current for evaluating storage capacity.

- Timing to start discharge:

After leaving to stand for about one hour with the battery fully charged

- Solution temperature during discharge :  $30 \pm 2^\circ\text{C}$
- Discharge current : 5-hour rate current
- End voltage of discharge : 10.4(V)(to be varied depending on battery)
- Formulation of temperature compensation for storage capacity :

When performing discharge test at solution temperature other than  $30^\circ\text{C}$ , the storage capacity at  $30^\circ\text{C}$  is calculated according to the following compensating formula, provided that this applies to solution temperatures in the range of  $10 \sim 40^\circ\text{C}$ .

$$C_{30} = C_t (1 + 0.005 (t - 30))$$

$C_{30}$  : The storage capacity compensated into  $30^\circ\text{C}$  (Ah)

$C_t$  : The storage capacity at  $t^\circ\text{C}$  (Ah)

$T$  : The average temperature of solution during the final two hours of discharging

The maximum charge/discharge current capacity of the battery performance testing system now in use is limited to 30 (A). The testing procedures need to be modified for application to batteries rated at 60 (Ah) or above.

#### b. Service life test

The service life test is carried out on batteries subjected to the storage capacity test. In this test, charge and discharge operations are repeated under the following conditions to determine service life.

- Discharge : 4 hours at 0.05C(A)
- Charge : 2.5 hours at 0.1C(A) (approx. 125% of discharge capacity)
- Solution temperature : 33°C ~ 45°C
- Conduct storage capacity test every 100 cycles. After the storage capacity test, the battery is fully charged and then repeated charge and discharge operations are carried out.
- End of test :

When it is confirmed that the capacity determined by the storage capacity test every 100 cycles has fallen below 80% of the rated storage capacity and that the capacity can no longer be recovered.

- Service life cycles :

Determine the number of cycles at which the capacity has fallen below 80% of the rated value from the number of cycles vs. storage capacity curve, provided that the number of cycles operated in the storage capacity test is added.

#### c. Battery characteristic test

The battery voltage and capacity, cycle service, depend not only on the materials of the battery, but also on solution temperature, current, etc. To determine battery characteristics, the following tests are conducted.

- Charge/discharge characteristic test at the point of different current

Charge and discharge the battery at constant currents (5-hours rate, 10-hours rate, and 20-hours rate charge/discharge currents) to determine voltage vs. current characteristic. Measure the solution's specific gravity and open-circuit voltage during the test to determine relationships between charge/discharge current and specific gravity, and battery storage capacity.

- Temperature vs. charge/discharge characteristic test

Charge and discharge the battery at constant temperatures (-10°C, 10°C, 30°C, 50°C and so on) to determine voltage vs. temperature characteristic. Measure the specific gravity and open-circuit voltage during the test to determine temperature vs. specific gravity characteristic and temperature vs. battery storage capacity characteristic.

#### ③ Test results

The local batteries and imported batteries were subjected to the tests explained above. From the data in the table, local batteries are shown to have a shorter

service life. The batteries with the shortest life sustained just about 125 cycles and this means approx. Four months at one cycle per day.

Table 4.6-5 Performance testing of batteries

Battery Name	Nominal Capacity	Discharge Capacity C5	Nominal Efficiency	Numbers of cycles	Expected Life	Total discharging Capacities	Battery Price	Cost of 1Ah	Cost Related to Boliden battery
	(Ah)	(Ah)	(%)		(Month)	(Ah)	(Sp)	(Sp/Ah)	
Shola (Local)	70	28.1	40.1	167	6.68	3425	1500	0.43	1.19
Njma (Local)	70	22	31.4	125	5	2561.8	1500	0.58	1.61
Taj (Local)	70	33.7	48.1	159	6.36	3297	1500	0.45	1.25
Boliden (imported)	85	54.1	63.6	367	14.7	9662.4	3500	0.36	1
Thender (imported)	100	61.9	61.9	536	21	13498	3500	0.26	0.72

#### ①Future direction

The tests conducted so far have disclosed that local batteries have shorter lives than imported ones, and that the quality is not uniform enough among products of the same local manufacturers. To improve this situation, an UNDP engineer who is expert in battery manufacturing technology was dispatched to Syria. The test results obtained by this system will be analyzed and studied in cooperation with the UNDP expert to improve the production technology of local battery manufacturers.

#### (3) The system evaluation system

In this project, collection and analysis of operation data of representative house are executed with a data logger. However, there are some differences in power consumption among houses and it is difficult to understand the consumption of all houses in reality. Therefore, various usage patterns of individual PV systems are simulated by this system evaluation system. The charge/discharge controller developed by SSRC/HIAST and the inverter can be tested and evaluated.

#### ①System outline

The system evaluation system consists of signal transducer, data logger, computer, controller, and inverter.

Table 4.6-6 Configuration of system evaluation system

	Component	Specification	
Signal Transducer	DC converter voltage	SV-00-II	Input DC 0 ~ 50W, Output DC 0 ~ 2V, Power source AC 220V 50Hz
	Shunt resistance		Input DC 0 ~ 100A, Output DC 0 ~ 50mV
	PT transformer	PT-60-II	Input AC 0 ~ 300V, Output DC 0 ~ 2V, Power source AC 220V 50Hz
	CT transformer	CT-50-II	Input AC 0 ~ 5A, Output DC 0 ~ 2V, Power source AC 220V 50Hz
	DC transformer	MEWT-240-II	Input AC 220V/5A, Output DC 0 ~ 2V, Power source AC 220V 50Hz
	Coupling transformer	TCS-55-II	Input AC 0 ~ 300V, Output DC 0 ~ 2V, Power source AC 220V 50Hz
	Data logger (LS3300ptV)	Input Record interval Power source	Input(Analog) : 8ch 0 ~ 2V, Input(Pulse) : 2ch 1,2,5,10,60 minute AC 100V 50/60Hz, DC 6V
	Control unit for charge/discharge (C40)	Nominal voltage Admitted current	DC 24V, DC 40A
	Inverter (PW 800I)	Input Output	DC 24V AC 220V, 50Hz, Capacity 800VA

## ② Testing situation

Individual DC and AC systems, which are the same as those used in this project were installed in SSRC/HIAST. System performance and durability are evaluated for various usage patterns. The performance of new system equipment is tested as well.

### a. Individual DC system

The Fedre's system was simulated. Two fluorescent lamps were controlled by a timer to maintain the design demand. In Syria, insolation fluctuates throughout the year. In summer, surplus power is generated because of increasing insolation. In the winter rainy season days of autonomy continue, so the PV system might stop. Therefore, various operating conditions are set and data are measuring. On this test, the following view is taken into account.

#### < Point of view >

- System stopped or not
- Operation of charge controller is normal or not
- Battery voltage is adequate or not

#### < Measuring points >

- PV array voltage and current

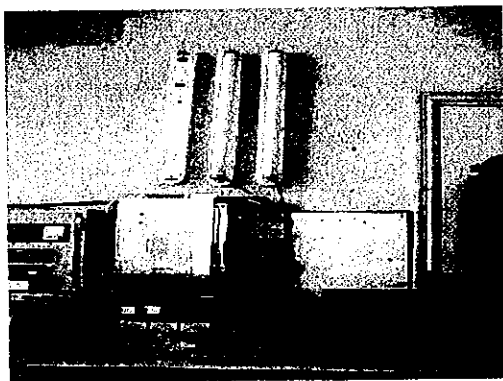
- Battery terminal voltage, charge, and discharge current

#### b. Individual AC system

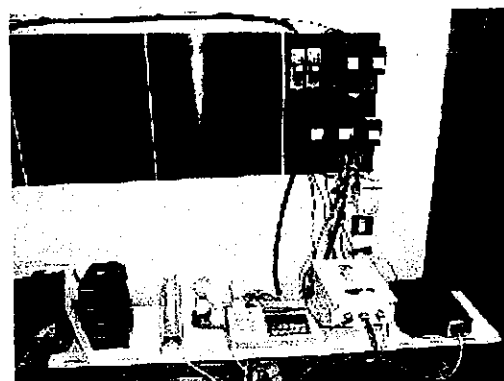
The Kalif's system was installed and this system use a controller developed by SSRC/HIAST. The simulation of the AC system tests various operations and SSRC/HIAST controller.

#### <Measuring points>

- DC : Battery terminal voltage, charge, and discharge current  
Inverter input voltage and current
- AC : Inverter output voltage, current, frequency, and output



(1)DC system



(2)AC system

Fig. 4.6-12 System evaluation system

### ③Direction in the future

At present, these systems are operating adequately. The operating conditions of these systems will change and they will continue to operate. Data are collected and system durability needs to be evaluated. The collected data provide information on the functions of controller and capacity evaluation of these systems. In the future, these data will be utilized to design systems and to develop equipment.

In addition, this system is used for evaluating newly developed equipment and in technical training for new engineers.

### (4) PV system design tool

PV system equipment design and development are executed by SSRC/HIAST. To do more efficient work, a PV system design tool was introduced.

#### ①System outline

PV system design tool consists of computer, designing software, and plotter etc.

Table 4.6-7 Specification of PV system designing tool

Component	Specification	
Computer	CPU Memory HDD Floppy Display	Samsong Pentium II 300MHz, 64MB 6.5GB 3.5 inch FDD, 1.44MB 17 inches Color
Plotter	ENCAD	CAD Jet II Serial RS 232C and Parallel
Printer	HP	DESKJET 1120C Paper size : A3 Printing Resolution : 600*600dpi
PV system designing tool		PVS for Windows

## ② Conditions of use

The PV system design tool is used for the following purposes.

### a. PV system design

When PV system design tool and software are used, PV array and battery capacity is calculated automatically only inputting insolation and demand. Thus, system design is simplified and time needed is reduced. This system is expected to be effectively used to design PV system in the future.

### b. Simulation of system operation

This software is available to simulate power generated and system operation. If these functions are utilized, operation of designed system is checked and introduced system can be evaluated.

### c. Design and drawing of equipment

SSRC/HIAST is developing a charge controller and an inverter for the PV system. The PV system design tool is used for designing and drawing circuits.



(1) PV system designing tool



(2) Situation of use

Fig.4.6-13 PV system designing tool

### ③Effective use in the future

This design tool has various functions. Therefore, when the system is introduced, basic design and simulation of operation, etc. can be done efficiently in all PV application fields. Moreover, a new engineer can also understand the design flow and can use it for training etc., because the procedure is the same as for manual calculation. In addition, this system can be used for drawing PV array structures and architecture.

### (5) I-V curve tracer

In this project, mono-crystal, poly-crystal, and amorphous types of PV module made in Japan were purchased. The mono-crystal PV module that SSRC/HIAST manufactured was adopted as well. To evaluate the reliability of various PV modules, the outputs of these modules need to be checked periodically. This I-V curve tracer is portable, so PV module output can be measured not only at this project site but also in other rural areas. These data are very useful for evaluating PV modules made by SSRC/HIAST in the future.

#### ①Outline

This I-V curve tracer consists a tracer which can absorb power generated, note-type computer, and printer.

Table 4.6-8 Specification of I-V curve tracer

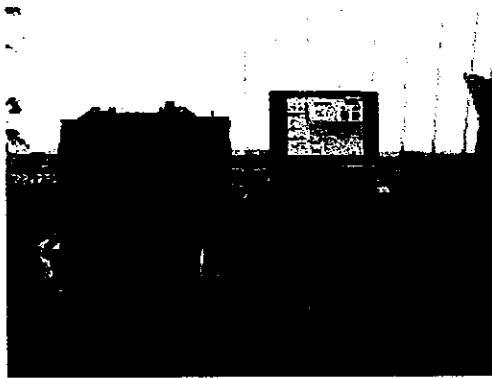
Component	Specification	
I-V curve tracer (SPI-Array Tester 800)	Range of measurement Dimensions Weight Power source Accessories	Voltage : DC 0~600 V, Current : DC 0~75 A, Capacity : 10W~36kW W34cm·D29cm·H15cm 4.5kg Power supply from connected computer Reference cell and temperature sensor (K type)
Note type computer	Model	Toshiba Satellite 2500CD/2.1
Printer (HP-340)	Print processes Power source	Inkjet type Stored battery AC220V 50/60Hz

The I-V curve provides basic data to obtain the characteristics of PV and degradation and breakdown of PV module (array). However, after measuring the I-V curve, it is necessary to compensate for the insolation and the temperature at the standard value (insolation:1.0(kW/m<sup>2</sup>) and cell temperature:25°C). This I-V

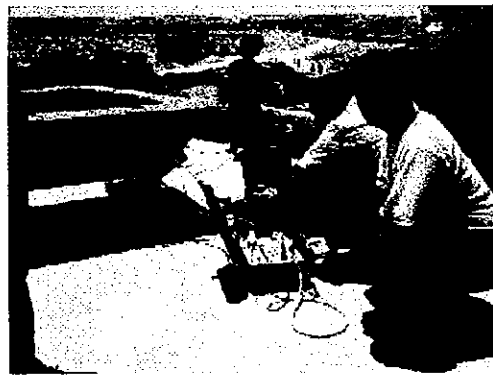
curve tracer can measure the I-V curve within 45(sec) and measured data are compensated from actual to rated data using computer, reference cell and temperature sensor.

### ②Status of use

A couple of PV systems at each project site were selected and I-V curve was measured by the study team and SSRC/HIAST in Aug 1999. Later, SSRC/HIAST measured its own PV module and PV array output at Ab-Sorra village, which is located south of Damascus.



(1) I-V curve tracer



(2) Measuring

Fig.4.6-14 I-V curve tracer

### ③Effective use in the future

The degradation characteristics etc. of various PVs can be understood by periodically measuring them using the I-V curve tracer, because various PVs such as amorphous models were installed in this project. Moreover, it is possible to use it to find a breakdown and to investigate the cause. An I-V curve tracer is effective for maintenance checks etc. on the system to be introduced in Syria in the future.

#### 4.6.4 Assistance to improve battery manufacturing technology from UNDP

The local and imported batteries were evaluated by the battery evaluation system. Based on this evaluation, the local battery was found to have a shorter life than imported ones, and has variable quality. According to the initial plan, the battery introduced from Japan will be replaced with a local battery after their life has expired. Therefore, improved performance is necessary.



An UNDP expert was dispatched to improve the manufacturing technology of the local company. Public and private manufacturers were surveyed and the following items were reported and recommended.

< Present status of manufacturer >

- ① In the private sector, the specification of materials used and manufacturing process have some problems. Therefore, technological improvement in the private sector is difficult.
- ② In the public sector, the specification of materials used and manufacturing process were satisfied. The staff is excellent and keen to study, and their knowledge of batteries is deep enough. However, some processes, materials, and facilities need to be improved.

< Recommendations for improvement >

- ① Grid of greater thickness is required for PV batteries. The initial proposals are 3.1mm for the positive and 2.5mm for the negative grid. These can be varied to some extent to fit the plate groups in the cell compartment of the Syrian container.
- ② An imported low-antimony alloy is necessary for PV batteries. The typical composition of the alloy is Pb-2%, Sb-0.15%, As-0.2%, Sn-0.05%Se.
- ③ Imported pure lead (99.97%) is required to make lead oxide for use in PV batteries.
- ④ Better control of conditions during curing should be examined with the possible use of a new humidity chamber with variable humidity and temperature controls. This would enable a better process with an initial period of high humidity or steaming (development of tribasic sulphate with hydrosetting of the paste), followed by reduction of humidity to low levels (when the residual lead is oxidized), and finally a period of drying (when the moisture content is reduced to a low level).

- ⑤ Closer control of plate drying after formation is necessary for a good dry charged negative plate. (The Company intends to buy a new drying oven.)
- ⑥ A microporous polyethylene or a PVC separator with a small average pore size is required for a PV battery. A pore size of <1 micron is desirable. Possible suppliers are given in the Appendix.
- ⑦ A thin glass mat next to the positive plate, to support the active material is desirable for a PV battery. This, together with a reasonably tight assembly will prevent the positive material from shedding during service.
- ⑧ A new type of polypropylene container with a through-the-partition inter-cell connector (now available from the Syrian Battery Company) should be used for the PV battery. Automatic assembly equipment would improve the quality and the consistency of batteries and should be used when available. The Company already has heat-sealing equipment for the container-to-lid seal and is considering the purchase of the remaining assembly equipment that are necessary.

Based on this survey result and recommendation, a contract was exchanged between SSRC/HIAST and the public company to improve the production line and to manufacture the battery for PV use. From Dec 1999, manufacture of four prototypes of the 12V-200(Ah) battery, which is same as the centralized and DC system was started.

The recommendation of the UNDP expert stated that SSRC/HIAST staffs are excellent and able to respond to the evaluation of the new battery. Testing of these four prototype batteries will be started after completion of manufacture.

- \* Two batteries : life cycle test using battery evaluation system
- \* One battery : for Katoura
- \* One battery : for Fedre

In addition, SSRC/HIAST receives various materials for the PV cell and others for manufacturing PV modules of 10kW from UNDP. Because SSRC/HIAST has the

equipment to manufacture and evaluate PV module, SSRC/HIAST will improve production and evaluation technology.

Thus, the study team expects that various equipment introduced by this project will be used effectively and SSRC/HIAST will improve further technology as a technical leader in Syria in cooperation with UNDP. The study team expects to contribute to the introduction of the PV system as well.

Through this project, PV system design, installation, operation management, and maintenance were executed in cooperation with SSRC/HIAST, and technology was transferred to SSRC/HIAST to introduce the PV system into Syria in the future. As a result, the centralized and individual systems were operated continuously without any serious problems since start of operation.

**\* Centralized system**

Since the start of operation, power demand started to increase from the second year. At present, actual power demand is almost equal to the designed demand, however, the trend of consumption is continuing to increase. On the other hand, five new houses were built in Zarzita, which was electrified. In the future, it is necessary to consider responding to those houses and to enlighten villagers about effective usage repeatedly.

**\* Individual system**

The individual system was operated without any failures. Thus, the initial design is adequate. However, based on the analysis of operating data, some surplus power is expected in daytime in summer. Therefore, if an effective plan to use this power such as for a fan used in daytime is studied, this system will be utilized much more in the future. Toward the future introduction, if the necessary scale of PV system according to house dimensions and economy is studied, effective introduction can be expected.

The technical level of SSRC/HIAST is excellent based on the results of maintenance and operation management. The technology transfer is all reflected correctly. Therefore, future introduction of the PV system into Syria can be done by Syrian side.

Moreover, the meteorological system, PV system evaluation system, and battery evaluation system are used to improve SSRC/HIAST technology adequately.

Using the outcome of this project, if an understanding of the PV system is brought out in cooperation with governmental bodies such as the Ministry of Electricity, the PV system can be expected to be popularized in Syria.